Inflation and corporate investment in selected OECD countries in the years 1960-2005 – an empirical analysis

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Abstract: Theoretical models point at various channels of the impact of inflation on corporate investment. This article attempts to answer the question what are the direction and strength of this possible impact examining the relationship between corporate investment and inflation on the sample of 21 OECD countries in the years 1960-2005. The obtained negative relationship, statistically and economically significant, proves robust to changes in the specification of the estimated equation, estimators, frequency of variables used in the study and analysed period. Moreover, the results obtained suggest nonlinear character of this relationship: marginal effect on corporate investment is higher at inflation rates between 3 and 5.5 per cent. These results suggest that the impact of inflation on corporate investment dynamics may be the source of nonlinear nature of the relationship between GDP growth and inflation identified in previous empirical studies. Finally, taking into account the direct impact of inflation on investment, variables approximating the cost of capital utilisation prove to be statistically insignificant determinants of corporate investment.

JEL classification: C23, D22, D81, E22, E31, E44

Key words: investment, inflation, panel data

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1. Introduction

As a result of the global financial crisis which entered its severe stage in 2008, the mitigation of the consequences of the crisis, not only through very low interest rates but also by means of other non-standard tools, has been perceived for the past two years as the biggest challenge for monetary policy. At that time, it could seem that the role of the central bank involving price stability aimed at limiting the costs of inflation receded into the background. In the second half of 2010, however, at least some emerging economies have recorded signs of growing inflationary pressure.

Despite the signs of building this pressure, central banks may be prevented from tightening their monetary policy by fears of discouraging corporate investment and, as a result, prolonging the period of recovery from the economic slowdown. Central banks have to compare this risk with another possible risk which has been given less focus in public discussions since the outbreak of the global financial crisis, i.e. the negative impact of inflation on corporate investment. This impact will be addressed in the article.

Theoretical models point at various channels through which inflation can affect corporate investment. These channels are not, however, analysed in one consistent model. Meanwhile, the direction of this impact may differ across channels depending on the level of inflation rate. Additionally, complex interactions are possible between them. These limitations of the theory provide a background for strictly empirical research on the response to the general question whether inflation has any significant impact on corporate investment and what the direction and the strength of this possible impact are.

The present article attempts to answer the above question. Empirical studies have given relatively little attention to complex analysis of this relationship. Instead, they have focused on the analysis of particular channels of inflation impact on corporate investment. The aggregate impact of inflation on corporate investment was analysed mainly as an additional aspect of the studies on the influence of inflation on economic growth. The rest of the article is structured as follows:

- Section 2 presents the main channels of the impact of inflation on corporate investment, as indicated by the theory and findings of empirical research on particular impact channels.
- Section 3 presents the range of the sample analysed in this article and reasons for its selection.
- Section 4 analyses the relationship between inflation and investment based on simple descriptive statistics.
- Section 5 is devoted to the estimation of a number of panel models analysing the strength and direction of the impact of inflation on corporate investment.
- Section 6 presents the analysis performed in order to evaluate the robustness of results.
- Section 7 summarises major conclusions following from the study.

2. Channels of the impact of inflation on corporate investment[1]

The key channels of the impact of inflation on corporate investment are connected with the following market imperfections[2]:

(i) asymmetry of information,

(ii) uncertainty and

(iii) nominal rigidities in the tax systems.

Asymmetry of information between economic agents in the process of investment financing causes three kinds of problems: adverse selection (see Akerlof, 1970), moral hazard (see Jaffee and Russell, 1976) and costly state verification (see Townsend 1979; Gale and Hellwig, 1985). These consequences may lead to credit rationing, which limits the possibility for enterprises to obtain capital for investment, even if expected return on investment exceeds the costs of capital employment. Even if fully anticipated, inflation exacerbates the consequences of information asymmetry and hampers the development of financial institutions. Inflation, as a result of e.g. regulations determining the value of nominal interest rate, may reduce the real rate of return on savings (see e.g. Barnes et al., 1999 or Boyd et al., 2001), and, consequently, discourage people from saving and stimulate them to take out loans, including persons incapable of paying them back (see e.g. Boyd et al., 1996). Moreover, it constitutes a tax imposed on the real value of enterprises' own funds, the investment of which is often a condition for obtaining external funding (see e.g. Boyd and Smith, 1998 or Huybens and Smith, 1999). A decline in enterprises' own funds resulting from that may be, at the same time, exacerbated by enterprises' decisions aimed at avoiding this tax (see e.g. Smith and van Egteren, 2005). Inflation does not only reduce firms propensity to gather own funds but also their ability to do so, as it reduces profit margins above the unit cost[3]. At the same time, inflation introduces additional "noise" to investment project assessment by lenders, thus hindering the identification of profitable projects (see e.g. De Gregorio and Sturzenegger, 1994; Baum et al., 2004). Finally, inflation may enhance the moral hazard among financial institutions themselves. They may hope that their potential losses will be at least partially financed by the government, for which it will be difficult to evaluate to what extent they are the result of exposure to the financing of risky projects and to what extent they result from unstable economic conditions, mirrored in growing inflation, beyond control of financial institutions (see e.g. McKinnon, 1991; De Gregorio, 1996).

In the light of both the theories and empirical studies, changes in inflation within the range of its very low values do not affect the extent of financial intermediation, yet after exceeding a certain low threshold, further rise in inflation hinders its growth; all the negative effects of inflation on the development of the financial sector become apparent when inflation is moderate (see e.g. Boyd et al., 2001; Rousseau and Wachtel, 2002 or Khan et al., 2006). Moreover, in the developed countries the negative impact of inflation on the financial sector and, consequently, on corporate investment becomes apparent at lower inflation levels than in the developing countries (see e.g. Cuadro et al., 2003). Higher capital per person employed in

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[1] This chapter summarizes main findings from the literature review presented in Ciżkowicz et al. (2010).

[2] In case of no market imperfections the direction of inflation's impact on investment depends on technical assumptions that do not easily yield to unambiguous empirical verification. For the review the impact of inflation on capital accumulation in general equilibrium and monetary search models with no market imperfections see Ciżkowicz et al. (2009).

