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ARCH AND STRUCTURAL BREAKS IN UNITED STATES INFLATION

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ABSTRACT

United States Phillips curves are routinely estimated without accounting for the shifts in mean inflation. As a result we may expect the standard estimates of Phillips curves to be biased and suffer from ARCH. We demonstrate this is indeed the case. We also demonstrate that once the shifts in mean inflation are accounted for the ARCH is largely eliminated in the estimated model and the model defining expected rate of inflation in the New Keynesian model plays no significant role in the dynamics of inflation.

Keywords: Philips curve, ARCH, structural breaks, inflation, markup.
JEL Classification: C22, E31.

1. INTRODUCTION

This paper examines the hypothesis that the observed ARCH in estimated models of United States inflation is the result of unaccounted shifts in the mean rate of inflation in the data. This hypothesis is based on the following understanding of the data. Russell (2006, 2011) and Russell and Chowdhury (2013) argue inflation in the developed world cannot be a 'truly' integrated process as it appears to have a lower boundary around zero and an upper boundary at some moderate rate of inflation. They also argue that inflation cannot be a stationary process with a constant mean over the past fifty years as this would imply only one long-run rate of inflation, one expected rate of inflation, and one short-run Phillips curve. Furthermore, this implies that Phillips' (1958) original curve did not 'break down' with changes in expected inflation towards the end of the 1960s. They conclude that while inflation is a non-stationary process it is most likely to be a stationary process around a shifting mean. The latter is due to

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discrete changes in monetary policy and allows for numerous long-run and associated expected rates of inflation that are central tenants of 'modern' theories of the Phillips curve.[1]

Graph 1 shows United States quarterly inflation for the period March 1960 to March 2013 measured as the quarterly change in the natural logarithm of the gross domestic product (GDP) implicit price deflator at factor cost multiplied by 400 to provide an 'annualised' rate of inflation.[2] The graph reveals two characteristics of United States inflation. First, the shifting mean rate of inflation discussed above is evident. These shifts can be identified formally by applying the Bai and Perron (1998) technique to identify multiple breaks in the mean rate of inflation.[3] Nine breaks in mean are identified in the inflation data implying there are ten inflation 'regimes' within which we believe statistically the mean rate of inflation is constant. The identified mean rates of inflation in each regime are shown on Graph 1 as solid thin horizontal lines.

The second characteristic is the variance in inflation increases during the turbulent high inflation years of the 1970s before declining to lower levels following the 'Volker deflation' in the early 1980s. This 'clustering' of high and low variance into discrete periods suggests that the variance in inflation may be serially correlated. Since Engle's (1982) seminal Nobel Prize winning paper, a popular way to model this 'clustering' in the variance in the inflation data is to estimate some form of auto-regressive conditional heteroscedastic (ARCH) type models of inflation. Much of the ARCH literature on inflation has focused on (i) the unpredictability of inflation when the variance increases; and (ii) the relationship between the mean and the variance of inflation.[4] Interest in the former is due to the welfare costs associated with agents holding mistaken inflation expectations and the later due to Friedman's (1977) conjecture in his Nobel Prize lecture that the mean rate of inflation and the variance of inflation are positively related. Importantly this literature interprets the ARCH as due to some 'real' economic interaction between central banks, firms and agents.

An alternative explanation of the ARCH in inflation is that it is simply a statistical artefact due to the miss-specification of the estimated model. In particular, our visual impression from Graph 1 that the variance of inflation is not constant and our formal tests of heteroscedasticity proceed under the assumption that inflation is a stationary process with a constant mean. However, as argued above, inflation may contain a shifting mean and if these shifts are accounted for then the conditional variance may be constant and the data homoscedastic. We

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1 The term non-stationary in this paper encompasses all statistical processes other than stationary with a constant mean. It therefore includes stationary around a shifting mean. 'Modern' theories include the Friedman-Phelps expectations augmented, New Keynesian and hybrid theories of the Phillips curve.

