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Working Paper

A note on the dynamics of persistence in US inflation

Working Papers, No. 2008-12

Provided in Cooperation with:

Bank of Mexico, Mexico City

Suggested Citation: Noriega, Antonio E.; Ramos-Francia, Manuel (2008) : A note on the dynamics of persistence in US inflation, Working Papers, No. 2008-12, Banco de México, Ciudad de México

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Banco de México
Documentos de Investigación

Banco de México
Working Papers

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August 2008

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A Note on the Dynamics of Persistence in US Inflation*

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Abstract

Empirical research on the degree and stability of inflation persistence in the US has produced mixed results: some suggest high and unchanged persistence during the last few decades, while others argue in favor of a decline in persistence since the early 1980s. We contribute to this debate by applying a test specifically designed to test for multiple changes in persistence, allowing for consistent estimation of the possible change dates, and robust to level breaks. We show that post-WWII US inflation (monthly and quarterly) became highly persistent during the “Great Inflation” period, and then switched back to a low persistence process during 1984, and has remained stationary until the present day.

Keywords: Inflation, Multiple change in persistence, Stationarity, Great inflation.

JEL Classification: C12, C22, E31, E52

Resumen

La investigación empírica sobre el grado y la estabilidad de la persistencia de la inflación en los EUA ha producido resultados mixtos: algunos autores sugieren que la persistencia ha sido alta y constante durante las últimas décadas, mientras que otros argumentan a favor de una disminución en la persistencia a partir del principio de los 1980s. Esta nota contribuye a este debate mediante la aplicación de un procedimiento específicamente diseñado para probar la presencia de cambios múltiples en persistencia, que al mismo tiempo provee una estimación consistente de las posibles fechas de cambio, y que es robusto a cambios estructurales en el nivel de la serie. Mostramos que la inflación de la post-guerra en los EUA (tanto mensual como trimestral) se volvió altamente persistente durante el periodo conocido como la “Gran Inflación”, para después cambiar a un proceso de baja persistencia a partir de 1984, manteniéndose así hasta la fecha.

Palabras Clave: Inflación, Cambios múltiples en persistencia, Estacionariedad, Gran Inflación.

*We thank Carlos Capistrán, Daniel Chiquiar, Héctor Salgado, Arnulfo Rodríguez and seminar participants at Banco de México, Universidad de Guanajuato, El Colegio de México and CIDE for helpful comments, and to Mario Alberto Oliva for excellent research assistance.

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1 Introduction

The degree of inflation persistence contains vital information for the monetary policy making process. In particular, it helps in the decision process towards adjusting the policy instrument to achieve the desired target and, in general, it constitutes a very important element in the formulation of optimal monetary policy.

Empirical research on the degree and stability of inflation persistence in the US has produced mixed results. The debate centers around a possible decline in persistence during the Great Moderation in the early eighties.¹ For instance, Beechey and Osterholm (2007) find significant swings in inflation persistence, which is found to have risen during the 1970s and then fallen during the 1980s. Using different techniques as well as a different definition of persistence, Cogley and Sargent (2002) and Kumar and Okimoto (2007) arrive at similar conclusions. Some other papers documenting declines in inflation persistence for the US include Levin and Piger (2003) and Benati (2002).

In contrast, Pivetta and Reis (2007) show that inflation persistence has remained high and unchanged over the last three decades. In the same vein see Gadea and Mayoral (2006), and Batini and Nelson (2002). Finally, Robalo Marques, C. (2004), argues that "the evidence on whether inflation persistence was higher in the sixties and seventies than in the two last decades or whether inflation is persistent at all, ultimately hinges on the type of mean assumed when computing persistence." (p. 31).

