ISSN 1791-3144

**University of Macedonia
Department of Economics**

Discussion Paper Series

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they related?**

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Discussion Paper No. 12/2010

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Inflation, inflation uncertainty and growth: are they related ?

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Abstract

We examine the relationship between inflation uncertainty, inflation and growth using annual historical data on industrial countries covering in many cases more than one century. Proxying inflation uncertainty by the conditional variance of inflation shocks, we obtain the following results. (1) There is significant evidence for the positive effect of inflation uncertainty on inflation supporting the Cukierman-Meltzer hypothesis. (2) There is mixed evidence on the causal effect of inflation on inflation uncertainty. (3) There is strong evidence that inflation uncertainty is not detrimental to output growth.

Keywords: Inflation uncertainty, growth, GARCH models

JEL Classification: E31, O40

Acknowledgements: The paper has benefited from the comments of an anonymous referee. Any remaining errors are our own responsibility. The project was co-funded by the European Social Fund and National Resources-(EPEAEK II)-PYTHAGORAS.

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Abstract

We examine the relationship between inflation uncertainty, inflation and growth using annual historical data on industrial countries covering in many cases more than one century. Proxying inflation uncertainty by the conditional variance of inflation shocks, we obtain the following results. (1) There is significant evidence for the positive effect of inflation uncertainty on inflation supporting the Cukierman-Meltzer hypothesis. (2) There is mixed evidence on the causal effect of inflation on inflation uncertainty. (3) There is strong evidence that inflation uncertainty is not detrimental to output growth.

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1. Introduction

High inflation is considered an undesirable outcome. In fact, during the last 20 years most central banks in industrial countries have set price stability as their primary objective. It is widely agreed that this focus of monetary policy on price stability has been the main cause of disinflation in these countries (Greenspan, 2004). Friedman's famous proposition that inflation is always and everywhere a monetary phenomenon has received wide acceptance by the economics profession and seems to be responsible for the emphasis on price stability. Nevertheless, the economics profession has been unable to provide a convincing argument for the welfare cost of inflation. In broad terms, inflation is considered costly because it makes the price mechanism a less effective apparatus in allocating resources efficiently. Friedman (1977) in his Nobel lecture argues that a variable, and hence uncertain, rate of inflation makes it harder to determine relative prices, which is necessary to allocate resources efficiently on the basis of these prices. Moreover, Friedman (1977) claims that inflation uncertainty is likely to be high during periods of high inflation.

Recently, there has been a growing interest in testing for the empirical relationship between inflation and inflation uncertainty. Davis and Kanago (2000) provide a comprehensive survey of these studies. Inflation uncertainty is usually measured by the conditional variance of the inflation series in a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) framework. The advantage of this framework is that it allows testing for the variability of inflation over time. With some exceptions (Grier and Perry 2000, Grier et al, 2004, Elder, 2004, Hwang, 2007), the studies of the inflation - inflation uncertainty nexus do not test for the bidirectional relationship between these two variables simultaneously. Rather, they first estimate the conditional variance of inflation and then perform Granger-causality tests for the impact of this variance (the proxy for inflation uncertainty) on inflation. Furthermore, with a few exceptions (Daal et al., 2005, Thornton, 2007) the majority of these studies employs data from recent years (post-World War II) and focus on the US or the G7.

In this paper, we differentiate from the majority of the literature in three ways. First, we estimate the relationship between inflation and the associated uncertainty simultaneously (thus increasing efficiency in the estimation procedure). Second, we use annual data for several industrial countries spanning the 19th and 20th centuries. Finally, we also test for the real effects of inflation uncertainty to search for evidence for the welfare costs of this uncertainty. The paper is outlined as follows. Section 2 describes our econometric methodology, section 3 presents our results, and section 4 concludes.