2 The Data Appendix provides details of the data used in this paper.

3 Details of how the breaks are estimated are provided in Section 3.1 and Table 1 below.

4 For example, see Engle (1983, 1988), Cosimano and Jansen (1988), Baillie, Chung and Tieslau (1996), Grier and Perry (2000) and Boero, Smith and Wallis (2008).

might then conclude that the observed heteroscedastic nature of inflation has no economic or behavioural relevance.

In the next section we set out and then estimate in Section 3 a general hybrid Phillips curve. In support of our hypothesis we find that once we account for the shifts in mean inflation there is little statistical evidence of ARCH in our estimated models of inflation. We also find that expected inflation as commonly measured in the standard New Keynesian literature plays no significant role in the dynamics of inflation after allowing for the shifts in mean inflation.

2. THE HYBRID PHILLIPS CURVE

To examine our hypothesis we estimate a hybrid Phillips curve of the form:[5]

$$\pi_t = \delta + \delta_f \pi^e_{t+1} + \delta_b \pi_{t-1} + \delta_\mu \mu_t + \sum_{m=1}^{10} \varphi_m D_m + \sum_{j=2}^{4} \omega_j I_j + \epsilon_t \qquad (1)$$

where inflation, π_t, depends on expected inflation, π^e_{t+1}, lagged inflation, π_{t-1}, a 'forcing' variable, μ_t, shift dummies representing the 10 inflation 'regimes', D_m, identified earlier by the Bai-Perron technique, and an error term, ϵ_t. The dates of the shift dummies are those estimated in the inflation data using the Bai-Perron technique and reported in Graph 1. With the shift dummies included we are estimating 10 short-run Phillips curves associated with the 10 inflation regimes where we believe statistically that the mean (or long-run) rate of inflation is constant.

The shifts in mean are 'rare events' and difficult for agents and economists to estimate. Following Russell and Chowdhury (2013) the shifts in mean inflation are assumed to be independent of the mean reversion process in the inflation data. On a practical level this allows us to estimate the dates of the shifts in mean independently of estimating equation (1). This independence assumption is commonly applied when estimating Gaussian mean reversion processes with structural breaks and first applied to shifts in mean inflation by Russell and Chowdhury. They defend the independence assumption with the following thought experiment. Assume an inflation regime of *n* periods is stationary with a constant mean. Now assume that *j* periods before the end of the regime agents can predict the next shift in mean. This implies that inflation will begin to adjust towards the new mean which implies the mean rate of inflation in the last *j* periods of the regime is different from the first *n-j* periods. This contradicts the initial assumption that the inflation regime of *n* periods has a constant mean.[6] Therefore, we

5 For the sake of space the four Phillips curve theories nested in the hybrid Phillips curve are not reproduced here but can be found in the references cited below.

6 In the transition between two long inflation regimes there may be a number of short inflation regimes where the mean is constant but these regimes cannot be identified with current statistical techniques. However, the

can conclude that if the data is stationary around a shifting mean as argued above then (i) agents cannot predict the next shift in mean, (ii) the process driving the breaks and the mean reversion process in the data are independent and uncorrelated, and (iii) estimating the dates of the structural breaks in mean independently of estimating equation (1) is valid. Note that the mean-shift-mean-reversion independence assumption conforms to our general understand that predicting, or forecasting, structural breaks in the mean rate of inflation is not possible, or at the very least, very difficult.

The three 'modern' theories of the Phillips curve are nested within the hybrid Phillips curve. In the standard unrestricted hybrid models of Galí and Gertler (1999) and Galí, Gertler and Lopez-Salido (2001) agents are both backward and forward looking and $\delta_f + \delta_b = 1 - d$ where $1 - d$ is the discount rate. If instead we restrict $\delta_f = 0$ and $\delta_b = 1$ then the hybrid curve collapses to the Friedman (1968) and Phelps (1967) (F-P) expectations augmented Phillips curve where agents are purely backward looking. Conversely, if we restrict $\delta_f = 1 - d$ and $\delta_b = 0$ then the hybrid curve becomes the New Keynesian (NK) Phillips Curve of Clarida, Galí and Gertler (1999) and Svensson (2000) where agents are purely forward-looking. Finally, the statistical process consistent (SPC) Phillips curve of Russell and Chowdhury (2013) where $\delta_f = 0$ and $0 \leq \delta_b < 1$ provides a fourth model of the Phillips curve.