[3] At this point, the theory might seem ambiguous (see on the one hand, e.g. Rotemberg, 1983; Head et al., 2006 or Russell et al., 2002, and, on the other hand, Ball and Romer, 1993 or Tommasi, 1994), yet the results of empirical studies indicate a rather negative impact of inflation on profit margins (see e.g. Batini et al., 2000; Banerjee et al., 2001; Banejree et al. 2007, or Banerjee and Russell, 2005).

the former ones forces enterprises to engage higher own funds in the financing of investments whose value is sensitive to changes in inflation (see e.g. Hamid and Singh, 1992; Boyd and Smith, 1998).

The second important channel of inflation impact on corporate investment it its effect on uncertainty as to the future value of variables which are of importance for investment decisions made by enterprises. The impact of inflation on investment through uncertainty depends on two, generally disjunctive, relationships.

On the one hand, it is the function of the impact of inflation on uncertainty about variables forming the basis for enterprises to formulate their assessment of future return on investment. Conclusions drawn from the review of theoretical and empirical literature are unequivocal: inflation, even within the range of low and moderate values, constitutes an important source of uncertainty. By increasing relative price variability (see e.g. Nautz and Scharff, 2006 or Banerjee et al. 2007, Caporale et al., 2010), inflation makes it difficult for entrepreneurs to assess what is worth manufacturing and what is not, as well as reduces the number of contracts and shortens the average period of contract duration (see e.g. Reagan and Stulz, 1993 and Guerrero 2005). By escalating uncertainty about future inflation (see e.g. Ball and Cecchetti, 1991; Evans, 1991; Evans and Wachtel, 1993), inflation increases uncertainty about the level of interest rates and about that part of future tax burdens affecting, directly or indirectly, the cost of capital utilisation which depends on inflation. Finally, it intensifies the uncertainty stemming from relative price variability as long as nominal price rigidities emerge (Friedman, 1977).

On the other hand, the impact of inflation on investment through its effect on uncertainty is determined by the relation of investment and uncertainty. Although intuitively we are inclined to conclude that the higher the uncertainty, the lower the propensity of enterprises to embark on new investment, this relationship is not unambiguous in the light of the theory (see, on the one hand, e.g. Hartman, 1972; Abel, 1983; Lee and Shin, 2000 and, on the other hand, McDonald and Siegel, 1987 or Abel et. al, 1996). Conclusions derived from models are the function of adopted assumptions whose adequacy to reality is, in some cases, questionable (Dixit and Pindyck, 1994). The majority of empirical studies indicate, however, that a rise in inflation leading to growing uncertainty accompanying investment decisions of enterprises reduces their propensity to invest (see e.g. Ferderer, 1993; Serven and Solimano, 1993 or Pindyck and Solimano, 1993; Kalckreuth, 2000; Byrne and Davis, 2004; Fisher, 2009).

The third important channel of inflation impact on corporate investment is the interaction between inflation and the tax system. If it is not fully indexed, inflation affects the cost of capital utilisation. It may also differentiate this cost, depending on the type of capital asset (length of depreciation period) or the structure of investment financing (see e.g. Feldstein et al., 1978). As a result, this leads to a change in both the level and direction of capital allocation. However, the sign and the strength of this impact depend on many assumptions concerning, inter alia, detailed solutions of the tax system (see e.g. Sorensen, 1986; Cohen et al., 1999), free capital flow (see, on the one hand, Hartman 1980, and, on the other hand, Desai and Hines, 1997) or the manner the government uses additional (stemming from lack of full indexation) tax revenues (see e.g. Bullard and Russell, 2004). Consequently, they cannot be unambiguously identified on the grounds of the theory. However, models unequivocally suggest that changes in inflation through interactions with the tax system are not neutral for investment decisions made by enterprises.

Empirical studies do not unequivocally identify the direction and strength of the impact of inflation on investment through interactions with the tax system, either. The main reason for such ambiguity is the fact that a major part of empirical studies is strongly linked to the assumptions of particular theoretical models (see e.g. Feldstein 1980; Chirinko, 1987; Bullard and Russell, 2004). The dependence of arbitrary assumptions adopted in those models is transferred to the results of empirical analyses.

All the three channels of inflation impact on investment are interrelated. For example, uncertainty is one of the reasons for market incompleteness and, consequently, their level of development, connected with the relationship of inflation and asymmetry of information, becomes increasingly significant for the economy. On the other hand, imperfection of financial markets related to information asymmetry deepens the acuteness of the uncertainty. Finally, the effects of both uncertainty and asymmetry of information may be enhanced by the interaction between inflation and the tax system. Despite such relationships, we are not familiar with any study which would analyse the impact of inflation on investment through all the channels within one, internally coherent model.

These limitations of the theory provide room for a purely empirical study on the joint impact of inflation on investment. The empirical literature so far has not focused on this issue sufficiently. This issue was analysed, so to speak, ‘by the way’ when studies were carried out on the impact of inflation on economic growth as one of the possible channels of this impact (see e.g. Fischer, 1993; Bruno, 1993; Barro, 1995; Andres and Hernando, 1997).

3. Selection of the sample and data sources

Our analysis of the impact of inflation on corporate investment has been based on an annual panel data covering the period of 1960-2005 and the sample of 21 OECD developed countries[4].

The study has not taken into account the years 2006-2009, as this was the period of strong turmoil in the analysed countries. This brought about major fluctuations in fundamental variables addressed in this article. In the countries examined, this period was marked by both a strong rise in investment amidst low inflation (2006), a considerable fall in investment amidst relatively high inflation (2008) and a deep fall in investment amidst low inflation (2009). These data constitute one but not unique piece of evidence corroborating the fact that in the years of the crisis and in the period immediately preceding it the relationships between macroeconomic variables become disturbed. However, we have concluded it is far too early to isolate those disturbances or assess their durability.

In none of the countries selected for the analysis the annual inflation measured by the CPI growth exceeded 30% which is a moderate level in accordance with the classification suggested by Dornbusch and Fischer (1991). The sample narrowing the scope of analysis to the impact of inflation on investment within the range of its low and moderate values was selected for two reasons.

- First, analysis based on a sample in which some countries experienced episodes of very high inflation might lead to errors in generalising the results obtained. Temple (2000) indicates that in samples consisting of countries experiencing different inflation levels, the relationship between inflation and other economic variables may strongly depend on few outliers.

[4] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Norway, the Netherlands, New Zealand, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States of America.

