UNIVERSIDAD EAFIT

Vigilada Mineducación

Documentos de trabajo

Economía y Finanzas

Nº 20-11

2020

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Unconventional Monetary Policy and Inflation in the U.S.: How Much Inflation was Missing?

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March 12th of 2020

Abstract

The U.S. inflation rate for the period 2008-2016 was abnormally low despite the execution of a high expansive monetary policy, which has been called "the missing inflation paradox". In this paper we estimate the missing inflation as the difference between the inflation predicted, and the observed rate using two monetarist models. The results support the adequacy of this approach to explain the inflation during 1970-2005. However, after that, the estimated missing inflation was around 3.5%-3.9% annually on average. Interestingly, this phenomenon apparently starts in 2006, previous to the beginning of the Great Recession. Although we do not present a formal explanation, the models used allow us to suspect the existence of an unusually high (and transitory) increase in the demand for real money balances.

JEL classification: C51, E31, E51, E52, E41

Key Words: inflation, missing inflation, monetary policy, money demand

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1. Introduction

The unconventional monetary policy became in the main mechanism used by the Federal Reserve Bank (FED) to support the recovery of the U.S. financial system, employment and growth after the beginning of the Great Recession (Krishnamurthy and Vissing-Jorgensen, 2013; Engen *et al.* 2015; Gagnon *et al.*, 2011; Wu and Xia, 2015; Kapetanios *et al.*, 2012; Frazscher, *et al.,* 2014; Baumeister and Benati, 2012).

Theoretically, the large money expansion jointly with the decrease on the interest rates should come together with a strong increase in prices. However, the annual average inflation from 2008-2016 was 1.5%, showing an abnormally low performance compared even with previous periods when the monetary policy was more restrictive (for example, from 1990-2006 the annual average inflation was 2.25% while the FED interest rate was 5.86%). This phenomenon has been called the "missing inflation paradox", and it has been recognized by analysts and policy makers (Irwin, 2017; Roubini, 2017; Barnier, 2017).

Although the literature has been mainly concentrated on trying to explain this phenomenon (Coibion and Gorodnichenko, 2013; Calvo, 2016; Bobeica and Jarociński, 2017), less attention has been put into the quantification of the "missing inflation". Using the monetarist theory as a reference, in this paper we calculate how much inflation was "missing" in the U.S. during the period 2008-2016. To this end, we use the cointegration approach proposed by Johansen (1991, 1995), to establish the long-run relationship between inflation, money growth, GDP growth and interest rate growth. Additionally, as a robustness check, we use one of the models proposed in Benati *et al.* (2016), which includes structural restrictions on their estimation of money demand.

Models used show that inflation can be accurately forecasted using the monetarist approach from 1970-2005. However, from 2008-2016 the "missing inflation" becomes systematically positive, showing that inflation should be higher, between 3.5% - 3.9% on annual average, in comparison with the observed data. Interestingly, the results suggest that the "missing inflation" phenomenon started in 2006, before the beginning of the Great Recession. These results support the idea that inflation was abnormally low, which justifies the importance of strengthening research on this area.

The rest of the paper is organized as follows: on section two we present a standard monetary model to obtain the long-run inflation determinants. Section three shows the data used for

estimation and the cointegration model obtained. Section 4 presents the "missing inflation" estimations using both models. Finally, on section five we conclude.

2. The Quantitative Theory of Money and Inflation

One of the simple and most used theoretical frameworks to understand the relationship between the money growth and price level is the monetarist theory (Friedman and Schwartz, 1963). This theory proposes the equilibrium in the money market as the equality between the real money supply (M/P) and money demand (L), which depends on the real income (Y) and nominal interest rate (R):

$$\frac{M}{P} = L(Y, R) \qquad (1)$$

Rewriting (1) and totally differentiating, it is possible to establish the evolution of price level in terms of changes on money supply and money demand:

$$\frac{dP}{P} = \frac{dM}{M} - \frac{dL}{L} \qquad (2)$$

Now, considering the arguments of the money demand function, we obtain the money demand elasticities on income and interest rate as:

$$\frac{dL}{L} = \frac{Y}{L}\frac{\partial L}{\partial Y}\frac{dY}{Y} + \frac{R}{L}\frac{\partial L}{\partial R}\frac{dR}{R} \qquad (3)$$