If inflation is stationary around a shifting mean then estimating equation (1) without incorporating the regime shift dummies we should expect; (i) the estimates of both δ_f and δ_b will be biased upwards;[7] and (ii) an over-rejection of the null hypothesis of conditional homoscedasticity.[8] Therefore we might expect that if the shift dummies in equation (1) are significant then the bias on the estimates of the dynamic inflation terms will be reduced along with any evidence of ARCH in the estimated model.

3. ESTIMATING UNITED STATES SHORT-RUN PHILLIPS CURVES

3.1 The Data

The model is estimated with quarterly seasonally adjusted United States data for the period March 1960 to March 2013. Inflation is measured as the quarterly change in the natural logarithm of the gross domestic product (GDP) implicit price deflator at factor cost. In keeping

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logic of the 'thought experiment' remains that within each short inflation regime agents cannot predict the next shift in mean.

7 This is a generalisation of Perron (1989). Russell *et al.* (2011) provides an extensive analysis of the Perron effect due to not accounting for the shifts in mean when estimating United States Phillips curves and find the bias is substantial.

8 See Lumsdaine and Ng (1999).

with much of the recent NK literatures the forcing variable is the markup and measured as the natural logarithm of the price series divided by unit labour costs which is equivalent to the inverse of labour's share of national income measured at factor cost. The inflation regimes are identified with the Bai and Perron (1998) algorithm that minimises the sum of the squared residuals in an estimated 'shifting means' model:

$$\pi_t = \sum_{i=1}^{k+1} \gamma_i + \tau_t \qquad (2)$$

where γ_i is a series of $k+1$ constants that estimate the mean rate of inflation in each of $n = k+1$ inflation regimes and τ_t is a random error. The final model was chosen using the Bayesian Information Criterion. The estimated dates and mean rates of inflation for the ten identified inflation regimes are reported in Table 1. Also reported in Table 1 is some historical economic context associated with each inflation regime. While the Bai-Perron technique is a purely statistical process the identified inflation regimes are broadly consistent with economic history in the United States.

Expected inflation, π^e_{t+1}, is commonly measured in the standard NK literature as its forecasted value based on information publicly available at time t and published in $t-1$.[9] The forecasted value of inflation is obtained by regressing inflation on lags of inflation and the markup for periods $t-2$ to $t-5$. The regression is estimated using ordinary least squares (OLS) and the static forecast of inflation is included in the estimation of the model with a lead of one period. To overcome the possible simultaneous nature of inflation and the markup the contemporaneous markup in equation (1) is also replaced with its forecast value based on the data published in period $t-1$. The static forecast, μ^f_t, is obtained from regressing the markup on lags of itself and inflation for periods $t-1$ to $t-4$. Finally, the models based on equation (1) are estimated with OLS with White heteroscedastic consistent standard errors and covariances.[10]

3.2 The Estimated Models

Model 1 reported in Table 2 retrieves the standard results of the hybrid Phillips curve literature by estimating equation (1) assuming the inflation data is stationary with a constant mean. This is achieved by restricting the shift dummies to be the same across all the inflation regimes. We see the sum of the estimated coefficients on the dynamic inflation terms $\delta_f + \delta_b$ is insignificantly different from 1 with the estimated value for δ_f considerably larger than δ_b. The residuals of the estimated model are non-normal, serially correlated and heteroscedastic. Introducing four impulse dummies in Model 2 that correspond to the largest four residuals in the estimated model reduces but does not eliminate evidence of ARCH in the standard model. The dates of the impulse dummies are March 1972, September and December 1974 and

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9 This is one conceptual interpretation of using instrumental variables for π^e_{t+1}.

10 This is equivalent to estimating equation (1) with a two-stage-least-squares estimator.

December 1977 which coincide with the turbulent period during and after the first OPEC oil price shock and represent the idiosyncratic nature of the inflation process at that time. These results are consistent with the standard literatures on the hybrid Phillips curve and ARCH inflation.