Given the importance of inflation persistence for assessing the optimality of monetary policies, and the little consensus about the degree of inflation persistence in the empirical literature, this paper aims at providing new evidence on the dynamics of inflation persistence, based for the first time on a recently developed time-series approach, specifically designed to test for multiple changes in persistence, which is also robust to the presence of structural breaks. We concentrate on a test allowing multiple changes in persistence (as opposed to tests for a single change in persistence) since once a change from, say, $I(0)$ to $I(1)$ is detected in the inflation rate, one expects this change to be temporal, because corrective measures would be implemented eventually to make inflation stationary again.² The application of the test developed by Leybourne et. al. (2007) to the US inflation rate in section 3 shows

¹Some authors argue that this timing in the slowdown in persistence is related to changes in the monetary policy environment, since it coincides with a period in which the Fed adopted a more aggressive response to inflation (Carlstrom and Fuest (2008)) and inflation expectations (Boivin and Giannoni (2006)). Once expectations have been anchored, they are unlikely to adjust to temporary increases in the inflation rate, which reduces the persistence of shocks.

²Although, when modeling inflation from a public finance perspective, revenue smoothing would imply, under certain conditions, that inflation follow optimally a martingale process (see for example Mankiw (1987), Trehan and Walsh (1990), etc). Nevertheless, it would probably be difficult today to find any policymaker that would think that inflation should be determined using this approach.

that, apart from a short period of strong volatility from the post-WWII to the early fifties, and the period known as the 'Great Inflation' (early 1970s-early 1980s), inflation in the US has behaved in a stationary way, around a nonconstant mean.

2 Test for multiple changes in persistence

We apply a test for changes in the order of integration of a time series developed by Leybourne, Kim and Taylor (2007, LKT in what follows). This test allows consistent estimation of the change dates, and its large and finite sample properties are not affected by the presence of (multiple) level breaks. Also note that tests for a single change in persistence, as those of Kim (2000), Harvey, et. al. (2006), and Leybourne et. al. (2006) are inconsistent against processes which display multiple changes in persistence.³ Hence, the test applied in this paper is the only methodology in the literature which is valid in the presence of multiple changes in persistence. The data generation process (DGP) consists of the following Time-Varying (TV) $AR(p)$:

$$\begin{aligned} y_t &= d_t + u_t \\ u_t &= \rho_i u_{t-1} + \sum_{j=1}^{k_i} \phi_{i,j} \Delta u_{t-j} + \varepsilon_t, \quad t = 1, \dots, T \end{aligned} \tag{1}$$

where y_t is the inflation rate, $d_t = z'_t \beta$ is the deterministic kernel, which in this case simplifies to $z_t = 1$ and $\beta = \beta_0$, the (possibly non-constant) level of inflation, and ε_t is a martingale difference sequence.⁴ In (1), u_t is taken to be a TV $AR(p)$ process, rewritten such that $k_i = p_i - 1, i = 1, \dots, m + 1$, where m is the number of changes in persistence. Note that (1) permits that the dominant AR root, ρ_i , and the lag coefficients, ϕ_{ij} , differ across the $m + 1$ separate regimes.

There are two hypotheses: the null, $H_0 : y_t \sim I(1)$ throughout, that is, $\rho_i = 1 \forall t$, and the alternative, $H_1 : y_t$ undergoes one or more regime shifts between $I(1)$ and $I(0)$ behavior. That is, under the alternative ρ_i is subject to $m \geq 1$ unknown persistence changes, giving rise to $m + 1$ segments with change point fractions given by $\tau_1 < \tau_2 < \dots < \tau_{m-1} < \tau_m$. The procedure partitions $y_t, t = 1, \dots, T$ into its separate $I(0)$ and $I(1)$ regimes, and consistently estimates the associated change point fractions. LKT define the fraction $\tau \in (\lambda, 1)$, for a

³Moreover, the augmented Dickey-Fuller (ADF) test will not be consistent either, when applied to persistence change series, since the $I(1)$ part will dominate asymptotically.