Replacing (3) in (2), we derive an expression for the evolution of prices in terms of money, income and the nominal interest rate growth:

$$\frac{dP}{P} = \frac{dM}{M} - \frac{Y}{L}\frac{\partial L}{\partial Y}\frac{dY}{Y} - \frac{R}{L}\frac{\partial L}{\partial R}\frac{dR}{R} \quad (4)$$

Renaming the terms in (4), we find the elasticity of the price level respect to its determinants and the expected signs as:

$$\frac{dP}{P} = \beta_1 \frac{dM}{M} - \beta_2 \frac{dY}{Y} - \beta_3 \frac{dR}{R} \quad (5)$$

Equation (5) shows the long run relationship between price level change and its determinants. The parameter β_1 is the elasticity of inflation in respect to money growth and should be close to one (see eq. 4), which implies that the transmission of money growth to prices is almost

complete. Parameter β_2 captures the sensitivity of money demand to changes in real income and it should be negative ($\frac{Y}{L}\frac{\partial L}{\partial Y} > 0$), while β_3 ($\frac{R}{L}\frac{\partial L}{\partial R} < 0$) should be negative.

3. Model specification and data

To find the theoretical long-run determinants of the inflation in (5), we estimate the following model:

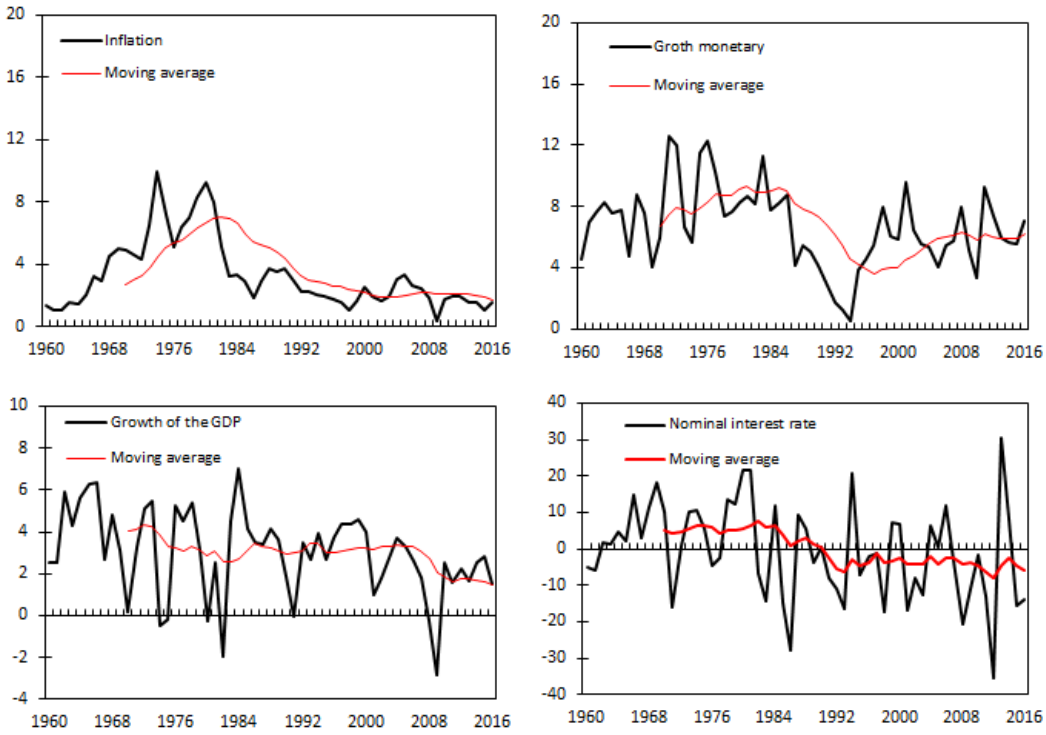
$$\pi_t = \beta_0 + \beta_1 m_t + \beta_2 y_t + \beta_3 r_t + \varepsilon_t \qquad (6)$$

Where π_t is the inflation rate; m_t is the nominal money growth; y_t is the GDP growth and r_t is the nominal interest rate growth[4].

