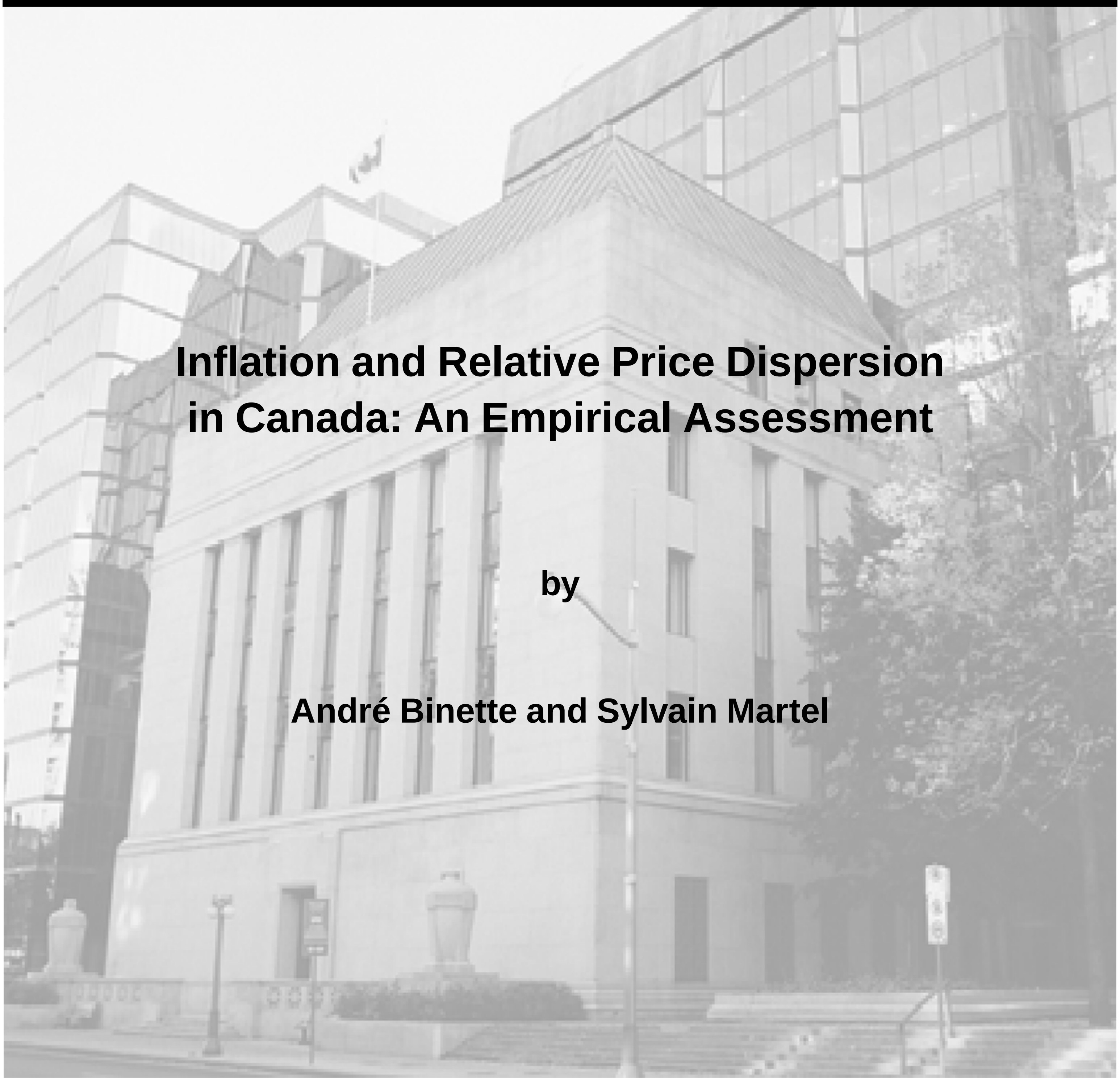
Bank of Canada Banque du Canada

Working Paper 2005-28 / Document de travail 2005-28



Inflation and Relative Price Dispersion in Canada: An Empirical Assessment

by

André Binette and Sylvain Martel

ISSN 1192-5434

Printed in Canada on recycled paper

Bank of Canada Working Paper 2005-28

October 2005

Inflation and Relative Price Dispersion in Canada: An Empirical Assessment

by

André Binette and Sylvain Martel

Research Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
abinette@bankofcanada.ca
smartel@bankofcanada.ca

Contents

Acknowledgements

Special thanks to Allan Crawford and Frédérick Demers for continually providing us with suggestions and econometric support. Useful suggestions and advice offered by Richard Dion, Maral Kichian, Claude Lavoie, and workshop participants at the Bank of Canada are gratefully acknowledged. Thanks to Louis Morel for his technical advice.

Abstract

The authors investigate empirically the relationship between different aspects of inflation and relative price dispersion in Canada using a Markov regime-switching Phillips curve. They examine three theories that explain movements in relative price dispersion: the signal extraction model, the extension of the signal extraction model, and the menu cost model. The authors show that expected inflation, which is captured by the menu cost model, is the aspect of inflation that is most closely associated with relative price dispersion. Furthermore, this result seems robust to different specifications. The authors, however, cannot completely discard inflation uncertainty (the signal extraction model), especially when using core inflation. They also observe a strong asymmetry regarding the impact of positive and negative unexpected inflation on relative price dispersion using total inflation, but this asymmetry is not observed for core inflation. This suggests that the strong asymmetry arises mainly from the presence of components typically associated with supply shocks, and not from the presence of downward nominal rigidities, as Aarstol (1999) proposes, following Ball and Mankiw (1992a,b).