Model 3 in the same table reports the estimates of equation (1) with the unrestricted shift dummies and the impulse dummies. We now see that the sum of the dynamic coefficients are significantly less than 1, the residuals are normally distributed, serially uncorrelated and conditionally homoscedastic. Furthermore, the estimated coefficient on expected inflation is now insignificantly different from zero.

Finally Model 4 in Table 2 reports the estimated Phillips curve with the insignificant expected inflation term restricted to zero. The estimated value for δ_b remains significantly less than one by a wide margin and significantly greater than zero. The residuals remain normally distributed and serially uncorrelated and there is no significant evidence that the residuals are heteroscedastic. With the shifts in mean accounted for in the estimation of the Phillips curve we find that (i) there is little evidence of ARCH in the estimated models; and (ii) the data is inconsistent with the hybrid, New Keynesian and Friedman-Phelps theories of the Phillips curve and consistent with the SPC Phillips curve.

4. CONCLUSION

The estimates above suggest that the apparent ARCH process in United States inflation data can be explained as a statistical artefact due to unaccounted breaks in the mean rate of inflation implying the observed ARCH may have no behavioural significance. Furthermore, the estimates indicate that if we account for the shifts in mean inflation then the estimates suggest that there is no significant role for the model defining New Keynesian expected rate of inflation in the dynamics of inflation. The standard interpretation of the F-P Phillips curve is also not supported by the data. In contrast, once the shifts in mean inflation are accounted for, the statistical process consistent Phillips curve is supported by the data.

5. REFERENCES

Bai, J. and P. Perron (1998). Estimating and testing linear models with multiple structural changes. *Econometrica* 66: 47-78.

Baillie, R.T., Chung, C.F. and Tieslau, M.A. (1996). Analysing inflation by the fractionally integrated ARFIMA-GARCH model, *Journal of Applied Econometrics*, 11, 23-40.

Boero, G., J. Smith and K.F. Wallis (2008). Modelling UK Inflation Uncertainty, 1958-2006, Robert F. Engle Festschrift Conference, San Diego, 21 June 2008.

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

Cosimano, T.F., and D.W. Jansen (1988). Estimates of the variance of U.S. Inflation Based upon the ARCH Model: Comment, *Journal of Money, Credit and Banking*, vol. 20, no. 3, August, pp. 409-421.

Engle, R.F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation, *Econometrica*, 50, 987-1007.

Engle, R.F. (1983). Estimates of the Variance of U.S. inflation Based on the ARCH Model, *Journal of Money, Credit and Banking*, vol. 15, no. 3, August, pp. 286-301.

Engle, R.F. (1988). Reply to Cosimano and Jansen, *Journal of Money, Credit and Banking*, vol. 20, no. 3, August, pp. 422-23.

Friedman, M. (1968). The role of monetary policy, *American Economic Review*, 58, 1 (March), pp. 1-17.

Friedman, M. (1977). Nobel Lecture: Inflation and Unemployment, *The Journal of Political Economy*, vol. 85, no. 3, pp. 451-72.

Galí, J., and M. Gertler (1999). Inflation Dynamics: A Structural Econometric Analysis, *Journal of Monetary Economics*, vol. 44, pp. 195-222.

Galí, J., Gertler M., and J.D. Lopez-Salido (2001). European Inflation Dynamics, *European Economic Review*, vol. 45, pp. 1237-1270.

Grier, K.B. and Perry, M.J. (2000). The effects of real and nominal uncertainty on inflation and output growth: some GARCH-M evidence, *Journal of Applied Econometrics*, 15, 45-58.

Lumsdaine, R.L. and S. Ng (1999). Testing for ARCH in the presence of a possibly misspecified conditional mean, *Journal of Econometrics*, vol. 93, pp. 257-279.

Perron, P., (1989). The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis, *Econometrica*, vol. 57, no. 6, November, pp. 1361-1401.

Phelps, E.S. (1967). Phillips curves, expectations of inflation, and optimal unemployment over time, *Economica*, 34, 3 (August), pp. 254-81.

Phillips, A. W. (1958). The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957, *Economica*, 25, pp 1-17.

Russell, B. (2006). Non-Stationary Inflation and the Markup: an Overview of the Research and some Implications for Policy, Dundee Discussion Papers, Department of Economic Studies, University of Dundee, August, No. 191.