The model was estimated using U.S. annual data from 1960-2007 from the Federal Reserve Bank of St. Louis database (FRED). The inflation was calculated using the GDP deflator; the money growth was measured using M2 money aggregate and the economic growth was calculated using the real GDP. Finally, the bond yield of the 10 years Treasury Bills was used as a measure of the nominal interest rate. The period was selected to maximize the data availability and to isolate our estimations from the crisis effect. Following Dewald (1998), we use the 10-year moving average smoothed series for the estimations, trying to control for the short-term series variability (see Figure 1).

Figure 1. United States: Inflation, Money Growth, GDP Growth and Nominal Interest Rates (annually and ten years moving average)

[4] To avoid for possible endogeinity problems on the estimation, one alternative specification could be to rewrite the nominal interest rate using the real interest rate and the expected inflation. However, the last variable is not available for all period considered. Moreover, the correlation between the observed and expected inflation from 2003-2017 (when both series are available) is 0.57, which is relatively low and justifies the specification proposed.



Source: FRED and own calculations

We first check the integration order of the series using the Augmented Dickey Fuller test (ADF) and the Phillips-Perron (PP) tests. The results (Table 1), show that all series are I (1), which suggest that it is appropriate to test for the existence of a possible long-run relationship between them. Following Johansen (1991, 1995), we use the λ_{trace} and λ_{max} statistics, and found at least one cointegration relationship (Table 2). Finally, we estimate the long and short-term relationships (Table 3).

Table 1. Dickey Fuller and Phillips-Perron Unit root tests for selected smoothed series 1970-2007

Moving average variables of growth rates	In levels		In first differences		Integration order
Augmented Dikey-Fuller	**ADF**	**p-value**	**ADF**	**p-value**	
Implicit GDP Deflactor	-2.9380	0.0521	-3.8290	0.0065	I(1)
Monetary Aggregate M2	-1.4093	0.5669	-3.0297	0.0416	I(1)
Gross Domestic Product	-2.9374	0.0509	-4.8692	0.0003	I(1)
Nominal interest rate	-1.1227	0.6965	-6.3254	0.0000	I(1)
Phillips - Perron	**PP**	**p-value**	**PP**	**p-value**	
Implicit GDP Deflactor	-1.0835	0.7121	-4.1189	0.0028	I(1)
Monetary Aggregate M2	-1.0597	0.7212	-3.0662	0.0383	I(1)
Gross Domestic Product	-2.1809	0.2163	-4.7515	0.0005	I(1)
Nominal interest rate	-1.0727	0.7162	-6.3396	0.0000	I(1)

Source: Own calculations

Table 2. Cointegration test for smoothed series, 1970-2007

Hypothesized, No. of CE(s)	Eigenvalue	Trace Statistic	Maximum Eigenvalue Statistic
None *	0.7026	68.0394	42.4392
		[54.0790]	[28.5881]
		(0.0018)	(0.0005)
At most 1	0.3245	25.6001	13.7285
		[35.1928]	[22.2996]
		(0.3647)	(0.4871)
At most 2	0.2296	11.8716	9.1304
		[20.2618]	[15.8921]
		(0.4604)	(0.4199)

Source: Own calculations. Numbers in brackets indicate the critical values at 5%. Numbers in parentheses correspond to the MacKinnon-Haug-Michelis (1999) p-values.

Results show the expected signs for the long run estimated elasticities in all cases. The long run elasticity of inflation to money growth is 0.06, which is surprising considering the theoretically strong relationship between both variables. The sensibility of the price level at interest rates changes and GDP growth are higher: 0.38 on the first case, and 2.99 on the second case.