2. Econometric methodology

We use a GARCH-in-Mean (GARCH-M) model enriched with lagged inflation in the conditional variance equation. The model is described by equations (1) - (3) below:

$$\pi_t = \Phi_0 + \sum_{i=1}^n \Phi_i \pi_{t-i} + \sum_{i=1}^m \Phi_{\pi i} \varepsilon_{t-i} + \gamma h_{\pi} + \varepsilon_t \quad (1)$$

$$\varepsilon_t = \nu_t \sqrt{h_{\pi}} \quad (2)$$

$$h_{\pi} = \omega_{\pi} + \sum_{j=1}^k \alpha_{\pi j} \varepsilon_{\pi-j}^2 + \sum_{j=1}^l \beta_{\pi j} h_{\pi-j} + \delta \pi_{t-1} \quad (3)$$

Equation (1) is the general ARMA(n,m) model, where π_t represents the inflation rate. The error process is given by equation (2) where $\sigma_{\nu}^2 = 1$. Since $\{\nu_t\}$ is by assumption a white noise process that is independent of past realizations of ε_{t-i} , the conditional and unconditional means of ε_t are equal to zero. The conditional variance of ε_t is given by (3).

The in-mean coefficient γ tests for the impact of inflation uncertainty on inflation. This is the so-called Cukierman-Meltzer (1986) hypothesis. It predicts that, in response to more uncertainty about the stance of monetary policy, and hence the rate of inflation, the monetary authority has an incentive to surprise the public and apply over-expansionary monetary policy in anticipation of output gains. A negative sign for the in-mean coefficient would be consistent with the stabilization hypothesis

advanced by Holland (1995). In response to more inflation uncertainty, and fearing of the possible real effects of such uncertainty, central banks may try to counteract this uncertainty by contracting their money supply, thus reducing inflation. Coefficient δ in equation (3) tests for the level effect, i.e., the effect of inflation on inflation uncertainty (the Friedman hypothesis). By definition of the GARCH-M model, the conditional variance of inflation can affect inflation only contemporaneously. This is quite restrictive since a central bank adjusts its money supply growth rate to a change in inflation uncertainty with a time lag. Therefore, inflation, being highly correlated with money growth, is also affected with a time lag following a change in inflation uncertainty.

On the basis of the above analysis, for countries where the coefficient γ is found not to be statistically significant, we estimate the GARCH model without the in-mean term. We then use the estimated conditional variance of inflation in performing Granger-causality tests in order to test for the lagged impact of inflation uncertainty on inflation in line with the above discussion. To test for the lagged effect of inflation uncertainty on inflation, the following equation is run:

$$\pi_t = \phi_{\pi 0} + \sum_{i=1}^k \phi_{\pi i} \pi_{t-i} + \sum_{j=1}^k \zeta_j \hat{h}_{\pi-j} + \varepsilon_{\pi t}, \quad (4)$$

where $\hat{h}_{\pi-j}$ is the lagged conditional variance of the inflation rate estimated with the GARCH model. Rejection of the null hypothesis that all $\zeta_j = 0$ implies that inflation uncertainty Granger-causes inflation.

To test for the effect of inflation uncertainty on output growth, we estimate the following equation for output growth Y :

$$Y_t = \phi_{Y0} + \sum_{i=1}^k \phi_{Yi} Y_{t-i} + \sum_{j=1}^k \xi_j \hat{h}_{\pi-j} + \varepsilon_{Yt} \quad (5)$$

We then test the null hypothesis that all $\xi_j = 0$. Rejection of the null hypothesis and evidence that $\sum \xi_j < 0$ is consistent with Friedman's argument that inflation uncertainty has negative real effects.

3. Data and results

(i) Data

We use annual data on CPI and real GDP to construct the rates of inflation and output growth, respectively. The sample includes 22 industrial countries listed in Table 1 along with the respective sample length. The data sources are Mitchell (2000) and International Financial Statistics for the CPI and Maddison (2003) for real GDP. For several countries in our sample the inflation and/or growth series cover part of the 19th century.

(ii) Results

Following the construction of the annual inflation and real output growth series, Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests indicate all series are stationary (see Tables 2 and 3). The regression models on which the unit root tests are based do not include a constant term and a time trend. In the next step, we use the standard LM test to test for ARCH effects in inflation. The test results reported in Table 4 indicate strong evidence for GARCH effects in all countries, except Spain. The finding of GARCH effects with annual-frequency data is not very surprising given that our time series are very long (over 100 years of data for several countries) thus indicating periods of both low and high variability of inflation¹. Table 5 reports the results of the GARCH-M estimation². We only report the estimated coefficients γ and δ and some diagnostics (the Q-statistics for the residuals and squared residuals). The results indicate that the estimated coefficient γ is statistically significant in most cases. Moreover, in the majority of those cases (eleven of fourteen), the coefficient is positive, thus providing support to the Cukierman-Meltzer hypothesis. This conclusion is broadly consistent with other studies (e.g., Daal et al., 2005). Mixed results are obtained regarding the sign of δ . In six countries the effect is positive, in five countries it is negative, and in the rest of the

¹ The German data are split into two parts as, owing to the inability to estimate a sensible model for the full period, we decided to omit the hyperinflation years 1922 and 1923.

cases the coefficient is insignificant. Thus, we only find limited support for Friedman's claim that a higher inflation rate leads to more uncertainty regarding the inflation rate.