- Second, the studies analyzing inflation-growth nexus published to date suggest that a potential threshold value the excess of which would significantly change the dependence of corporate investment on inflation should rather be sought at the moderate inflation level (see e.g. Ghosh and Phillips, 1998; Khan and Senhadij, 2001; Kremer et al.; 2010, Espinoza et al., 2010; Omay and Kan, 2010)

The data we analyse are obtained from the OECD Economic Outlook Database. The study focuses on the annual real dynamic of fixed gross capital formation in the corporate sector (*inv_corp*) and the annual percentage change of the CPI index[5] (π). Due to the lack of complete data, the number of observations for which both values are available is 912. In the case of panel model estimation, the size of the sample is smaller and depends on the set of explanatory variables used in a given model.

4. Simple descriptive statistics

Table 1 presents frequency distribution of inflation and investment growth rates. The data presented suggest that the share of the number of cases of negative annual investment growth rate in the total number of cases for a given inflation range was a growing function of inflation: for observations in which inflation did not exceed 3%, the negative investment growth rate appeared, on average, in 20% of cases, whereas in the case of inflation ranging between 15% and 20%, it was registered twice as often.

[Table 1 here]

Table 2 compares the mean and the median of both variables for the subsamples, classified according to growing inflation value. This comparison indicates that potential relationship between inflation and investment dynamics is negative: the higher the average inflation level, the lower the average growth rate of investment.

[Table 2 here]

Simple statistics presented above, even though suggesting a negative correlation between inflation and investment growth rate, do not form the basis for drawing conclusions about the strength or statistical significance of this relation. They fail to explain, for example, whether the relationship between inflation and investment is maintained when the effect of other variables which determine investment dynamics is taken into account. Therefore, the following section analyses the relationship between inflation and investment growth based on the estimation of multidimensional panel models.

5. Panel models of corporate investment

[5] In the case of the United Kingdom, with no CPI data available for the whole period, the Retail Price Index (RPI) was applied, as published in the on-line database of the UK Office for National Statistics.

When selecting the specification of the model, we opted for an approach based on reduced model estimation.

- On the one hand, we are not aware of any theoretical model accounting for all the impact channels described in Section 2 that could constitute the basis for estimating a structural model. It is true that an estimation of several structural models, each of them taking into account a number of the existing channels of influence, could be an alternative to a reduced model. However, this would not allow us to account for the interactions between individual channels, and would also preclude a consistent assessment of their relative significance. Therefore, it would be impossible to achieve the main benefit that structural models should provide, namely, a clear and consistent interpretation of results.
- On the other hand, the purpose of this study is to identify the direction and strength of the combined impact of inflation on corporate investment, which is the resultant of all the previously described effects, rather than the identification of particular mechanisms and fine-tuning them to the best theoretical model.

Drawing on the estimation of reduced models is quite common in empirical research on the determinants of investment (cf. the articles described in Section 2, and, e.g. Leahy and Whited, 1995; Guiso and Parigi, 1999; Chirinko et al., 1999; Pelgrin et al., 2002).

The selection of explanatory variables, in addition to the annual inflation rate, was made on the basis of conclusions from theoretical and empirical studies devoted to the determinants of investment:

- The first two variables we selected are meant to approximate changes in the cost of capital utilisation. Although economists come across serious problems with empirical verification of the dependency of investment on the cost of capital (see e.g. Blanchard, 1986 or Baddeley, 2003 for a review), it has a strong theoretical basis (e.g. Jorgenson, 1963; Tobin, 1969).
  - The first variable is the relative price of capital goods (*rel_cost)*, expressed as the natural logarithm of the relation of the deflator of investment in the private enterprise sector to the GDP deflator. The variable shows how the prices of capital goods purchased by enterprises change against the prices of other goods and services.
  - The second variable is the nominal long-term interest rate (*ir)*. Obviously, the cost of capital depends on the real, rather than nominal interest rate. In most empirical research, however, the real interest rate is determined in a simplified manner, i.e. by subtracting the current inflation rate from the nominal interest rate. As in the analysed model the rate of inflation is already present as a separate explanatory variable, including it for the second time as a discounting factor would distort the interpretation and relevance assessment of the relationship between inflation and investment. In turn, the calculation of the real interest rate in a correct way consisting in accounting for the expected, rather than current inflation, is not possible due to the lack of relevant data.
- The third variable is the real GDP growth (*gdp*), which allows us to account for so called accelerator effect. The results of most empirical studies prove that this variable is a significant and robust determinant of investment, and its significance in explaining the volatility of investment processes is greater than the significance of any measure of the cost of capital (cf. e.g. Chirinko, 1993; Baddley, 2003)).

- The last variable is the growth rate of public investment *(inv_pub)*. The direction of its impact on the growth rate of business investment is ambiguous[6]. On the one hand, the impact of government investment on private capital formation depends on the purpose to which public funds are allocated. For example, government investment that focus on providing adequate infrastructure may increase the relative attractiveness of investing in a given country or region, thus supporting private investment. On the other hand, regardless of the type of public investment, it implies (with the level of other expenses unchanged) either higher taxes or bigger liabilities incurred by the state, which in turn should limit enterprises' propensity or ability to invest.
- Some authors (e.g. Easterly and Rebelo,1993; Serven, 1998) suggest to incorporate into the investment models variables measuring the size of the public sector (e.g. the expenditure-to-GDP ratio) or the degree of imbalances in public finances (e.g. debt-to-GDP or deficit-to-GDP ratio). However, the main impact of these values on private investment occurs through the interest rate channel, which has already been included in the model.

In the base model we decided to adopt a specification in which corporate investment is a function of current explanatory variables. The literature presents specifications with very different delay structures. For example, Chirinko et al. (1999) analyse a model in which investment in a given year depends on the cost of capital utilisation in as many as six previous years, while Pelgrin et al. (2002) draw on an analysis of the current influence of investment determinants. The impact of an arbitrarily chosen term structure on the estimation results has been presented in the section devoted to the robustness analysis.

We started the estimation of the investment model with the following functional form:

$$inv\_corp_{it} = f(\pi_{it}, gdp_{it}, inv\_pub_{it}, rel\_\cos t_{it}, ir_{it}) + \varepsilon_{it} \qquad (1)$$

where the growth rate of corporate investment (*inv_corp*) is a linear function of the inflation rate (π) and the set of control variables; ε is a error term and subscripts i = 1, ..., 21 and t = 1, ..., 46 identify, respectively, the cross-sectional and temporal dimensions of the data.

We started by testing the hypothesis of non-stationarity of the variables selected for the model, using the test proposed by Pesaran (2005)[7]. The results summarised in Table 3, indicate that in the case of the analysed variables the null hypothesis of non-stationarity of all time series occurring within the individual variables should be rejected in favour of the alternative hypothesis whereby a significant part of those series is stationary[8].