JEL classification: C32, E31
Bank classification: Inflation and prices

Résumé

Les auteurs examinent empiriquement la relation entre différents aspects de l'inflation et la dispersion des prix relatifs au Canada en utilisant une courbe de Phillips spécifiée à l'aide d'un modèle de régression markovien. Ils analysent trois théories qui cherchent à expliquer les mouvements dans la dispersion des prix relatifs : le modèle à signaux brouillés, une extension de ce modèle et le modèle à coûts d'étiquetage. Les auteurs montrent que l'inflation anticipée, qui est captée par le modèle à coûts d'étiquetage, est l'aspect de l'inflation lié le plus étroitement à la dispersion des prix relatifs. Qui plus est, ce résultat semble robuste pour différentes spécifications. Toutefois, les auteurs ne peuvent pas rejeter complètement la significativité de l'incertitude (le modèle à signaux brouillés), surtout lorsqu'ils font appel à une mesure de l'inflation tendancielle. Ils constatent aussi que les variations positives et négatives imprévues de l'inflation totale ont des effets très asymétriques sur la dispersion des prix relatifs, mais que cette asymétrie n'est pas observée dans le cas de l'inflation tendancielle. Ce résultat donne à penser que la forte asymétrie découle principalement des composantes typiquement associées à des chocs d'offre, et non pas de la présence de rigidités nominales comme l'avance Aarstol (1999), dans la lignée de Ball et Mankiw (1992a et b).

Classification JEL: C32, E31
Classification de la Banque: Inflation et prix

1. Introduction

The goal of monetary policy in Canada is to contribute to solid economic performance and rising living standards for Canadians by keeping inflation low, stable, and predictable. For this reason, central banks have a natural interest in the relationship between inflation and relative price dispersion. As Friedman (1977) made clear in his Nobel lecture, relative price dispersion is a direct means by which inflation can induce welfare-diminishing resource misallocation. An important function of the price system is to efficiently transmit the information that economic agents need in order to allocate resources efficiently. Given that the information required is contained in relative prices, the noise coming from inflation can make it difficult to optimally use the information.

The positive relationship between relative price dispersion and inflation has practically become a stylized fact in economics. The recent literature focuses on explaining relative price dispersion through specific aspects of inflation: trend inflation, inflation uncertainty, and unexpected inflation. Since the early 1990s, Canada has had lower trend inflation and lower inflation uncertainty. Research on the effects of these changes on relative price dispersion can provide evidence of the welfare cost of inflation (as described by Friedman 1977).

Staff at the Bank have an ongoing interest in the relationship between inflation and relative price dispersion in Canada.[1] This paper aims to improve our understanding of this relationship. Our work differs from the recent literature in three respects: we use a Markov regime-switching Phillips curve, the implicit price index of personal expenditure on consumer goods and services, and quarterly data. As with previous researchers, we examine three main theories to explain the relationship between inflation and relative price dispersion: the menu cost model, the signal extraction model, and the extension of the signal extraction model. We also test the robustness of our results along different margins.

The rest of this paper is organized as follows. Section 2 describes the theories linking inflation and relative price dispersion. Section 3 reviews the recent literature. Section 4 explains our measure of relative price disper-

[1] Vitek (2002) has done recent work on the subject using the Canadian industrial product price index.

sion. Section 5 provides our system of equations. Section 6 highlights our main findings. Section 7 examines the robustness of the results. Section 8 concludes and suggests directions for future research.

2. Theories Linking Relative Price Dispersion and Inflation

As Longworth (2002) states, "relative prices are real variables . . . and their variability will be heavily influenced by the variability of real factors across industries, producers, retailers, etc." Unfortunately, this kind of microeconomic database is very costly to produce, so not much empirical work has been done using real variables as determinants of relative price dispersion.[2] The recent literature relies heavily on different aspects of inflation to explain relative price dispersion. The following three main theories are based on the basic assumptions of limited information and sticky prices:

(i) Barro's (1976) signal extraction model (based on Lucas 1972) predicts that relative price dispersion increases with ex ante inflation uncertainty. This relationship arises because agents have incomplete information about the state of the economy. The greater the ex ante variability of aggregate nominal shocks, the greater the misperceptions and the more individual firms adjust prices instead of output in response to idiosyncratic real demand shocks. The individual firms do not know whether any particular price change in their market is caused by a change in the aggregate demand or by a change in relative product demand. This less-variable quantity supplied implies that prices are more widely dispersed to equate quantity demanded. In this model, realized aggregate demand shocks have no effect on relative price dispersion, because all firms have identical price elasticities of supply.

(ii) In the Hercowitz (1981) and Cukierman (1983) extension of the Lucas and Barro model, *realized* aggregate demand shocks do affect relative price dispersion, because firms do not have the same price elasticity of supply. Given this difference, firms with high elasticities of supply adjust their prices less than firms in other sectors in response to a given aggregate demand shock. Hence, this extension model predicts that the size of the relative price dispersion is related to the size of the shock. According to this model,

[2] Baldwin, Durand, and Hosein (2001), using sectoral data, suggest that relative productivity growth is a possible determinant of relative price dispersion.

one should note that the sign of unexpected inflation is irrelevant. In other words, relative price dispersion is affected only by the size of unexpected inflation, whether positive or negative.

(iii) The relationship between expected inflation and relative price dispersion is explained by different models in the literature. Models with fixed costs of changing prices are the most common approach used to explain this relationship;[3] they were pioneered by Sheshinski and Weiss (1977). In their model, there is no uncertainty about the rate of inflation: because of adjustment costs, price-setting firms would not change prices continuously, but at discrete intervals. One implication of the model is that "if the timing of firms' price adjustments is independent, then we would observe a variance of price change across products or firms which increases with the rate of inflation" (p. 301). As is common in the literature, we use the expression "menu cost model" to refer to the link between expected inflation and relative price dispersion.

3. Literature Review

Mills (1927) and Graham (1930) pioneered the empirical research on the relationship between relative price dispersion and inflation. Using descriptive studies, both found that relative price dispersion increased with inflation. Confirmed by the modern literature initiated by Vining and Elwertowski (1976) and Parks (1978), this basic relationship has almost become a stylized fact.[4] However, there is no real consensus regarding which aspect of inflation explains relative price dispersion.

Using the monthly U.S. producer price index to generate an unweighted measure of relative price dispersion, Grier and Perry (1996) construct a bivariate GARCH-in-mean (GARCH-M)[5] model to estimate the conditional variance of inflation and its effect on relative price dispersion in a single system. Measured by this conditional variance, inflation uncertainty is the only significant determinant of relative price dispersion. This result is robust to changes in the sample period, the measure of relative price dispersion, the

[3]Ball and Cecchetti (1991) explain that staggered wage setting can also imply a link between trend inflation and relative price dispersion.