Table 6 reports the results of Granger-causality tests regarding the effect of inflation uncertainty on growth. The effect is statistically significant in only eight cases. In only two of these cases inflation uncertainty is detrimental to output growth. Thus, Friedman's argument regarding the real effects of inflation uncertainty receives very little support. In fact, for six countries we find that inflation uncertainty raises growth, a result consistent with the theoretical model of Dotsey and Sarte (2000) and evidence provided in Fountas et al. (2004) and Fountas and Karanasos (2007) using post-World War II data on industrial countries. In most of the countries examined, inflation uncertainty has no statistically significant effect on output growth. In Table 3 we also report the results of Granger-causality tests for the impact of inflation uncertainty on inflation for countries where evidence for such an effect was not provided on the basis of the GARCH-M model³. In four countries, inflation uncertainty affects inflation with a time lag and, as previously, the direction of the effect is mixed.

(iii) Discussion

Given the very long time span of this study the results obtained should be interpreted with caution. The power gain of using a long time series may be offset by the possibility of structural breaks. The results obtained in this study suggest that, with a few exceptions, uncertainty about inflation has no, or positive, effect on growth. This finding provides some support to the Dotsey and Sarte (2000) prediction regarding the positive effect of inflation uncertainty on growth. However, one should not go too far and derive policy implications from this result. Creating inflation uncertainty would be a very perverse incentive to "stimulate" growth. There are possibly other explanations for the positive effect of inflation uncertainty on growth. First, a possible reason for the result is misspecification: the actual process driving inflation dynamics may differ from the estimated model, either due to structural

² No GARCH model satisfying all theory-implied parameter restrictions could be estimated for Belgium.

³ In all Granger-causality tests the maximum lag is set at 4.

breaks or some other reason. Second, the model may be picking up some correlation, rather than a causal relationship between inflation uncertainty and inflation. This might be the case if there is a third causal variable that has inadvertently been omitted from the specification. This may be especially true with the bivariate, low frequency specification. Third, over the observed time period and at the specified frequency, potentially insufficient variation in inflation uncertainty may lead to difficulty in adequately estimating the desired relationship.

4. Conclusions

We have tested for the relationship between inflation and inflation uncertainty and for the real effects of inflation uncertainty using annual data spanning over one century for 22 industrial countries. Our evidence supports the following three conclusions. First, in most cases where we find a significant effect of inflation uncertainty on inflation, the effect is positive supporting the Cukierman-Meltzer hypothesis. Second, there is mixed evidence concerning the effect of inflation on inflation uncertainty, thus providing only partial support to Friedman. Third, inflation uncertainty seems not to be detrimental to growth. On the basis of this evidence, the recent emphasis placed by several central banks on price stability may be exaggerated.

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Table 1: Data

Country	Consumer Price Index	Gross Domestic Product
Australia	1901*	1870
Austria	1914	1870
Belgium	1920	1846
Canada	1910*	1870
Denmark	1815	1820
Finland	1914	1860
France	1840*	1820
Germany	1820*	1850
Great Britain	1781*	1830
Greece	1914*	1921
Hungary	1924	1924
Ireland	1922	1921
Italy	1861*	1861
Japan	1868*	1870
The Netherlands	1880	1820
New Zealand	1907	1870
Norway	1914	1865
Portugal	1929	1865
Sweden	1830	1820
Switzerland	1890	1850
USA	1800*	1870
<p>Notes: The starting point differs across countries of our sample.</p> <ul style="list-style-type: none">• * In these countries, the sample period ends in 2003 for the CPI.• In the rest of the countries the sample period ends in 2004 for the CPI.• In all countries the sample period ends in 2001 for GDP		

Source: The CPI data are taken from the International Financial Statistics (IMF) and Mitchell (2000); the GDP data are from Maddison (2003).