[Table 3 here]

[6] For example, Voss (2002) confirmed the effect of public investment crowding out private investment in the US and Canadian economies. In turn, Argimon et al. (1997), as well as Lopez (2001), point to the opposite effect (the so-called crowding-in) in the case of public infrastructural investment in 14 developed OECD countries and in Spain, respectively. In the context of panel models of investment, Pindyck and Solimano (1993) demonstrated that the size of public investment has a negative and significant impact on private investment both in developed OECD countries and in the developing ones.

[7] Broad overview of stationarity testing methods and discussion of the related issues can be found, for example, in the article by Breitung and Pesaran (2005).

[8] This is obviously not tantamount to the proposition that all the series within the given variable are stationary. This is one of the limitations of the stationarity tests of panel data

The rejection of the hypothesis of non-stationarity of variables included in the analysis allows us to proceed with the estimation of the model. The first approach uses a pooled estimator (OLS). Thus model (1) assumes the following form:

$$inv\_corp_{it} = \alpha_0 + \beta_1 \pi_{it} + \beta_2 gdp_{it} + \beta_3 inv\_pub_{it} + \beta_4 rel\_\cos t_{it} + \beta_5 ir_{it} + \varepsilon_{it} \qquad (2)$$

Functional form (2) ignores the possibility of individual effects, i.e. specific characteristics of a given country (such as differences in the quality of institutions, access to natural resources, etc.) that are not included in the model but affect the dependent variable. In case this assumption is not true, the estimator is biased, hence it is regarded in the literature as the first approximation, rather than the final form of the model. The estimation results of equation 2 presented in column (1) of Table 4 show a statistically and economically significant negative effect of inflation on corporate investment: an increase in the inflation rate by 1 p.p. leads to a decline in investment growth by 0.18 p. p. in the same year. The effect of the investment accelerator is also significant: an increase in the GDP growth rate by 1 percentage point leads to a rise in investment growth by 2.12 percentage points. The results also indicate that in the surveyed countries public investment crowds out corporate investment: the increase in the growth of the former by 1 p.p. results in decrease of the latter by 0.17 p.p. In contrast, the impact of cost variables, i.e. the relative price of capital and the long-term interest rate, proved to be insignificant[9].

In the next step we waived the assumption of no systematic differences between countries. Thus, we estimated:

- a fixed effects model (FE), which assumes homogeneous coefficients of the explanatory variables but allows for different constant term for particular countries;

  $$inv\_corp_{it} = \alpha_i + \beta_1 \pi_{it} + \beta_2 gdp_{it} + \beta_3 inv\_pub_{it} + \beta_4 rel\_\cos t_{it} + \beta_5 ir_{it} + \varepsilon_{it} \qquad (3)$$

  where α_i is a constant term for a country with index *i*,

- and a random effects model (RE), in which individual effects are treated as random values and are included in the error term;

  $$inv\_corp_{it} = \alpha_0 + \beta_1 \pi_{it} + \beta_2 gdp_{it} + \beta_3 inv\_pub_{it} + \beta_4 rel\_\cos t_{it} + \beta_5 ir_{it} + v_{it} \qquad (4)$$

  where $v_{it} = \varepsilon_{it} + \alpha_i$.

The estimation results of thus defined models are presented in columns (2) and (3), respectively, of Table 4. The FE of inflation is still negative, slightly smaller in absolute terms than in the case of OLS estimator, but statistically insignificant at 10%. In turn, results for the RE model indicate the significance of this coefficient estimates at the level below 5% and its value similar to the OLS estimates. Conclusions concerning the impact of other variables on corporate investment dynamics do not differ from those formulated on the basis of OLS estimation results.

[Table 4 here]

[9] In the case of parameters for the last two variables, 95% confidence interval is wide enough to cover both positive and negative values, hence it is impossible to determine the consistency of the sign of estimates with the economic theory.

The discrepancy between the FE and RE coefficient of inflation leads to the question which of the estimators "better" describes the analysed relationship. Unfortunately, the set of tests designed to answer this question does not provide a clear conclusion (see Table 4):

- the critical value of the Wald test for the FE model indicates that the fixed effects introduced to the model are statistically significant;
- Breusch-Pagan test for the RE model indicates on zero variance of random effects;
- Hausman test, directly examining the differences between FE and RE coefficients, confirms that the RE estimates are characterised by a smaller variance than obtained by the FE estimator.

Therefore, the results of the tests reveal that the RE estimator provides more precise estimates, yet random effects explain a very small part of the variability of the error term.

The correctness of interpretations of the estimates obtained hitherto depends additionally on the fulfilment of two assumptions: homoscedasticity and no autocorrelation of the error term (from the same time periods between individual countries, as well as between different periods for the same country). Applied tests indicate that the null hypothesis of homoscedasticity (Wald test), no cross country correlation (Breusch-Pagan test) and no autocorrelation of error term (Wooldrige test) should be rejected[10].

In the case when previously mentioned assumptions are violated, a panel-corrected standard errors (PCSE) estimator proposed by Beck and Katz (1995) can be applied. The results of the PCSE estimation are presented in column (1) of Table 5. The impact of inflation on corporate investment growth is negative and statistically significant at the level of 10%. The strength of this effect is similar as in the case of previous models. The value and significance of coefficient of GDP growth and public investment growth practically do not change, either. Finally, there are no apparent signs of the impact of cost variables on enterprises' investment decisions.

The consistency of the estimators presented above may be affected by endogeneity problem stemming from potential correlation between regressors and error term. To control for this possibility we used instrumental variables (IV) method. Columns (2) of Table 5 presents the estimation results of the FE model obtained with two-step generalized method of moments (IV/GMM2S)[11]. Inflation, GDP growth and public investment growth were considered as endogenous variables[12], whereas the first lags of analyzed variables were adopted as instruments. Consistency of the GMM2S estimator depends on the validity of the instruments used. To test for this we applied Hansen's J-test of overidentifying restrictions. The joint null hypothesis is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. The test statistic (p-value = 0.33) indicates that the null hypothesis can not be rejected[13].