[4]See Golob (1993) for a detailed review of the literature on the relationship between relative price dispersion, inflation, and real economic activity.

[5]GARCH: Generalized autoregressive conditional heteroscedasticity.

covariance structure of the model, and the specification of the variable for trend inflation.

To test the three theories, Aarstol (1999) also uses the monthly U.S. producer price index to generate an unweighted measure of relative price dispersion. Because his autoregressive/moving average (ARMA) model of monthly inflation rejects the hypothesis of independence of the squared residuals, he uses a GARCH (1,1) process to specify the conditional variance of inflation. As specified by the series generated by the GARCH and the one-period-ahead forecast of inflation, the Lucas-Barro signal extraction model and the menu cost model receive some support from the data. The asymmetry found between the coefficients on the positive and negative unexpected inflation variables implies a rejection of the Hercowitz-Cukierman version of the signal extraction model even if positive unexpected inflation is extremely significant. Aarstol suggests that the presence of downward rigidity in prices could help to explain this rejection, and he acknowledges the finding of Ball and Mankiw (1992a,b).[6]

Vitek (2002) conducts an empirical investigation of dynamic interrelationships among inflation, inflation uncertainty, relative price dispersion, and output growth within a trivariate GARCH-M model. Using the monthly Canadian industrial product price index, he finds evidence that relative price dispersion rises with both trend inflation and inflation uncertainty. However, the choice of whether to use weighted or unweighted measures of relative price dispersion and the symmetry characteristic of the process governing inflation uncertainty matter.[7] Inflation uncertainty is significant and dominates trend inflation in models where a weighted measure is used. In contrast, trend inflation alone is significant if the unweighted measure is used, but only if the process governing inflation uncertainty is symmetric.

[6]According to Ball and Mankiw (1992a,b), the sign of the inflation surprise matters. When firms face a negative shock and want to reduce their relative prices, the needed adjustment is small because inflation will do most of the job. In contrast, a positive shock implies that the needed adjustment is amplified by the presence of inflation. Note that this asymmetric response will be more pronounced in periods of high inflation.

[7]The author allows for asymmetric effect from positive and negative unexpected inflation on inflation uncertainty. Following Brunner and Hess (1993) and Joyce (1995), positive unexpected inflation will increase inflation uncertainty by a greater amount than negative unexpected inflation.

4. Measure of Relative Price Dispersion

To construct our measure of relative price dispersion, we follow the recent literature and use the measure proposed by Parks (1978). Our measure of relative price dispersion (RPD) in period t is calculated as:

$$RPD_t = \sqrt{\sum_{i=1}^{119} w_{i,t}(\pi_{i,t} - \pi_t)^2}, \tag{1}$$

where $\pi_{i,t}$ is the inflation rate of the ith component, π_t is the aggregate inflation rate, and w_i is the variable weight of the ith component.[8] The inflation rates are defined as the annualized quarterly change in the relevant seasonally adjusted consumption deflator from 1966Q2 to 2002Q4. We create this measure of relative price dispersion using the implicit price index of personal expenditure on consumer goods and services that includes 119 components. The use of quarterly inflation stems from the choice of the price index and also reflects the finding of Ram (1988), who compares monthly and quarterly series and concludes that the quarterly series seems more appropriate to test the theories. Given the importance of market-specific shocks to the prediction of the Lucas-Barro model, we first use this most comprehensive measure of RPD instead of deliberately ignoring the energy and food components to control for supply shocks. This decision is important because tobacco products and motor fuels and lubricants account for the main spikes in our measure of relative price dispersion after 1986.[9] Figure 1 shows our measure of relative price dispersion along with the aggregate inflation rate.

[8]Given the availability of the weights and the apparent cost of imposing that they are equal across industries, we do not construct an unweighted measure of relative price dispersion.

[9]From 1966Q2, we can observe five major spikes in our measure. The component "accident and sickness insurance," roughly measured by subtracting claims paid from premiums earned, is mainly responsible (48 per cent and 39 per cent) for the increases observed in 1980Q1 and 1981Q1. The category "motor fuels and lubricants" is highly significant (56 per cent and 24 per cent) in 1986Q2 and 1991Q1. Tobacco products almost exclusively explain the shock in the first half of 1994, due to a large decrease in taxes.

5. Models of Inflation and Relative Price Dispersion

To study the interaction between particular aspects of inflation and relative price dispersion, we estimate a vector autoregressive exogenous (VARX) model with a Markov switching process for inflation using the maximum-likelihood method. We select the Markov switching approach given the findings and suggestions of recent Bank of Canada working papers on two important aspects of inflation. Demers (2003) investigates the linearity and parameter constancy assumptions of a standard reduced-form Phillips curve for Canada using two techniques: the methodology of Bai and Perron (1998) and a three-regimes Markov switching model. Both techniques strongly reject the assumptions. Crawford and Kasumovich (1996) suggest that a simple ARMA model may ignore relevant information used by agents in forming inflation expectations. Keeping these findings in mind, we construct the following non-linear Phillips curve with three regimes[10]:

$$\begin{aligned}\pi_t &= C_{s,t} + \phi_{s,t-1}\pi_{t-1} + \beta_{s,t-1}ygap_{t-1} + \delta_{s,t-1}re_{t-1} \\ &\quad +\theta_{s,t-1}ener_{t-1} + D_{11}gst + D_{12}tob + \epsilon_t, \qquad (2)\end{aligned}$$

$$\epsilon_t \sim i.i.d.N(0, \sigma^2_{\epsilon_{s,t}}). \qquad (3)$$

As specified, demand-side pressures enter via the output gap ($ygap$), while supply-side pressures are included through variables for import price inflation (re) and real energy price inflation ($ener$). The output gap is the usual measure estimated by the Bank of Canada (Laxton and Tetlow 1992); import price inflation is the growth rate of the real exchange rate specified as the nominal exchange rate multiplied by the ratio of the Canadian gross domestic product price index (1997=100) to the comparable U.S. index; the real