Table 2: Unit root tests for Inflation

Country	Dickey-Fuller ADF(4)	Phillips-Perron PP(4)
Australia	-1,606	-4,407
Austria	-2,867	-3,334
Canada	-2,268	-3,928
Denmark	-5,297	-8,679
Finland	-3,718	-4,053
France	-3,028	-4,288
Germany (I)	-2,005	-6,278
Germany(II)	-2,164	-5,631
Great Britain	-4,297	-9,659
Greece	-2,767	-5,911
Hungary	-1,649	-2,718
Ireland	-1,294	-2,400
Italy	-3,639	-5,768
Japan	-3,464	-5,251
Netherlands	-2,576	-5,612
New Zealand	-1,501	-2,269
Norway	-2,975	-3,796
Portugal	-1,170	-1,892
Sweden	-3,813	-5,181
Switzerland	-2,936	-3,943
USA	-3,801	-7,916
Notes: The tests do not include a constant. Order of augmentation (ADF) and lag truncation (PP) in parentheses. Critical value: -1,615(10%).		

Table 3: Unit root tests for Output Growth

Country	Dickey-Fuller ADF(4)	Phillips-Perron PP(4)
Australia	-2,866	-7,909
Austria	-3,932	-9,262
Belgium	-3,754	-8,366
Canada	-3,113	-6,653
Denmark	-2,761	-10,269
Finland	-3,093	-7,383
France	-5,529	-10,967
Germany	-5,101	-8,580
Great Britain	-3,537	-7,523
Greece	-3,065	-4,960
Hungary	-3,243	-6,186
Ireland	-0,038	-2,319
Italy	-3,915	-9,271
Japan	-3,107	-9,215
Netherlands	-4,912	-9,918
New Zealand	-3,026	-8,520
Norway	-2,481	-7,430
Portugal	-2,043	-9,488
Sweden	-2,957	-9,227
Switzerland	-3,665	-10,059
USA	-3,751	-6,938
Notes: The tests do not include a constant. Order of augmentation (ADF) and lag truncation (PP) in parentheses. Critical value: -1,615(10%).		

Table 4: ARCH LM Tests for inflation

Country	LM(1) p-value	LM(2) p-value	LM(4) p-value
Australia	5.604[0.01]	5.930[0.05]	7.331[0.12]
Austria	12.337[0.00]	12.909[0.00]	12.726[0.01]
Belgium	3.553[0.05]	3.765[0.15]	3.705[0.44]
Canada	6.865[0.00]	6.795[0.03]	7.625[0.10]
Denmark	5.624[0.01]	43.598[0.00]	89.437[0.00]
Finland	6.403[0.01]	6.611[0.03]	17.407[0.00]
France	76.641[0.00]	77.025[0.00]	81.485[0.00]
Germany I	5.251[0.13]	2.959[0.22]	23.694[0.00]
Germany II	11.526[0.00]	13.625[0.00]	15.911[0.00]
Great Britain	10.119[0.00]	15.549[0.00]	17.907[0.00]
Greece	16.613[0.00]	16.645[0.00]	25.084[0.00]
Hungary	9.803[0.00]	9.803[0.00]	9.811[0.04]
Ireland	29.181[0.00]	31.203[0.00]	32.237[0.00]
Italy	9.514[0.00]	9.758[0.00]	10.742[0.03]
Japan	58.737[0.00]	71.928[0.00]	77.513[0.00]
The Netherlands	6.119[0.01]	6.129[0.04]	16.362[0.00]
New Zealand	27.056[0.00]	29.214[0.00]	31.478[0.00]
Norway	7.538[0.00]	8.958[0.01]	50.484[0.00]
Portugal	19.018[0.00]	19.506[0.00]	21.699[0.00]
Spain	0.492[0.48]	0.772[0.67]	2.886[0.57]
Sweden	27.725[0.00]	28.113[0.00]	35.489[0.00]
Switzerland	36.619[0.00]	41.853[0.00]	50.546[0.00]
USA	47.571[0.00]	53.673[0.00]	59.043[0.00]
Notes: Obs* R squared are the numbers in the table. Included lags are given in parentheses and probabilities in brackets.			