Table 3. Cointegration and VEC model estimated using smoothed series, 1970-2007

Variables	Coefficients	Standard error	t-statistics
Cointegration model			
Implicit GDP Deflactor	1.0000	-	-
Monetary Aggregate M2	-0.0602	0.0765	-0.7871
Gross Domestic Product	2.9970	0.1962	15.2720
Nominal Interest Rate	-0.3823	0.0378	-10.1190
Constant	-12.9745	0.8857	-14.6487
Error correction model			
Cointegrating equation	-0.1498	0.0508	-2.9500
Implicit GDP deflactor (-1)	0.7928	0.2152	3.6832
Implicit GDP deflactor (-2)	-0.0122	0.2024	-0.0602
Monetary Aggregate M2 (-1)	0.0690	0.0955	0.7230
Monetary Aggregate M2 (-2)	0.1649	0.0995	1.6581
Gross Domestic Product (-1)	-0.1409	0.1549	-0.9096
Gross Domestic Product (-2)	-0.0170	0.1361	-0.1250
Nominal Interest Rate (-1)	0.0030	0.0206	0.1431
Nominal Interest Rate (-2)	0.0080	0.0198	0.4065

Source: Own calculations

4. Calculating the "missing inflation"

The "missing inflation" is calculated as the difference between observed and estimated inflation using data of money growth, GDP growth and real interest rate from 2008 to 2016. In the case of our cointegration model, the estimated inflation is:

$$\hat{\pi}_t = 12{,}97 + 0{,}06m_t - 2{,}99y_t + 0{,}38r_t \qquad (7)$$

Considering that our estimation shows a low elasticity of the inflation rate *vis-á-vis* the money growth, we also calculate the "missing inflation" using the money demand elasticities obtained in Benati *et al.* (2016) as a robustness check, when this elasticity is fixed on one. In this case, the "missing inflation" can be written as:

$$\hat{\pi}_t = m_t - (y_t - 0{,}4i_t) \qquad (9)$$

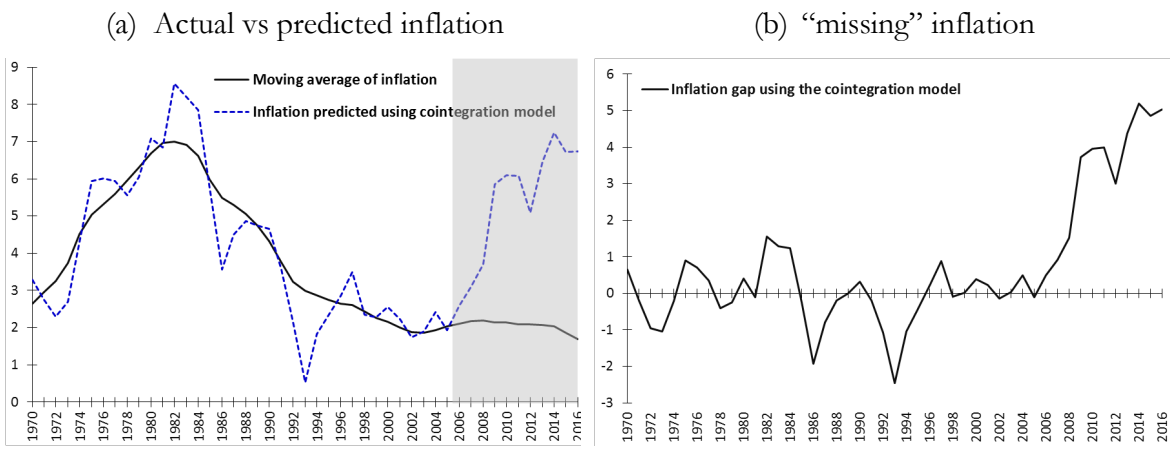
Figure 2 shows the annual observed, estimated and "missing" inflation using the cointegration model. The model replicates the performance of inflation rate in a consistent manner. First, with an increasing trend from 1970 up 1982 and then with a continuous decrease until the beginning of XXI century. However, after 2005 (shadowed area), the predicted inflation systematically starts to go up until 2014. On the contrary, the observed inflation tends to decrease.

The accuracy of the model to capture the inflation dynamics can be observed on panel (b) of Figure 2 and on Table 4. In fact, the average "missing inflation" on the period 1970-2007 is -0.02%. However, from 2008-2016, the average "missing inflation" is 3.96%. It is important to note that the "missing inflation" phenomenon apparently starts on 2006, a few years before the Great Recession.

Figure 3 shows the same results but using the Benati *et al.* (2016) model[5]. The results support the idea of an abnormally low observed inflation starting on 2006. The average "missing inflation" between 1970-2007 was -0.27%, while on the period 2008-2016 it was 3.51%, which is slightly lower that the results obtained using the cointegration model.