[10]The regime-generating stochastic process used in our model, s_t, is technically an ergodic Markov chain of order one. The number of states, m, in this process is defined according to the transition probabilities: $p_{ij} = \Pr\{s_t = i \mid s_{t-1} = j\}$, $\sum_{i=1}^{m} p_{ij} = 1 \quad i,j = 1, ..., m$, with transition matrix P. See Demers (2003) for more details.

energy price inflation is the annualized growth rate of the energy component of the Bank of Canada commodity price index deflated by the U.S. gross domestic product price index. Two dummies are added to capture the effects of unusual events.[11]

Our general specification of relative price dispersion, equation (4), is an autoregression with holes and exogenous variables (ARX (4)).[12] The exogenous explanatory variables (X) are included to capture the three theories. As is common in the literature, expected inflation, unexpected inflation, and inflation uncertainty are generated by the process in equation (2). Expected inflation, $\hat{\pi}_t$, is the one-period-ahead forecast of this equation and the squared values are used following the common practice in the literature.[13] To test the prediction of the Hercowitz-Cukierman model that the sign of the inflation surprise should be irrelevant, two auxiliary series are created from the residuals of equation (2). *Pux* is the squared value of unexpected inflation, ϵ_t, when it takes positive values (and zero otherwise), while *Nux* is created using the same logic with negative residuals. Inflation uncertainty, *Uncer*, is constructed as a weighted average of the forecast-error variance in each regime, where the weights are the estimated probabilities of being in each regime in period t.[14] For simplicity, we use a short-term definition of uncertainty (one quarter ahead), even though we recognize that a long-term measure is probably more appropriate, since economic decisions involve planning horizons well beyond one quarter. Our choice is based on the fact that the different measures of uncertainty are highly correlated (Crawford and Xue 2004). A dummy variable, d, is included in equation (4) to capture an aberration in the series in 1986Q2. The dummy variables used in equation (2) are also included to capture their direct effects on relative price dispersion.

[11] The two unusual events are the introduction of the GST at the beginning of 1991 and the drop in the tobacco tax in the first quarter of 1994.

[12] The only lag of the dependent variable used, the fourth one, could probably deal with an unusual pattern in the series or residual seasonality in the data.

[13] The squared values are often used either to resolve a scaling issue, capture possible non-linearities, or ensure that positive and negative inflation have the same impact.

[14] The use of $\hat{\pi}_t$, *Pux*, *Nux*, and *Uncer* as regressors in the equation for relative price dispersion implies a generated regressors problem (Pagan 1984). Following the common practice in the literature, we assume that any measurement errors are small and will not significantly alter our results.

$$
\begin{aligned}
RPD_t &= C_{rpd} + \alpha_1 RPD_{t-1} + \alpha_2 RPD_{t-4} + \gamma Pux_t + \eta Nux_t + \varphi \hat{\pi}_t^2 \\
&\quad + \lambda Uncer_t + \tau d_t + D_{21} gst + D_{22} tob + \upsilon_t. \qquad (4)
\end{aligned}
$$

The estimation of the system assumes that the covariance between ϵ and υ is zero, which means that ϵ_t and υ_t are orthogonal[15]:

$$
\begin{pmatrix} \epsilon_t \\ \upsilon_t \end{pmatrix} \sim i.i.d.N(0, \Omega) \ \ where \ \ \Omega = \begin{pmatrix} \sigma_{\epsilon_{s,t}} & 0 \\ 0 & \sigma_{\upsilon_t} \end{pmatrix}.
$$

Most studies in the literature use squared expected inflation and inflation uncertainty in the same equation to determine which theory dominates. In our case, the use of a similar specification is not suitable because the two determinants coming from the Markov regime-switching Phillips curve are highly correlated.[16] In fact, this high correlation is observed in many studies using different specifications for inflation (Crawford and Kasumovich 1996). An estimation using these two determinants generates a counterintuitive result for the signal extraction model, which suggests that squared expected inflation is the key determinant. The literature also suggests that the specific use of squared expected inflation to measure trend inflation instead of expected inflation should not qualitatively alter the results (e.g., Grier and Perry 1996; Aarstol 1999). Given the prevailing pattern of low inflation in Canada, however, it could be worthwhile to test whether imposing a non-linear relationship between expected inflation and relative price dispersion quantitatively affects the results regarding the benefits of low inflation.

Given these considerations, we proceed as follows: the first version tests the menu cost model versus the extension of the signal extraction model, and the second version tests the signal extraction model versus its extension. In the first version, we also use expected inflation instead of squared expected inflation to verify whether the benefit is different in the neighbourhood of 2 per cent inflation. The menu cost model predicts that φ is positive and

[15]We did verify this assumption, and the correlation between the errors terms is extremely close to zero.

[16]Figure 2 shows the two series. The statistical correlation is 0.94.

significant. Similarly, the signal extraction model predicts that λ is positive and significant. The extension of the signal extraction model predicts that γ and η are significant and not statistically different from each other.

6. Empirical Results

6.1 Inflation

Regarding the non-linear Phillips curve with Markov switching using total inflation, the transition probabilities imply the presence of three break points that are quite similar to those found by Demers (2003), who uses the typical measure of core inflation as the dependent variable.[17] The break dates are, respectively, 1973Q2, 1984Q3, and 1992Q1. Figure 3 shows the transition probabilities and the fitted value of our equation. As one should expect, the average inflation rate, inflation uncertainty, and inflation persistence decrease significantly from regime one to regime three. As with other researchers, we find a declining exchange rate pass-through, no role for the output gap in the low inflation regime, and a significant and declining interaction between the price of energy and inflation in Canada.[18]

6.2 Relative price dispersion

6.2.1 Version 1: the menu cost model and the extension of the signal extraction model

The first version of the model for relative price dispersion (Table 1) shows an estimated coefficient on squared expected inflation (φ) that is positive and significant at the 1 per cent level.[19] This suggests that the level of inflation is an important determinant of relative price dispersion, thus supporting the menu cost model.

[17] In the study by Demers (2003), core inflation is specified using the total consumer price index (CPI) excluding the eight most volatile components and the effect of changes in indirect taxes on the remaining components.