⁴We use this DGP for simplicity of presentation, but methods in LKT allow for linear trends and breaks in the level and trend of d_t .

given λ in $(0,1)$, and base their test H_0 vs. H_1 on the local *GLS* de-trended *ADF* unit root statistic, that uses the sample observations between λT and τT , called $DF_G(\lambda, \tau)$, obtained as the standard t -statistic associated with $\hat{\rho}_i$ in the fitted regression

$$\Delta y_t^d = \hat{\rho}_i y_{t-1}^d + \sum_{j=1}^{k_i} \hat{b}_{i,j} \Delta y_{t-j}^d + \hat{\varepsilon}_t, \quad t = \lambda T, \lambda T + 1, \dots, \tau T \quad (2)$$

where $y_t^d \equiv y_t - z_t' \hat{\beta}$, with $\hat{\beta}$ the OLS estimate of β obtained from regressing $y_{\lambda T}$ on $z_{\lambda T}$, where $y_{\lambda T} \equiv (y_{\lambda T}, y_{\lambda T+1} - \bar{\alpha} y_{\lambda T}, \dots, y_{\tau T} - \bar{\alpha} y_{\tau T-1})'$ and $z_{\lambda T} \equiv (z_{\lambda T}, z_{\lambda T+1} - \bar{\alpha} z_{\lambda T}, \dots, z_{\tau T} - \bar{\alpha} z_{\tau T-1})'$, with $\bar{\alpha} = 1 + \bar{c}/T$, and $\bar{c} = -10$. In the empirical applications below, we set $\lambda = 1/T$ such that $\lambda T = 1$. As in LKT, we use $\tau = 0.20$.⁵ For determining the value of k_i , we follow Pivetta and Reis (2007) and use the BIC. This criterion chooses the appropriate lag length for values of k_i between 0 and 4 (0 and 12) for quarterly (monthly) data, for every sample or sub-sample regression computed.

The test is based on doubly-recursive sequences of *DF* type unit root statistics:

$$M \equiv \inf_{\lambda \in (0,1)} \inf_{\tau \in (\lambda,1)} DF_G(\lambda, \tau) \quad (3)$$

with corresponding estimators $(\hat{\lambda}, \hat{\tau}) \equiv \arg \inf_{\lambda \in (0,1)} \inf_{\tau \in (\lambda,1)} DF_G(\lambda, \tau)$. Application of the M test yields the start and end points (i.e. the the interval $[\hat{\lambda}, \hat{\tau}]$) of the first $I(0)$ regime over the whole sample. The presence of any further $I(0)$ regimes can be detected sequentially by applying the M statistic to each of the resulting subintervals $[0, \hat{\lambda}]$ and $[\hat{\tau}, 1]$.⁶ Continuing in this way, all $I(0)$ regimes together with their start and end points can be identified. Note that the period between the end point of one $I(0)$ regime and the start point of the next $I(0)$ regime must represent an $I(1)$ regime.

3 Empirical results

The inflation series we investigate are quarterly and monthly, seasonally adjusted, spanning the period 1947:02 to 2008:01, and 1947:02 to 2008:04, respectively. The quarterly data are based on the GDP deflator, from the Bureau of Economic Analysis, while the monthly data on the CPI, from the Bureau of Labor Statistics.⁷

⁵As a robustness check in the empirical applications of next section, we used different values of τ and \bar{c} and obtained qualitatively similar results.

⁶Of course it could be the case that the $I(0)$ period indicated by the test lies at one extreme of the sample. In this case, the test can be applied to the resulting segment $[0, \hat{\lambda}]$ or $[\hat{\tau}, 1]$.

⁷We measure inflation as the annualized quarterly (monthly) change in the GDP deflator (CPI) calculated as $400 \ln(P_t/P_{t-1})$ ($1200 \ln(P_t/P_{t-1})$). All calculations were carried out using a GAUSS code, available from