Russell, B. (2011). Non-stationary Inflation and Panel Estimates of United States Short and Long-run Phillips Curves, *Journal of Macroeconomics*, vol. 33, pp. 406-19.

Russell, B., A. Banerjee, I. Malki and N. Ponomareva (2011). Dundee Discussion Papers, Economic Studies, University of Dundee, April, No. 252.

Russell, B. and R.A. Chowdhury (2013). Estimating United States Phillips Curves with Expectations Consistent with the Statistical Process of Inflation, *Journal of Macroeconomics*, vol. 35, pp. 24-38.

Svennson, L.E.O. (2000). Open Economy Inflation Targeting, *Journal of International Economics*, vol. 50, pp. 155-83.

APPENDIX 1 DATA APPENDIX

The United States data are seasonally adjusted and quarterly for the period March 1960 to March 2013. The United States national accounts data are from the National Income and Product Account tables from the United States of America, Bureau of Economic Analysis. The aggregate data were downloaded via the internet on 31 May 2013. The data are available at www.BillRussell.info.

Variable	Details
Inflation:	Nominal gross domestic product (GDP) at factor cost is nominal GDP (Table 1.1.5, line 1) plus subsidies (NIPA Table 1.10, line 10) less taxes (NIPA Table 1.10, line 11). The 'price' series is the GDP implicit price deflator at factor cost calculated as nominal GDP at factor cost divided by constant price GDP at 2005 prices (NIPA Table 1.1.6, line 1). Inflation is the first difference of the natural logarithm of the price series. Note that Graph 1 shows the estimated inflation regimes multiplied by 400 to provide an 'annualised' rate of inflation.
The Markup:	Calculated as the natural logarithm of nominal GDP at factor cost divided by compensation of employees paid (NIPA Table 1.10, line 2).

Table 1: Estimated Inflation 'Regimes' using the Bai-Perron Technique

Regime	*Dates of the 'Inflation Regimes'*	*Mean*	*Historical Context*
1	March 1960 to September 1964	0.003167	Low inflation following recession.
2	December 1964 to September 1967	0.007448	Loose monetary & fiscal policy associated with funding the Vietnam War.
3	December 1967 to December 1972	0.011539	World commodity price boom and breakdown of the Bretton-Woods exchange rate system.
4	March 1973 to March 1978	0.018534	First OPEC oil price 'shock'.
5	June 1978 to September 1981	0.021084	Second OPEC oil price 'shock'.
6	December 1981 to December 1984	0.010197	'Volker deflation'.
7	March 1985 to June 1991	0.007768	Depreciation of the $US following the Plaza Accord.
8	September 1991 to September 2003	0.004828	Decline to low inflation following recession.
9	December 2003 to September 2007	0.007966	Failure of the Federal Reserve to unwind the loose monetary policy following the 9/11 terrorist attach and the end of the technology share price 'bubble'.
10	December 2007 to March 2013	0.003785	Financial/debt crisis recession.

The minimum regime size is assumed to be 12 quarters (three years). The model was estimated using baiperron.src and multiplebreaks.src programmes written by Tom Doan in RATS 7.2. Note that in Graph 1 the mean rate of inflation in each regime is multiplied by 400 and shown as solid thin horizontal lines.