[18] See Appendix A for detailed results.

[19] Figure 4 shows the measure of the relative price dispersion along with the fitted value of the model (version 1).

Table 1: Estimation Results for the RPD Equation (version 1 with squared expected inflation)

Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	4.03	0.75	5.40
α_1	0.23	0.07	3.11
α_2	0.19	0.06	2.90
γ	0.24	0.08	2.95
η	-0.00	0.04	-0.02
φ	0.02	0.01	3.29
τ	10.28	1.98	5.18
D_{21}	1.80	1.81	0.99
D_{22}	4.97	1.14	4.36
Pseudo-adjusted R^2		0.41	
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		8.47	3.84
Ljung-Box test		Probability	
$Q(1)$		0.34	
$Q(2)$		0.39	
$Q(3)$		0.44	
$Q(4)$		0.42	
$Q^2(1)$		0.19	
$Q^2(2)$		0.32	
$Q^2(3)$		0.50	
$Q^2(4)$		0.34	

Our results for the extension of the signal extraction model suggest that γ and η are statistically different from each other, indicating the rejection of this theory. Note that the asymmetric response reflects a very strong coefficient associated with positive unexpected inflation. Aarstol (1999) obtains similar results.

Not surprisingly, when we use the level of expected inflation instead of the squared values, our results are not qualitatively altered (Table 2). The pseudo-adjusted R^2 remains the same at 0.41 and the level of inflation continues to be the key determinant of relative price dispersion. As noted in section 5, the more interesting question is whether the benefit of reducing inflation is significantly different in the neighbourhood of 2 per cent inflation. Our model suggests a modest benefit no matter which relation is used. In the non-linear model, a 1 percentage point reduction in the inflation rate leads to a 0.12 percentage point decline in relative price dispersion, and this decline is three times bigger with the linear model.[20] Given an average close

[20]Both models have a similar impact on relative price dispersion at an inflation rate of

to 7 per cent between 1992 and 2002, this represents a small reduction in relative price dispersion.

Table 2: Estimation Results for the RPD Equation (version 1 with expected inflation)

Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	3.62	0.72	5.00
α_1	0.24	0.07	3.45
α_2	0.18	0.07	2.77
γ	0.22	0.07	2.94
η	-0.01	0.05	-0.01
φ	0.21	0.07	3.20
τ	9.83	2.00	4.91
D_{21}	0.72	1.60	0.45
D_{22}	4.95	1.15	4.31
Pseudo-adjusted R^2		0.41	
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		7.56	3.84
Ljung-Box test		Probability	
$Q(1)$		0.35	
$Q(2)$		0.40	
$Q(3)$		0.44	
$Q(4)$		0.38	
$Q^2(1)$		0.14	
$Q^2(2)$		0.17	
$Q^2(3)$		0.29	
$Q^2(4)$		0.17	

6.2.2 Version 2: the signal extraction model and its extension

In this section, we test the prediction of the signal extraction model as well as an extension of the model.[21] The results suggest that inflation uncertainty plays a small role in explaining relative price dispersion (Table 3). The coefficient on inflation uncertainty (λ) is not significant at the 10 per cent

around 5 per cent. The elasticities are calculated using the formula $\varphi/(1-\alpha_1-\alpha_2)$ for the linear version and $2\varphi\pi/(1-\alpha_1-\alpha_2)$ for the non-linear version. For example, when inflation is 4 per cent, the elasticities are 0.36 and 0.28, respectively.

[21] The results related to the inflation specification remain virtually the same and are not reported.

level. The theory is rejected for the extension of the signal extraction model, but positive unexpected inflation still has a strong predictive power.

Table 3: Estimation Results for the RPD Equation (version 2)

Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	2.96	0.86	3.45
α_1	0.27	0.07	3.89
α_2	0.20	0.07	3.06
γ	0.22	0.08	2.81
η	-0.01	0.04	-0.13
λ	0.63	0.39	1.60
τ	9.70	2.03	4.76
D_{21}	1.95	1.90	1.02
D_{22}	4.89	1.17	4.18
Pseudo-adjusted R^2		0.39	
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		7.28	3.84
Ljung-Box test		Probability	
$Q(1)$		0.45	
$Q(2)$		0.54	
$Q(3)$		0.62	
$Q(4)$		0.56	
$Q^2(1)$		0.19	
$Q^2(2)$		0.29	
$Q^2(3)$		0.39	
$Q^2(4)$		0.20	

Our results from the model for total inflation suggest that the menu cost model is most closely associated with relative price dispersion, and that relative price has a strong asymmetric response to positive and negative unexpected inflation. We estimate that the benefits of reducing the inflation rate are relatively small when inflation is around 2 per cent.

7. Robustness Check

The recent literature shows that results can be influenced by the specification of the relative price dispersion measure. To test the robustness of our results, we examine some major findings in the literature. First, we investigate whether the level of disaggregation is important, following Goel and

Ram (1993). Second, we use a core inflation measure, following the findings of Fisher (1981), Taylor (1981), and Bomberger and Makinen (1993),[22] to test whether the relationship between inflation and relative price dispersion exists mainly as a result of food and energy price shocks. To complete our robustness check, we also make some modifications to the inflation specification.

7.1 A lower level of disaggregation (37 versus 119)

In general, the use of an alternative measure of relative price dispersion, constructed using 37 components, does not alter our results.[23] We still find strong support for the menu cost model. In this version, however, the signal extraction model could not be rejected at the 10 per cent level.

7.2 Core inflation

For our measure of core inflation, the results for the inflation specification are very similar to those obtained for total inflation, except for the last break date.[24] The break dates are, respectively, 1973Q3, 1984Q4, and 1995Q2. The difference lies in an additional transition stage in the series over 1991 to 1995. This new feature adds ambiguity to the model's transition to the low-inflation regime, delaying the break date until 1995Q2, when inflation reaches its lowest level. For relative price dispersion, the use of core inflation changes the conclusions slightly.[25] The menu cost model still gets strong support from the data as being most closely associated with relative price dispersion, but the signal extraction model also gets some support. The use of core inflation indicates that the asymmetric response of relative price dispersion to positive

[22] Starting with our initial dataset, our core measure is based on the Bank of Canada definition (total CPI excluding the eight most volatile components) and uses 109 components, instead of 119.