Table 5: Estimated coefficients γ and δ

Country	Coefficient γ	Coefficient δ	$Q(4)$	$Q^2(4)$
Australia	1.345[0.00]	0.020[0.01]	5.950[0.20]	2.688[0.61]
Austria	11.125[0.02]	-0.001[0.78]	0.586[0.90]	0.417[0.93]
Canada	11.752[0.05]	0.016[0.16]	1.964[0.74]	0.399[0.98]
Denmark	-5.364[0.00]	-0.003[0.41]	3.470[0.44]	0.501[0.97]
Finland	0.202[0.01]	-0.001[0.02]	6.661[0.15]	1.035[0.90]
France	-0.540[0.29]	-0.001[0.00]	2.083[0.72]	2.810[0.59]
Germany I (1820-1921)	0.862[0.14]	0.054[0.00]	0.971[0.80]	1.408[0.70]
Germany II (1924-2003)	2.718[0.00]	-0.005[0.00]	1.367[0.85]	4.493[0.34]
Great Britain	0.538[0.64]	-0.000[0.11]	4.390[0.35]	1.703[0.79]
Greece	1.672[0.00]	-0.053[0.16]	6.144[0.10]	2.015[0.56]
Hungary	-1.150[0.04]	0.004[0.71]	2.534[0.63]	0.418[0.98]
Ireland	7.250[0.02]	-0.001[0.00]	2.124[0.71]	0.371[0.98]
Italy	0.339[0.15]	0.008[0.00]	4.496[0.34]	2.356[0.67]
Japan	0.864[0.02]	0.002[0.90]	2.506[0.64]	2.282[0.68]
The Netherlands	2.718[0.00]	-0.007[0.00]	1.531[0.82]	0.466[0.97]
New Zealand	11.313[0.05]	0.006[0.06]	0.825[0.93]	4.483[0.34]
Norway	-3.139[0.11]	-0.002[0.25]	1.299[0.52]	0.272[0.87]
Portugal	6.036[0.09]	0.008[0.35]	1.825[0.76]	2.721[0.60]
Sweden	-26.718[0.00]	0.008[0.00]	3.868[0.27]	2.052[0.56]
Switzerland	2.166[0.47]	-0.002[0.32]	0.125[0.98]	2.096[0.55]
USA	1.037[0.43]	0.018[0.00]	5.305[0.25]	0.994[0.91]
<p>Notes: γ is the coefficient of the in-mean effect in the inflation equation. δ is the coefficient on the lagged inflation rate in the conditional variance of inflation equation. The Q-statistics test for serial correlation in the residuals and squared residuals, respectively. Probabilities are given in brackets.</p>				

Table 6: Wald tests

	Ho: Inflation uncertainty does not Granger-cause inflation			Ho: Inflation uncertainty does not Granger-cause growth		
Country	F-statistic	p-value	sign	F-statistic	p-value	sign
Australia	0.051(1)	0.82		0.089(2)	0.91	
Austria				33.903(1)	0.00	+
Canada				2.233(1)	0.13	
Denmark				0.002(1)	0.95	
Finland				3.411(4)	0.01	+
France	15.184(1)	0.00	+	1.156(1)	0.28	
Germany(1820-1921)	2.890(1)	0.09	+	0.069(1)	0.79	
Germany(1924-2003)				1.923(1)	0.16	
Great Britain	0.896(1)	0.34		0.995(1)	0.31	
Greece				0.481(1)	0.49	
Hungary				5.080(1)	0.02	+
Ireland				13.053(1)	0.00	-
Italy	0.737(1)	0.39		28.148(1)	0.00	+
Japan				2.734(1)	0.10	+
The Netherlands				4.745(1)	0.03	-
New Zealand				0.672(2)	0.51	
Norway	22.322(4)	0.00	-	0.035(1)	0.85	
Portugal				0.225(1)	0.63	
Sweden				0.037(1)	0.54	
Switzerland	5.360(2)	0.00	-	9.294(1)	0.00	+
USA	2.382(1)	0.12		0.773(1)	0.38	
<p>Notes: The first four lags of the dependent variable (inflation and output growth, respectively) have been examined. The Schwarz Bayesian Criterion (SBC) is used to determine the optimal lag (the number of lags chosen is given in parentheses). A (+/-) indicates that the sum of the coefficients on the lagged conditional variance of the inflation rate is positive/negative.</p>						