Table 2: United States Phillips Curves - Two Stage Least Squares

	Hybrid Phillips Curve			SPC Phillips Curve
	No Dummies	Spike Dummies Only	All Dummies	All Dummies
	1	2	3	4
π_{t+1}^{f}	0.6923 (6.5)	0.7056 (7.4)	0.2358 (1.6)	
π_{t-1}	0.2678 (2.9)	0.2356 (3.2)	0.1941 (2.5)	0.2204 (3.0)
μ_{t}^{f}	- 0.0107 (-0.8)	0.0002 (0.0)	-0.0429 (-1.9)	-0.0558 (-2.8)
Constant	0.0055 (0.8)	0.0003 (0.0)	0.0231 (2.0)	0.0303 (3.0)
Dummies (see Table 2b)	No	Yes	Yes	Yes
Coefficient Restriction Tests				
$\delta_f + \delta_b$	0.9601	0.9412	0.4300	0.2204
$\delta_f + \delta_b = 0$	[0.0000]	[0.0000]	[0.0039]	[0.0035]
$\delta_f + \delta_b = 1$	[0.5125]	[0.3010]	[0.0001]	[0.0000]
$\varphi_2 \ldots \varphi_{10} = 0$			[0.0246]	[0.0000]
Information Criteria				
$\bar{R}^2$	0.80	0.84	0.85	0.85
Akaike	-8.9897	-9.1915	-9.2050	-9.2077
Schwarz	-8.9255	-9.0631	-8.932	-8.9518
Residual Diagnostics				
LM(1) LM(1 to 4)	[0.0069] [0.0008]	[0.4141] [0.1690]	[0.7242] [0.8201]	[0.5385] [0.8802]
DW	2.18	2.06	2.03	2.05
J-B	[0.0000]	[0.0167]	[0.2981]	[0.2567]
ARCH	[0.0000]	[0.7024]	[0.3693]	[0.3797]
White	[0.0000]	[0.0021]	[0.0751]	[0.0793]
B-P-G	[0.0000]	[0.0021]	[0.0718]	[0.0737]

Table 2b: United States Phillips Curves
Estimated Shift and Impulse Dummies

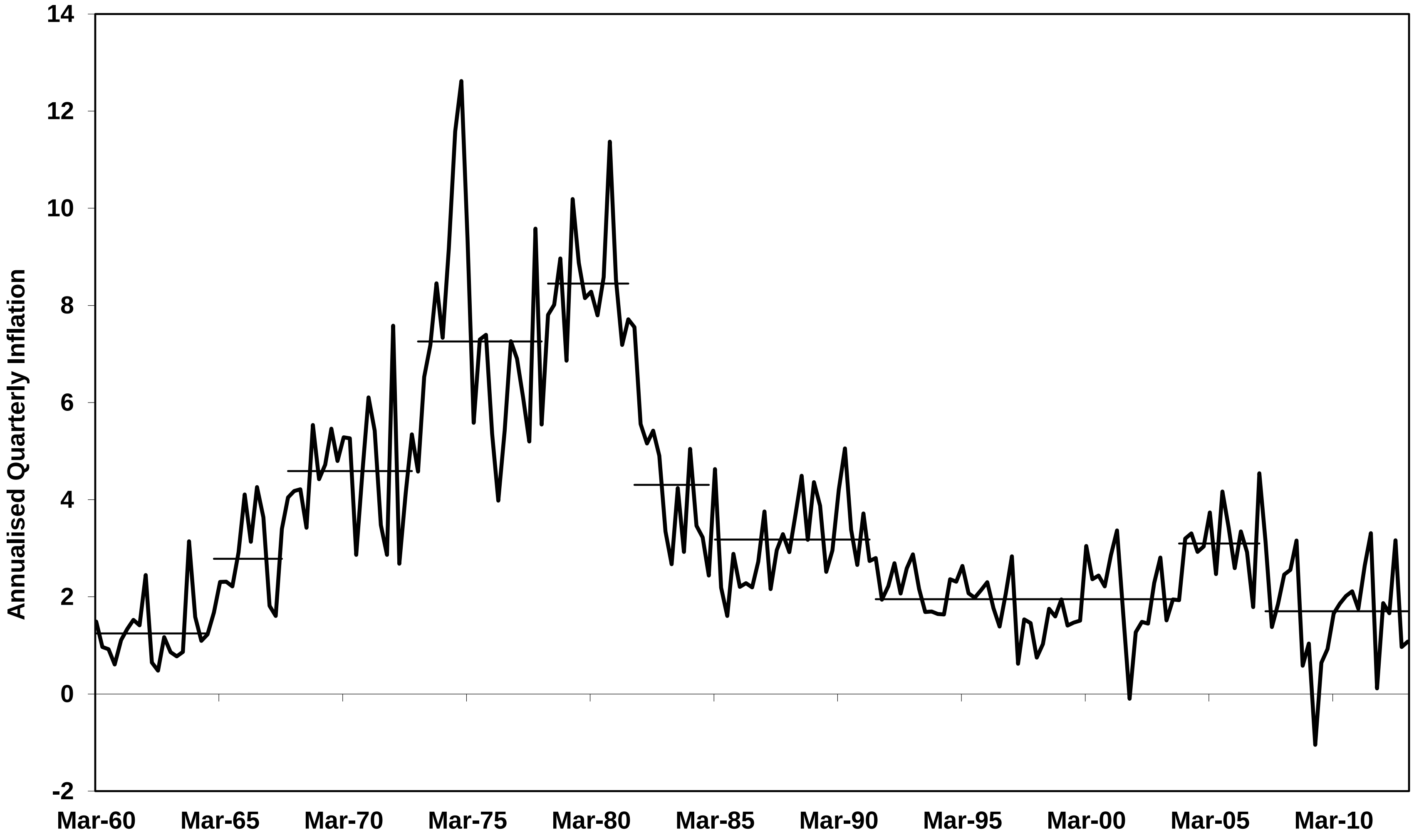
	Hybrid Phillips Curve		SPC Phillips Curve
	Spike Dummies Only	All Dummies	All Dummies
	2	3	4
D_2		0.0022 (2.4)	0.0029 (3.5)
D_3		0.0024 (1.8)	0.0035 (3.1)
D_4		0.0053 (2.8)	0.0078 (5.4)
D_5		0.0091 (4.0)	0.0123 (7.6)
D_6		0.0033 (2.6)	0.0044 (3.9)
D_7		0.0022 (2.7)	0.0029 (4.0)
D_8		0.0006 (1.2)	0.0008 (1.5)
D_9		0.0031 (2.9)	0.0040 (4.9)
D_{10}		0.0015 (1.6)	0.0019 (2.1)
$I_{Mar\ 1972}$	0.0086 (17.1)	0.0084 (12.4)	0.0084 (12.1)
$I_{Sept\ 1974}$	0.0094 (14.4)	0.0104 (10.7)	0.0103 (10.9)
$I_{Dec\ 1974}$	0.0102 (10.7)	0.0116 (9.3)	0.0114 (9.3)
$I_{Dec\ 1977}$	0.0086 (17.0)	0.0090 (11.2)	0.0090 (11.2)