[23] Appendix B provides detailed results. To resolve a problem of heteroscedasticity in the equation of relative price dispersion, we model the variance as an ARCH(2) process: $\sigma_t^2 = C_\sigma + \rho_1 \upsilon_{t-1}^2 + \rho_2 \upsilon_{t-2}^2$.

[24] Appendix C provides detailed results for the new inflation equation, and Figure 5 shows the transition probabilities and the fitted value.

[25] As expected, the explanatory power of the equation for relative price dispersion is higher when the core measure is used (0.52 versus 0.41).

and negative unexpected inflation is insignificant.[26] This suggests that much of the asymmetric response is in fact related to components that are excluded from core inflation, such as energy prices, and that it is not related to the presence of downward nominal rigidities, as Aarstol (1999) proposes.

7.3 The inflation specification

The inflation specification could potentially have a strong impact on our results, through its influence on the explanatory variables. As a result, we use a real-time output-gap measure, and drop all exogenous variables from the specification (simple AR(1) model with breaks).[27]

In using a real-time output gap measure, our aim is to examine the impact of using the available estimate of the output gap when people form expectations. The result is quite clear: this change to the inflation specification does not qualitatively alter our results vis-a-vis the equation for relative price dispersion.[28]

Regarding the AR(1) specification, our results are also not qualitatively different even if a simple likelihood-ratio test between the two specifications indicates that the exogenous variables bring additional information at the 5 per cent level. This suggests that inflation is mainly driven by mean shifts over history. In fact, Figure 7 shows that the one-period-ahead forecast remains unchanged.

The robustness checks confirm our primary findings that the level of inflation and, to a lesser extent, inflation uncertainty are the key determinants of relative price dispersion. Finally, using total inflation, we observe an important difference in the impact of positive and negative unexpected inflation on relative price dispersion. However, this difference disappears using core inflation, which suggests that the strong asymmetry is caused mainly by components typically associated with supply shocks.

[26] Appendix D and Figure 6 report results for the relative price dispersion specification.
[27] The real-time output-gap measure is taken from Cayen and van Norden (2005).
[28] The results are not provided here but they are available upon request from the authors.

8. Conclusion

Our main goal in this paper has been to empirically investigate the relationship between different aspects of inflation and relative price dispersion in Canada using an improved specification of inflation (a Markov regime-switching Phillips curve). We examined three theories that explain movements in relative price dispersion: the menu cost model, the signal extraction model, and the extension of the signal extraction model. Our results for the relative price dispersion equation suggest two main findings: the apparent superiority of the menu cost model over the other models, and the strong predictive power of positive unexpected inflation, mainly in the model for total inflation. Although we find that, in our dataset, the menu cost model is more closely associated with relative price dispersion than the signal extraction model, we cannot disregard the role of the latter. For the signal extraction model we get some support only when we use core inflation. We acknowledge that the high correlation between measures of expected inflation and uncertainty makes it difficult to distinguish between the two theories. Finally, we find no support at all for the extension to the signal extraction model using both core and total inflation. Using total inflation, we get a very strong coefficient associated with positive unexpected inflation; for core inflation, neither positive nor negative unexpected inflation are significant. This suggests that, with total inflation, the rejection of the extension of the signal extraction model is related to the presence of components typically associated with a supply shock, and not to the presence of downward nominal rigidities, as Aarstol (1999) proposes, following Ball and Mankiw (1992a,b).

Future research could examine other measures of inflation, especially the consumer price index, to determine whether our conclusions hold for them.

Bibliography

Aarstol, M. 1999. "Inflation, Inflation Uncertainty, and Relative Price Variability." *Southern Economic Journal* 66: 414-23.

Bai, J and P. Perron. 1998. "Estimating and Testing Linear Models with Multiple Structural Changes." *Econometrica* 66: 47-78.

Baldwin, J., R. Durand, and J. Hosein. 2001. "Restructuring and Productivity Growth in the Canadian Business Sector." Chapter 2 in *Productivity Growth in Canada*, catalogue no. 15-204, Statistics Canada.

Ball, L. and S.G. Cecchetti. 1991. "Wage Indexation and Discretionary Monetary Policy." *American Economic Review* 81: 1310-19.

Ball, L. and G. Mankiw. 1992a. "Asymmetric Price Adjustment and Economic Fluctuations." NBER Working Paper Series No. 4089.

Ball, L. and G. Mankiw, 1992b. "Relative-Price Changes as Aggregate Supply Shocks." NBER Working Paper Series No. 4168.

Barro, R. 1976. "Rational Expectations and the Role of Monetary Policy." *Journal of Monetary Economics* 2: 1-32.

Bomberger, W. and G. Makinen. 1993. "Inflation and Relative Price Variability: Parks' Study Reexamined." *Journal of Money, Credit, and Banking* 25: 854-61.

Brunner, A. and G. Hess. 1993. "Are Higher Levels of Inflation Less Predictable? A State-Dependent Conditional Heteroscedasticity Approach." *Journal of Business and Economic Statistics* 11: 187-97.

Cayen, J-P. and S. van Norden. 2005. "The Reliability of Canadian Output Gap Estimates." *North American Journal of Economics and Finance.* Forthcoming.

Chang, E.C. and J.W. Cheng. 2000. "Further Evidence on the Variability of Inflation and Relative Price Variability." *Economics Letters* 66: 71-77.

Crawford, A. and M. Kasumovich. 1996. "Does Inflation Uncertainty Vary with the Level of Inflation?" Bank of Canada Working Paper No. 96-9.

Crawford, A. and L. Xue. 2004. "Inflation Uncertainty Over Long Horizons." Photocopy.

Cukierman, A. 1983. "Relative Price Variability and Inflation: A Survey and Further Results." In *Variability in Employment, Prices and Money*, edited by K. Brunner and A. Meltzer, 103-57. Amsterdam: Elsevier Science Publishers.

Davis, G.K. and B. Kanago. 1999. "Inflation and Relative Price Volatility." Photocopy.