[10] Fo all three tests respective p-values were lower than 0.001 .
[11] Standard errors and statistics are robust to the presence of heteroskedasticity and autocorrelation.
[12] The endogeneity is not an issue in case of remaining control variables. To verify this we used standard endogeneity test defined as the difference of two Sargan-Hansen statistics (for the equation with the smaller and larger set of instruments, respectively). Results are not presented but are available on request.
[13] It should be stressed that even in this case GMM2S estimator may be subject to weak instrument problem meaning that excluded instruments are only weakly correlated with the endogenous regressors (see Stock et al., 2002). If the assumption that error term has IID distribution is dropped, relevant weak instruments test is Kleibergen and Paap (2006) Wald rank F statistic which in analyzed model equals F= 1.01. Unfortunately in case of applied specification critical values for this test are not available.

[Table 5 here]

The results of the estimation indicate that both in the case of inflation and the growth of GDP, the direction of their impact on investment remained unchanged. As regards inflation, the absolute value and precision of its coefficient's estimate rose significantly as compared to previous models. The coefficients of cost variables do not allow a convincing interpretation of the impact of those variables on investment growth: while the estimated parameter for the interest rate, though statistically significant at 5%, is positive, the parameter at the relative cost of capital is not significantly different from zero.

In the analysed model, it has so far been assumed that the impact of inflation on corporate investment is linear, i.e. independent of the initial level of inflation. However, the conclusions of theoretical and empirical research discussed in Section 2 suggest that this relationship may be of a more complicated, nonlinear nature. To investigate such a possibility, we used two methods.

First, we conducted an analysis of changes in the coefficients determining the impact of inflation on investment dynamics in equation (2) which were estimated with the rolling regression technique. For this purpose, observations available in the sample were sorted according to the increasing rate of inflation, and then a multiple estimation of model (2) (using OLS estimator) was estimated starting from the first 100 observations and adding one observation at each subsequent step. Figure 1 shows how the values and a 95% confidence intervals of the estimated coefficient of inflation change, as the sample expands with subsequent observations. Coefficient estimate in the initial part of the sample is unstable: it turns permanently negative if the highest value of inflation in the sample runs at a level of at least 2.5%, reaching statistical significance for samples where the highest level of inflation is not lower than 3.5%. The scale of the impact of inflation on investment dynamics depends on the range of its value. As the scope of the sample is extended by observations where the inflation ranges from about 3% to around 5.5%, the point value of the estimates decreases (the strength of the relationship increases), reaching the minimum value of approximately -0.8. Expanding the sample by observations with higher inflation values (over 5.5%) leads to a gradual increase in the estimates (weakening of the relationship), up to the value of -0.18, which is the result of model estimation for the entire sample.

[Figure 1 here]

Thus, the observations made suggest that the impact of inflation on investment is nonlinear, and its strength depends on the range of the initial value of inflation. Changes in the range of values smaller than 2.5% do not produce a clear response of corporate investment. In turn, an increase (decrease) from the level above 3.0% leads to a decrease (increase) in investment growth. In addition, the response to the same change in inflation is significantly stronger if the initial value of inflation lies in the range of 3.0-5.5% than when it is above 5.5%. Such character of the examined relationship also indicates that its direction and strength do not depend critically on the presence in the sample of observations with high inflation (in relation to the sample's average). On the contrary, their inclusion in the sample weakens the strength of the negative impact of inflation on investment. This conclusion contrasts with the one formulated in studies examining the effects of inflation on the rate of economic growth. For example, in the study by Bruno and Easterly (1998), the exclusion of countries with inflation above 40% from the sample rendered the negative relationship between inflation and growth estimated on the entire sample insignificant.

Second, we conducted a re-estimation of model (1) extending the set of explanatory variables with an interactive variable $\pi\_3\_5.5$. The aim of this extension was to answer the question whether the dependence of the strength of inflation impact on investment from the initial level of inflation, established with the use of the rolling regression analysis, was statistically significant. The interactive variable was defined as:

$$\pi\_3\_5.5_{it} = \begin{cases} 0; & \pi_{it} < 3.0 \ \vee \ \pi_{it} > 5.5 \\ \pi_{it}; & \pi_{it} \geq 3.0 \ \wedge \ \pi_{it} \leq 5.5 \end{cases} \tag{5}$$

We adopted this interval on the basis of estimates obtained by the rolling regression method, thus performed selection is obviously still arbitrary in nature. Analysis of the inflation threshold could be performed using panel threshold model proposed by Hansen (1999), however it may be severely biased due to endogeneity of regressors observed in analyzed model. The purpose of our analysis is however not to identify precisely the threshold values, but rather to determine whether the nonlinearity observed from the results of the rolling regression is significant for the estimated relationship.

The results of the estimation of model (1) extended by the interactive variable are presented in Tables 6 and 7. In case of inflation, GDP growth and public investment growth both the coefficient estimates and its standard errors do not differ significantly from the values obtained for the model without an interactive variable. In turn, the coefficient of the variable $\pi\_3\_5.5_{it}$ fluctuates, depending on the estimator, in the range of -0.28 to -0.53 and, in each case, is statistically significant at the level of 10%. This means that if the initial level of inflation ranges between 3 and 5.5%, the impact of inflation changes on corporate investment growth is two to three times higher than in a situation where inflation runs outside that range.

These results suggest that the impact of inflation on corporate investment dynamics may be the source of nonlinear nature of the relationship between GDP growth and inflation identified in previous empirical studies.

[Table 6 here]

[Table 7 here]

6. Robustness of results

In the case of a study based on the reduced model, before final conclusions as to the relationship analysed can be drawn, it is necessary to analyse the robustness of the obtained results to changes in the structure of the sample, set of explanatory variables, specification of the equation, etc. As revealed by studies devoted to the relationship between inflation and economic growth, the accuracy and strength of conclusions formulated on the basis of models devoid of this type of analysis can easily be questioned. For example, Levine and Zervos (1993) demonstrated that the exclusion of Nicaragua and Uganda only from the analysed large sample of countries rendered the relationship between inflation and growth estimated on the whole sample no longer significant.