Figure 2. Actual, Predicted and "Missing" Inflation Using the Cointegration Model

1970-2007.



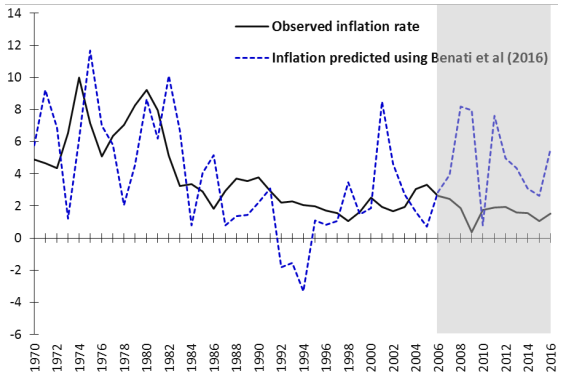
Source: own calculations using FRED data

Figure 3. Actual, Predicted and "Missing" Inflation Using the Benati *et al.* (2016) Model

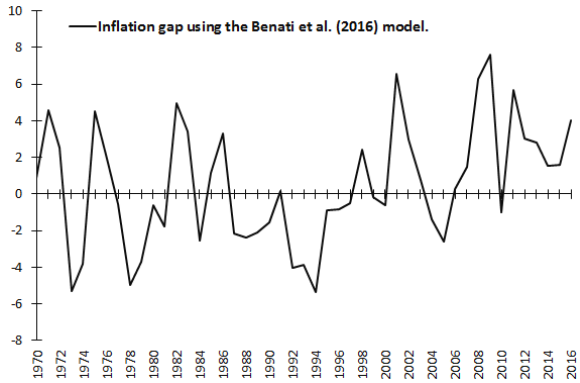
1970-2007.

[5] On this case, we use annual data instead 10 years moving averages, to be consistent with the model estimation strategy. It explains the higher series variability compared with our model.

(c) Actual vs predicted inflation



(d) "missing" inflation



Source: own calculations using FRED data.

Table 4: Actual, Predicted and "Missing" Inflation. Annual Average, 1970-2016

Description	Periods	Observed inflation	Estimated inflation	Gap inflation
Cointegration model*	1970 - 2007	4.00	3.98	-0.02
	2008 - 2016	2.03	5.99	3.96
	1970 - 2016	3.62	4.36	0.91
Benati et al. (2016)	1970 - 2007	3.92	3.65	-0.27
	2008 - 2016	1.50	5.01	3.51
	1970 - 2016	3.45	3.91	0.46

Source: own calculations using FRED data. The cointegration model estimations (*) was calculated using the smoothed series.

In sum, although both models replicate the observed inflation in an accurate way from 1970-2005, the inflation estimated was systematically higher that the inflation observed during 2006-2016. Additionally, with both models we estimate a similar "missing inflation" average on this period: 3.96% using the cointegration model, and 3.51% using the Benati *et al.* (2016) model.

5. Final remarks

One of the salient features of the US economy during the 2008-2016 period was its lower average rate of inflation, given the highly expansionary stance of the monetary policy. Based on two monetarist models, we estimate that the "missing inflation" was around 3.51%-3.96% average annually, which shows the importance of this phenomenon.

From the monetarist perspective, our results suggest that the demand for real money balances from 2008-2016 increased more than we would expected according to the behavior of real GDP and the interest rate of the U.S., explaining the non-increase on inflation. At this point remembering on of Keynes ideas about uncertainty and money demand could be interesting: *"…a large increase in the quantity of money may cause so much uncertainty about the future that liquidity-preferences due to the precautionary-motive may be strengthened; whilst opinion about the future of the rate of interest may be so unanimous that a small change in present rates may cause a mass movement into cash…" (Keynes, 1936, p.172).* More recently, Anderson, Bordo and Duca (2016), supports the idea that uncertainty affects the money demand during the financial crises.

Beyond the explanations, this work suggests the importance in strengthening the research on the effects of the Great Recession and the unconventional monetary policy on the dynamics of money demand, prices and inflation.

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