Table 1 gathers information on the sample over which the test is applied, the corresponding sample sizes, the estimated values of the AR order, the values of the M statistic of LKT and, in the last two columns, the beginning and end of the identified $I(0)$ segments. The M test is initially applied over the whole sample, detecting an interior $I(0)$ regime between 1950:02 and 1966:01, for which the unit root null is rejected at the 1% level (the M statistic is -8.36 and the critical value from LKT for $T = 250$ is -4.51 at the 1% level). The test is then applied over 1947:02-1950:01 and the M statistic resulted not significant at the 10% level (and thus is not reported in Table 1). The search for a further stationary regime continues by applying the test over the sample 1966:02-2008:01, which yields the second $I(0)$ regime corresponding to the period 1992:03-2003:04. A third $I(0)$ regime is uncovered over 1967:04-1973:01 when the test procedure is applied over the subsample 1966:02-1992:02. Continuing in this fashion, the procedure uncovers a total of 5 $I(0)$ regimes. As can be deduced, the $I(1)$ regimes should correspond to the periods 1947:02-1950:01 and 1973:02-1984:01 (not reported), for which the unit root cannot be rejected, using critical values in LKT.⁸

TABLE 1
Results of the LKT test for Quarterly Inflation

<i>Sample</i>	<i>Sample Size</i>	\widehat{k}_i	M	<i>I(0) Periods</i>	
				<i>Start</i>	<i>End</i>
1947:02 - 2008:01	244	3	-8.36**	1950:02	1966:01
1966:02 - 2008:01	168	0	-5.55**	1992:03	2003:04
1966:02 - 1992:02	105	0	-4.93**	1967:04	1973:01
1973:02 - 1992:02	77	0	-3.90*	1984:02	1992:01
2004:01 - 2008:01 ^a	17	0	-5.31*	2004:01	2008:01

** and * denote significance at the 1% and 10%, respectively

^aFor this sample $K_{max}=0$, due to limited degrees of freedom.

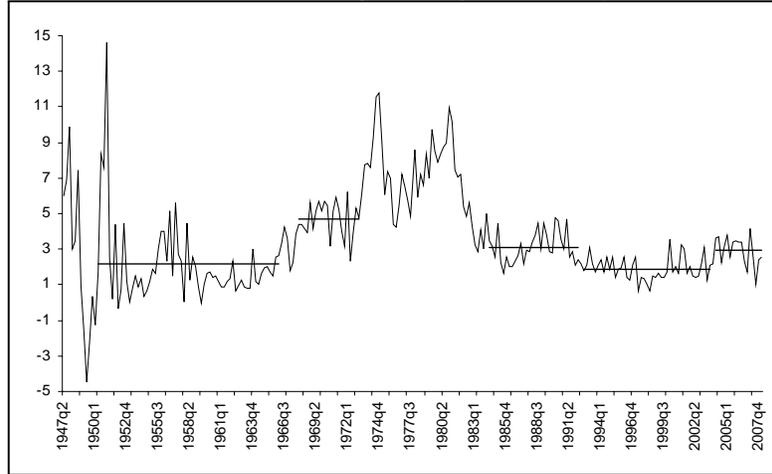
Figure 1 presents results in a graphic way. In the graph, a straight line indicates an $I(0)$ period, as identified by the M test. For convenience, this line is drawn at the mean of each of the $I(0)$ periods it defines.

the authors upon request.

⁸To compare our results with Pivetta and Reis's (2007), we applied the LKT test over their sample: 1947:02-2001:03, and confirmed our findings, i.e., a decline in persistence from 1984 to 2001. These contradicting results might be due to the great uncertainty on the exact value of inflation persistence at any given point in time, resulting from the wide confidence intervals and credible sets estimated by Pivetta and Reis (2007).

FIGURE 1

Results of the LKT test for Quarterly Inflation, 1947:02-2008:01



As can be seen from the graph, the two $I(1)$ periods detected by the test correspond to the post-war period of high volatility and the period known as the 'Great Inflation'. Table 2 reports summary statistics for the $I(0)$ and $I(1)$ periods identified by the M test. Note that, in general, the periods after the 'Great Inflation' register low values for the reported statistics.