In the first stage, we examined how a change in the assumption about the temporal structure of the relationship between inflation and investment will change the results. To this end, we reformulated model (1) replacing the current values of regressors with their values lagged by one year, while maintaining the current values of those variables which proved statistically significant in previous specifications. The delayed response of investment to changes in their main determinants may reflect the specificity of the decision-making process and also that of production and installation of capital goods. In addition, we expanded the set of regressors with a delayed explained variable, which allow us to take into account a possible inertia specific for investment projects, which had been hitherto ignored. The modified model had the following form:

$$inv\_corp_{it} = f(inv\_b_{it}, \pi_{it}, \pi_{it-1}, gdp_{it}, gdp_{it-1}, inv\_pub_{it}, inv\_pub_{it-1}, rel\_\cos t_{it}, ir_{it}) + \varepsilon_{it} \quad (6)$$

The estimation of autoregressive model (6) with the use of "classical" methods (i.e. OLS, FE and RE) may biased results[14]. In order to eliminate this problem, considering a relatively small number of countries in our study, we applied a procedure for correcting the bias of the FE estimator proposed by Bun and Kiviet (2002) and then modified for the analysis of unbalanced panels by Bruno (2005).

Column (2) of Table 8 presents the results obtained using this method (biased-corrected least square dummy variable, LSDVC) and column (1) gives the assessments obtained with the use of the classical FE estimator. Their comparison shows that the addition of delayed inflation resulted in shifting the main thrust of the impact from the current variable onto the delayed variable. The direction and strength of the effect remained consistent with the results obtained on the basis of previous models. Such a change might suggest that the inflation impulse is transmitted to the decisions of enterprises with some delay. In the case of GDP and public investment growth, their main impact on corporate investment occurs through changes in current values. Also the impact of the delayed growth of corporate investment on its current value was significant, which may confirm the inertia of investment processes.

[Table 8 here]

In the next step, the re-estimation of model (1) was carried out using the averaged values for five years non-overlapping periods. This modification allows us to see if the obtained results do not critically depend on the apparent short-term correlations between the analysed variables. The averaging of the data, though not devoid of weaknesses (cf. e.g. Hendry and Ericsson, 1991), is a method often used in testing hypotheses based on macroeconomic panel data, with the usually adopted averaging horizon of five years (cf. e.g. Ghosh and Phillips, 1998; Levine et al., 2000, Blanchard and Wolfers, 2000, Rousseau and Wachtel, 2002; Gruben and McLeod, 2003; Bowdler and Nunziata, 2007).

The results of the estimation of model (1) for thus defined panel are presented in Table 9 (Regression 1)[15]. The estimation was carried out on the basis of "classical" estimators (OLE, FE and RE). Due to the lack of an adequate number of observations, the GMM2S and the PCSE estimator were omitted. Regardless of the estimation method, the impact of inflation on investment is negative and statistically significant at the level of 5%. At the same

[14] This was first pointed out by Nickell (1981), in the context of the FE estimator.

[15] The reported result for this and following robustness tests are restricted to respective coefficient of inflation, its standard errors, *p*-values and number of observations. The remaining results did not change substantially what allows to maintain previously formulated conclusions.

time, the absolute value of the estimated coefficient is about two times higher than in the case of corresponding estimates made on annual data. This can be attributed to the "averaging" of the nonlinear effect observed when the correlation is estimated on annual data.

[Table 9 here]

The next step of the robustness analysis was to determine whether the estimated relationship between inflation and corporate investment depended critically on the inclusion in the sample of observations for years in which oil crises occurred. Supply shocks associated with oil prices could be responsible for the apparent correlation of inflation and investment, as they were accompanied by a simultaneous acceleration of price growth and weakening of economic growth (this effect, however, is at least partially controlled in previously estimated equations by including the GDP growth rate as a control variable). In order to examine whether this effect is significant for the analysed relationship, the model was re-estimated by removing observations for 1973-1975, 1979-1982 and 1990-1992 from the sample. Another possible approach would be to extend the set of control variables with oil prices (or oil price growth), yet the response of economies to the same price changes can vary between countries and periods. For example, the scale of changes in oil prices seen over the past decade was comparable with the changes in the periods of oil crises, even though the impact of these shocks on the economies of the developed countries proved very limited.

The estimation results of model (1) on a reduced sample are presented in Table 9 (regression 2). The exclusion of years marked by oil crises from the sample did not change the sign and the significance of the relationship between inflation and investment estimated on the entire data set. The response of investment, however, turned out to be about two times stronger than in the case of results obtained in the case of the model estimated for the entire sample. The increase in the parameter estimate is again a reflection of the nonlinearity characteristic of the inflation-investment relationship. In the years of oil crises the average level of inflation in the surveyed countries was among the highest in the whole examined period, and the results accounting for this nonlinearity indicated that inflation changes in the range of high (in the context of the analysed sample) values had a relatively smaller impact on investment growth than inflation changes in the range of 3-5.5%.

Another important test of robustness of the results received so far was the re-estimation of the model on the sample covering the years 1993-2005. During this period, central banks in many of the analysed countries embarked on pursuing a monetary policy based on direct inflation targeting. Such narrowing of the sample helps assess whether, after the changed regime of monetary policy pursuit, the conclusions about the impact of inflation on investment drawn on the basis of the entire period remained in force.

The results of the estimation carried out on a sample narrowed down to the period 1993-2005 are presented in Table 9 (regression 3). Except for the estimate obtained using the PCSE estimator, the coefficient of inflation in equation (1) is negative and statistically significant at the level of at least 10%. The values of estimated parameters are, in absolute terms, several times higher than in the case of results obtained for the model estimated for the entire sample. In part, the higher estimates probably result from the nonlinear relationship between inflation and investment growth. In the years 1992-2005, the average inflation in the examined countries was significantly lower than in the years 1960-1991 and, as demonstrated by the results accounting for this nonlinearity, changes in inflation in its lower range have a relatively greater impact on corporate investment than its changes in the higher range.

7. Summary and conclusions

In this article, we have analysed the relationship between the growth of corporate investment and inflation in 21 OECD countries in 1960-2005, i.e. in the case when inflation did not exceed its moderate levels. The main conclusions from this analysis are as follows:

- The relationship between inflation and investment in the analyzed group of countries was negative and statistically significant. This result was obtained irrespective of the estimators applied. It is also robust to changes in the specification of the estimated equation, data frequency and the period considered in the study.
- The resulting relationship is nonlinear in nature. At very low values of inflation (below 2.5%), the relationship is unstable. The increase in inflation in the range above 3.0% has a negative impact on investment. Moreover, the marginal impact of inflation is the greatest when it is in the range of approximately 3.0-5.5% and decreases with further inflation rise. The negative relationship between inflation and investment is therefore not limited only to the range of high inflation values and a given inflation rate may have a particularly strong negative impact on corporate investment when the initial level of inflation is low. These results suggest also that the impact of inflation on corporate investment dynamics may be the source of nonlinear nature of the relationship between GDP growth and inflation identified in recent empirical studies.
- The variables approximating the cost of capital utilisation, such as the long-term interest rate or the relative cost of capital are not statistically significant determinants of investment, if the direct impact of inflation is controlled in the model. In turn, the rate of economic growth (positive impact) and the scale of investment undertaken by the public sector (negative impact) have an impact on corporate investment that is significant and robust to various changes in model specification. Therefore, this is a result consistent with the results of other empirical studies, which indicate that the significance of "quantitative" variables (such as demand growth, production capacity utilisation, etc.) in explaining the volatility of investment processes is greater than it is true for any measures of the cost of capital.