Demers, F. 2003. "The Canadian Phillips Curve and Regime Shifting." Bank of Canada Working Paper No. 2003-32.

Fisher, S. 1981. "Relative Shocks, Relative Price Variability, and Inflation." *Brookings Papers on Economic Activity* 2: 381-431.

Fountas, S. 2001. "The Relationship between Inflation and Inflation Uncertainty in the U.K.: 1885-1998." *Economics Letters* 74: 77-83.

Friedman, M. 1977. "Nobel Lecture: Inflation and Unemployment." *Journal of Political Economy* 85: 451-72.

Goel, R.K. and R. Ram. 1993. "Inflation and Relative-Price Variability: The Effect of Commodity Aggregation." *Applied Economics* 25: 703-09.

Golob, J.E. 1993. "Inflation, Inflation Uncertainty, and Relative Price Variability: A Survey." Federal Reserve Bank of Kansas City Research Working Paper No. 93-15.

Graham, F.D. 1930. *Exchange, Prices, and Production in Hyperinflation: Germany, 1920-1923.* New York: Princeton University Press (reissued in 1967 by Russell and Russell).

Grier, K.B. and M.J. Perry. 1996. "Inflation, Inflation Uncertainty, and Relative Price Dispersion: Evidence from Bivariate GARCH-M Models." *Journal of Monetary Economics* 38: 391-405.

Hercowitz, Z. 1981. "Money and the Dispersion of Relative Prices." *Journal of Political Economy* 89: 328-56.

Joyce, M. 1995. "Modelling U.K. Inflation Uncertainty: The Impact of News and the Relationship with Inflation." Bank of England Working Paper No. 30.

Laxton, D. and R. Tetlow. 1992. *A Simple Multivariate Filter for the Measurement of Potential Output.* Technical Report No. 59. Ottawa: Bank of Canada.

Longworth, D. 2002. "Inflation and the Macroeconomy: Changes from the 1980s to the 1990s." *Bank of Canada Review* (Spring): 3-18.

Lucas, R. 1972. "Expectations and the Neutrality of Money." *Journal of Economic Theory* 4: 103-24.

Mills, F.C. 1927. "The Behaviour of Prices." National Bureau of Economic Research.

Pagan, A. 1984. "Econometrics Issues in the Analysis of Regressions with Generated Regressors." *International Economic Review* 25: 221-47.

Parks, R.W. 1978. "Inflation and Relative Price Variability." *Journal of Political Economy* 86: 79-95.

Rajeek, K.G. and R. Ram. 1993. "Inflation and Relative-Price Variability: The Effect of Commodity Aggregation." *Applied Economics* 25: 703-09.

Ram, R. 1988. "Inflation and Relative-Price Variability: Effect of Temporal Aggregation." *Economics Letters* 28: 141-46.

Reinsdorf, M. 1994. "New Evidence on the Relation between Inflation and Price Dispersion." *American Economic Review* 84: 720-31.

Rotemberg, J. 1983. "Aggregate Consequences of Fixed Costs of Price Adjustment." *American Economic Review* 73: 433-36.

Sheshinski, E. and Y. Weiss. 1977. "Inflation and Costs of Price Adjustment." *Review of Economic Studies* 54: 287-303.

Silver, M. and C. Ioannidis. 2001. "Intercountry Differences in the Relationship between Relative Price Variability and Average Prices." *Journal of Political Economy* 109: 355-74.

Stuber, G. 2001. "The Changing Effects of Energy-Price Shocks on Economic Activity and Inflation." *Bank of Canada Review* (Summer): 3-14.

Taylor, J.B. 1981. "On the Relation between the Variability of Inflation and the Average Inflation Rate." Carnegie-Rochester Series on Public Policy 15, 57-85.

Vining, D. and T. Elwertowski. 1976. "The Relationship between Relative Price and the General Price Level." *American Economic Review* 66: 699-708.

Vitek, F. 2002. “An Empirical Analysis of Dynamic Interrelationships among Inflation, Inflation Uncertainty, Relative Price Dispersion, and Output Growth.” Bank of Canada Working Paper No. 2002-39.

Wang. P., P. Wang, and N. Topham. 1999. “Relative Price Variability and Inflation Uncertainty - The UK Case.” *Applied Economics* 31: 1531-39.