TABLE 2
Summary Statistics for Quarterly Inflation

<i>Sample</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Serial Corr.</i>	<i>Order of Integration</i>
1947:02 - 1950:01	2.37	4.49	0.61	I(1)
1950:02 - 1966:01	2.14	2.30	0.36	I(0)
1967:04 - 1973:01	4.69	1.00	-0.14	I(0)
1973:02 - 1984:01	6.98	2.20	0.73	I(1)
1984:02 - 1992:01	3.11	0.88	0.29	I(0)
1992:03 - 2003:04	1.90	0.65	0.17	I(0)
2004:01 - 2008:01	2.91	0.83	0.07	I(0)

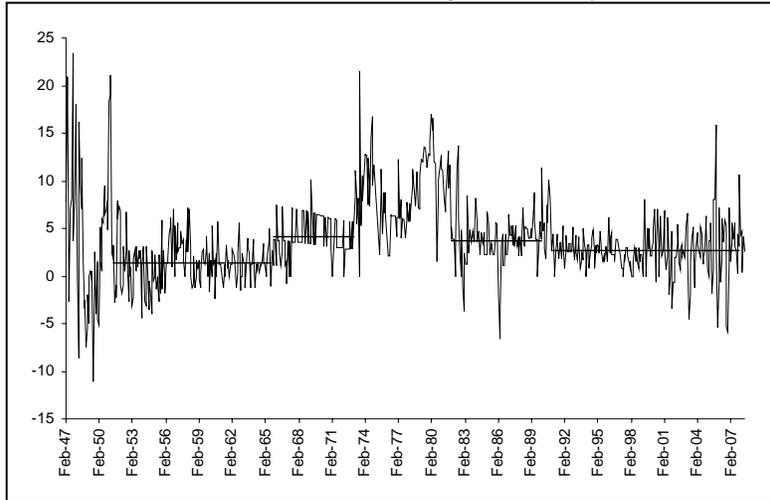
Table 3 and Figure 2 report results for monthly inflation, for which we observe a similar pattern, with nearly identical dates for the two $I(1)$ detected periods.

TABLE 3
Results of the LKT test for Monthly Inflation

<i>Sample</i>	<i>Sample Size</i>	\hat{k}_i	<i>M</i>	<i>I(0) Periods</i>	
				<i>Start</i>	<i>End</i>
1947:02 - 2008:04	735	1	-12.60**	1990:11	2007:10
1947:02 - 1990:10	525	0	-8.84**	1951:04	1961:06
1961:07 - 1990:10	652	0	-7.62**	1965:11	1973:01
1973:02 - 1990:10	213	0	-6.53**	1981:10	1989:12
1961:07 - 1965:10	52	2	-7.64**	1961:09	1965:08

** denotes significance at the 1% level.

FIGURE 2
Results of the LKT test for Monthly Inflation, 1947:02-2008:04



4 Conclusions

Our results seem to indicate that post-WWII US inflation (either quarterly or monthly) has behaved in a stationary fashion, with the exception of two periods, 1947-1950 and 1973-1983, during which it behaved as an $I(1)$ process. In particular, it switched from $I(1)$ to $I(0)$ after the end of the 'Great Inflation' period, and remained stationary until the present day. These results are in line with several empirical studies who find evidence of a decline in inflation persistence over the last few decades.

More importantly, our findings are congruent with arguments discussed in the literature on why inflation should behave in a stationary fashion, specially after the experience of the US 'Great Inflation' of the 1970s. First, as Hall (1999) argues, "...at least since 1979, there seems little doubt that policy has tried and succeeded in making inflation mean reverting.

Any hint of an upsurge in inflation results in the Fed stepping on the brake to bring inflation back to target. A second reason to expect mean reversion in the rate of inflation is that the main source of price disturbances -movements in the price of oil- are temporary. Even without good monetary policy, bursts of inflation are temporary” (p. 432). Third, central bank learning has induced changes in policy strategies, developing a taste for stabilizing inflation, which results in better economic outcomes (see for instance Beechey and Osterholm (2007), Sargent, Williams and Zha (2004) and Primiceri (2005)).

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