The obtained results suggest that the risk of negative impact of growing inflation on corporate investment should be treated as a counterbalance to the fears that the tightening of monetary policy may discourage firms from investing and, as a result, prolong the period of recovery from the economic slowdown.

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Table 1. Frequency distribution of inflation and corporate investment growth.

Inflation	Investment growth								
	<-5	-5-0	0-5	5-10	10-20	>20	negative	positive	Total
<3	3.0	5.2	10.5	11.1	6.6	1.2	8.11	29.39	37.5
3-5	2.4	3.4	4.8	7.1	4.1	0.6	5.81	16.56	22.4
5-10	3.6	3.7	5.6	5.2	4.6	1.1	7.35	16.45	23.8
10-15	2.1	1.1	2.4	2.1	1.6	0.3	3.18	6.46	9.6
15-20	0.7	1.1	1.3	0.3	0.8	0.1	1.76	2.53	4.3
>20	0.7	0.9	0.6	0.1	0.2	0.0	1.54	0.88	2.4
Total	12.4	15.4	25.2	25.9	17.9	3.3	27.74	72.26	100.0

Source: Own calculations

Table 2. Mean and median of inflation and corporate investment growth.

Inflation	Number of observations	Inflation		Investment growth	
		Mean	Median	Mean	Median
<3	342	1.8	2.0	5.2	5.1
3-5	204	3.9	3.8	4.5	5.3
5-10	217	7.1	6.8	4.2	4.5
10-15	88	12.1	11.8	3.2	3.5
15-20	39	17.0	16.9	1.9	2.2
>20	22	23.6	23.1	-1.9	-1.7
All observations	912	5.7	4.0	4.3	4.6

Source: Own calculations

Table 3. Results of panel stationarity test by Pesaran (2005).

	Variable	*t*-statistic	*p*-value
Without trend			
	inv_corp_{it}	-10.234	0.000
	π_{it}	-9.636	0.000
	gdp_{it}	-10.890	0.000
	inv_pub_{it}	-12.315	0.000
	rel_cost_{it}	-1.382	0.083
	ir_{it}	-4.628	0.000
With trend			
	inv_corp_{it}	-9.112	0.000
	π_{it}	-8.151	0.000
	gdp_{it}	-9.404	0.000
	inv_pub_{it}	-11.069	0.000
	rel_cost_{it}	-2.231	0.013
	ir_{it}	-2.275	0.011

Source: Own calculations

Table 4. Results of model (1) estimation on entire sample.

	OLS	FE	RE
	(1)	(2)	(3)
π_{it}	-0.1829**	-0.1162	-0.1648**
	(0.0704)	(0.0774)	(0.0721)
	[0.010]	[0.113]	[0.022]
gdp_{it}	2.1238**	2.2345**	2.1570**
	(0.0973)	(0.1039)	(0.0986)
	[0.000]	[0.000]	[0.000]
inv_pub_{it}	-0.1657**	-0.1646**	-0.1654**
	(0.0242)	(0.0243)	(0.0241)
	[0.000]	[0.000]	[0.000]
rel_cost_{it}	2.2930	-3.6822	0.5402
	(1.8260)	(2.9675)	(2.1065)
	[0.210]	[0.215]	[0.798]
ir_{it}	0.0620	0.0887	0.0607
	(0.0859)	(0.0952)	(0.0887)
	[0.471]	[0.352]	[0.494]
Total R^2	0.3902	0.3821	0.3894
Within R^2	NA	0.4120	0.3966
Between R^2	NA	0.2864	0.2411
Wald test of total significance (p value)	0.000	0.000	0.000
Wald test of total significance of fixed effects (p value)	NA	0.044	NA
LR Breusch-Pagan test of random effects (p value)	NA	NA	0.752
Hausman specification test (p value)	NA	0.431	
Number of observations	790	790	790

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

Table 5. Results of model (1) estimation on entire sample (continued).

	PCSE	GMM2S
	(1)	(2)
π_{it}	-0.1472*	-0.3578*
	(0.0870)	(0.2042)
	[0.091]	[0.080]
gdp_{it}	2.0910**	2.5309**
	(0.1084)	(0.9372)
	[0.000]	[0.007]
inv_pub_{it}	-0.1670**	0.2865
	(0.0264)	(0.4215)
	[0.000]	[0.497]
rel_cost_{it}	3.1294	-5.7543
	(2.3302)	(5.2487)
	[0.179]	[0.273]
ir_{it}	0.0172	0.5124**
	(0.1037)	(0.1772)
	[0.868]	[0.004]
Total R^2	0.3736	0.1542
Wald test of total significance (p value)	0.000	0.000
Hansen J-statistics	NA	0.330
Number of observations	790	774

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

Table 6. Results of model (1) estimation with interactive variable.

	OLS (1)	FE (2)	RE (3)
π_{it}	-0.2123**	-0.1471*	-0.1913**
	(0.0711)	(0.0784)	(0.0730)
	[0.003]	[0.061]	[0.009]
$\pi\_3\_5.5_{it}$	-0.3320**	-0.2874**	-0.3108**
	(0.1285)	(0.1304)	(0.1285)
	[0.010]	[0.028]	[0.016]
gdp_{it}	2.1474**	2.2480**	2.1806**
	(0.0974)	(0.1038)	(0.0988)
	[0.000]	[0.000]	[0.000]
inv_pub_{it}	-0.1628**	-0.1621**	-0.1625**
	(0.0241)	(0.0242)	(0.0241)
	[0.000]	[0.000]	[0.000]
rel_cost_{it}	2.4671	-2.9542	0.6618
	(1.8206)	(2.9784)	(2.1285)
	[0.176]	[0.322]	[0.756]
ir_{it}	0.0821	0.1051	0.0807
	(0.0860)	(0.0953)	(0.0891)
	[0.34]	[0.270]	[0.365]
Total R^2	0.3953	0.3885	0.3945
Within R^2	NA	0.4050	0.4038
Between R^2	NA	0.2652	0.2142
Wald test of total significance (p value)	0.000	0.000	0.000
Wald test of total significance of fixed effects (p value)	NA	0.066	NA
LR Breusch-Pagan test of random effects (p value)	NA	NA	0.752
Hausman specification test (p value)	NA	0.431	
Number of observations	790	790	790

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

Table 7. Results of model (1) estimation with interactive variable (continued).