Notes to Tables 2 and 2b

The dummy coefficient estimates reported in the table correspond to the same numbered models in Table 2. The models are estimated using quarterly seasonally adjusted data for the period March 1960 to March 2013 using 208 observations. Reported as ( ), ( ) and [ ] are t-statistics, f-statistics and probability values respectively. See Appendix 1 for details concerning the data and Section 3.1 for the estimation of the inflation regimes. Models are estimated with ordinary least squares with the lead in inflation and the markup replaced by their static 'forecast' values (see Section 3.1) which is equivalent to estimating the model with two-stage-least-squares. Models are estimated with White heteroscedastic standard errors and covariances.

Coefficient restrictions are Wald F tests. LM(1) and LM(1 to 4) reports the Breusch-Godfrey LM test of serially correlated residuals for one lag and one to four lags respectively. J-P reports the test that the skewness and kurtosis of the residuals are from a normal distribution. The ARCH test is the Engle Lagrange multiplier test for ARCH in the residuals. White tests the null hypothesis of no heteroskedasticity against heteroskedasticity of unknown general form in the residuals. B-P-G is the Breusch-Pagan-Godfrey test which is a Lagrange multiplier test of the null hypothesis of no heteroskedasticity against heteroskedasticity of the form $\sigma_t^2 = \sigma^2 h(z_t^{'} \alpha)$, where z_t is a vector of the independent variables from the mean equation. The null hypotheses of the LM, J-P and heteroskedasticity tests are no serial correlation, normally distributed residuals and no heteroskedasticity in the residuals respectively. Models estimated with Stata/SE 8.2, Eviews 7.1 and RATS 8.01.

Graph 1: United States Annualised Quarterly Inflation, Seasonally Adjusted, March 1960 – March 2013



Notes: Horizontal dashed lines indicate the ten inflation regimes identified by the Bai-Perron technique. Annualised quarterly inflation is measured as the change in the natural logarithm of the price index multiplied by 400.