	PCSE (1)	GMM2S (2)
π_{it}	-0.1740* (0.0869) [0.045]	-0.4821** (0.2052) [0.019]
$\pi\_3\_5.5_{it}$	-0.3444** (0.1275) [0.007]	-0.5267* (0.2983) [0.077]
gdp_{it}	2.1102** (0.1085) [0.000]	2.4661** (1.0420) [0.018]
inv_pub_{it}	-0.1643** (0.0263) [0.000]	0.3871 (0.5064) [0.445]
rel_cost_{it}	3.4450 (2.2938) [0.133]	-4.2369 (5.3652) [0.430]
ir_{it}	0.0289 (0.1034) [0.780]	0.6027** (0.2199) [0.006]
Total R^2	0.3860	0.056
Wald test of total significance (p value)	0.000	0.000
Hansen J-statistics (p-value)	NA	0.288
Number of observations	790	774

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

Table 8. Results of model (6) estimation.

	FE (1)	LSDVC (2)
inv_corp_{it-1}	0.0870**	0.1154**
	(0.0359)	(0.0084)
	[0.015]	[0.000]
π_{it}	0.0430	0.0422
	(0.1048)	(0.0343)
	[0.681]	[0.123]
π_{t-1}	-0.309**	-0.3137**
	(0.1162)	(0.1136)
	[0.008]	[0.006]
gdp_{it}	2.0444**	2.0475**
	(0.1104)	(0.0627)
	[0.000]	[0.000]
gdp_{t-1}	0.3259**	0.2577**
	(0.1411)	(0.0862)
	[0.021]	[0.003]
inv_pub_{it}	-0.1895**	-0.1903**
	(0.0245)	(0.0084)
	[0.000]	[0.000]
inv_pub_{t-1}	-0.0423*	-0.0377
	(0.0247)	(0.0278)
	[0.087]	[0.175]
rel_cost_{t-1}	-0.9369	-2.0411**
	(3.0498)	(0.3999)
	[0.759]	[0.000]
ir_{t-1}	0.1988**	0.2313**
	(0.0955)	(0.0331)
	[0.038]	[0.000]
Total R^2	0.4227	NA
Within R^2	0.4227	NA
Inter-group R^2	0.3198	NA
Number of observations	770	790

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

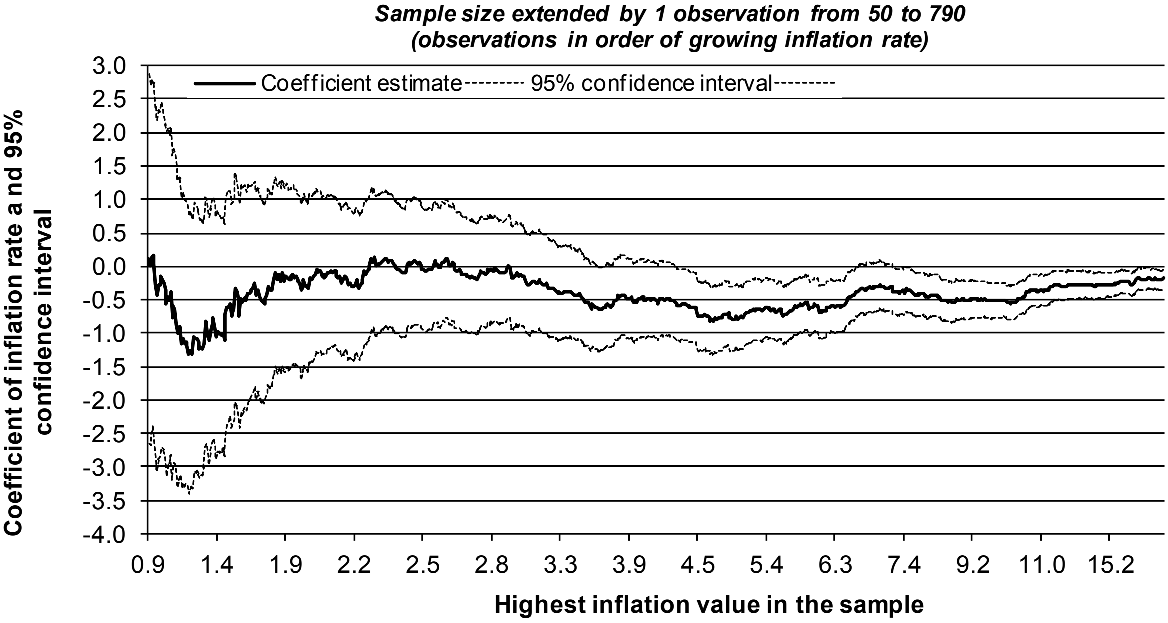
Table 9. Coefficient of inflation rate in model (1) - robustness analysis.

Model	coefficient	standard error	p-value	sample size
(1) Averaged data for 5-year periods				
OLS	-0.3304**	(0.0815)	[0.000]	163
FE	-0.3025**	(0.0871)	[0.001]	163
RE	-0.3240**	(0.0811)	[0.000]	163
(2) Excluding years 1973-73, 1979-82 and 1990-91				
OLS	-0.3428**	(0.1032)	[0.001]	600
FE	-0.3139**	(0.1122)	[0.005]	600
RE	-0.3393**	(0.1049)	[0.001]	600
PCSE	-0.2889*	(0.1560)	[0.064]	600
(3) 1993-2005 sample				
OLS	-0.7821**	(0.3471)	[0.025]	256
FE	-0.8251*	(0.4371)	[0.060]	256
RE	-0.7821**	(0.3471)	[0.025]	256
PCSE	-0.6043	(0.4191)	[0.112]	256

Note: One or two asterisks denote statistical significance at the level of 10% and 5%, respectively. Round brackets indicate standard errors, while square brackets *p*-values.

Source: Own calculations

Figure 1. Coefficient of inflation rate in equation (1) based on OLS rolling regression estimation.



Source: Own calculations