Figure 1: Inflation versus Relative Price Dispersion

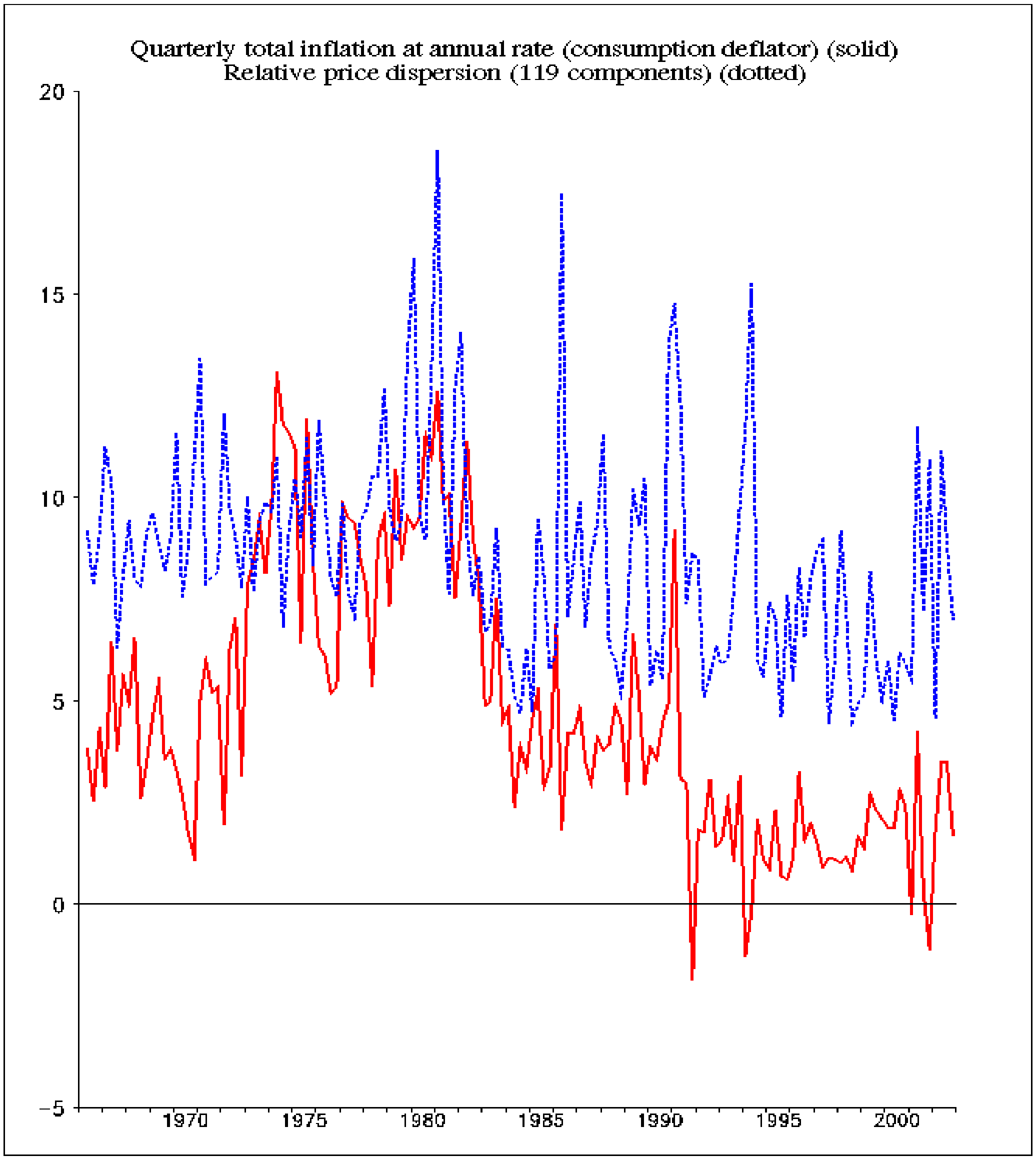


Figure 2: Inflation Uncertainty versus Expected Inflation

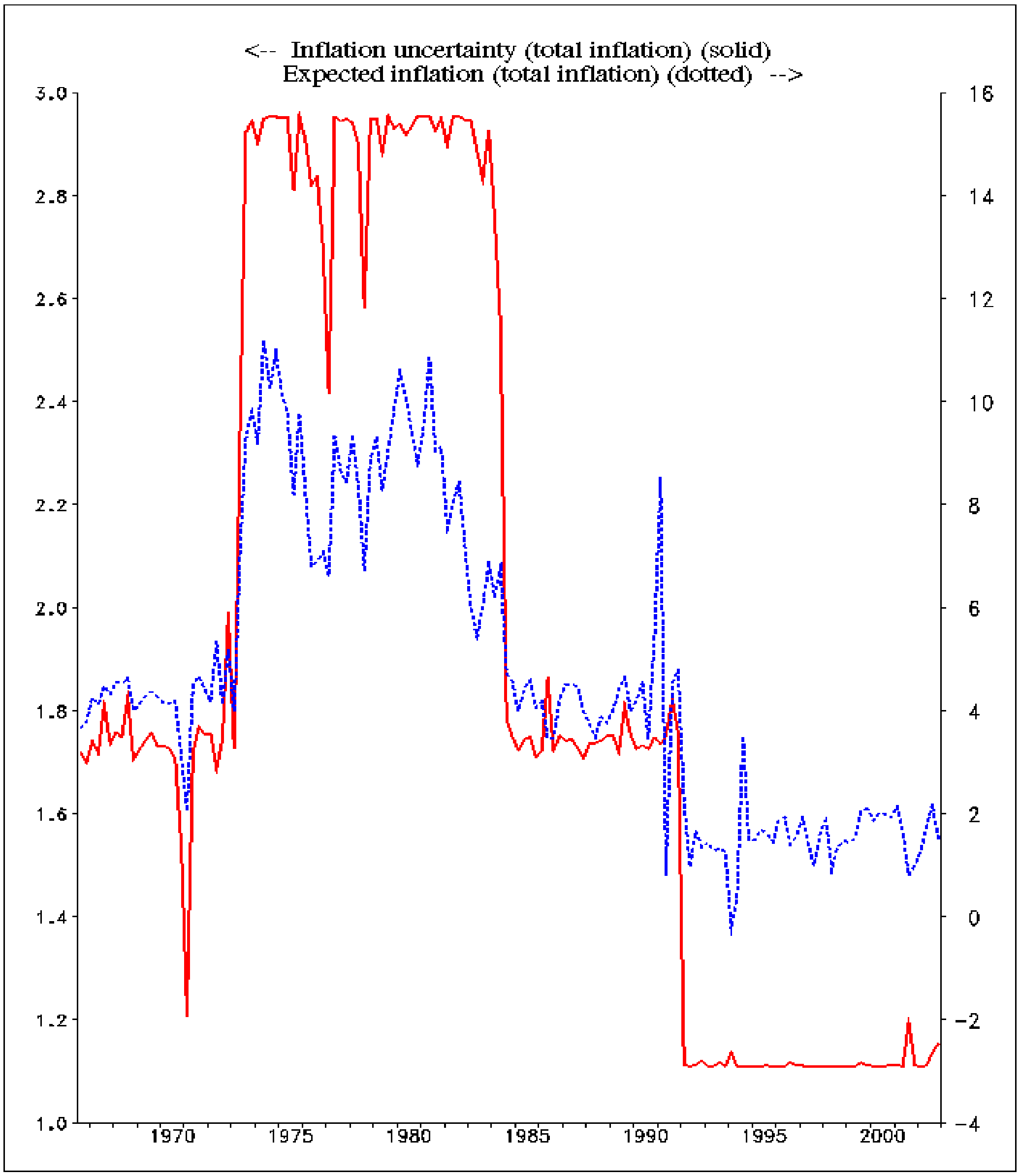


Figure 3: Transition Probabilities and Fitted Value for Total Inflation

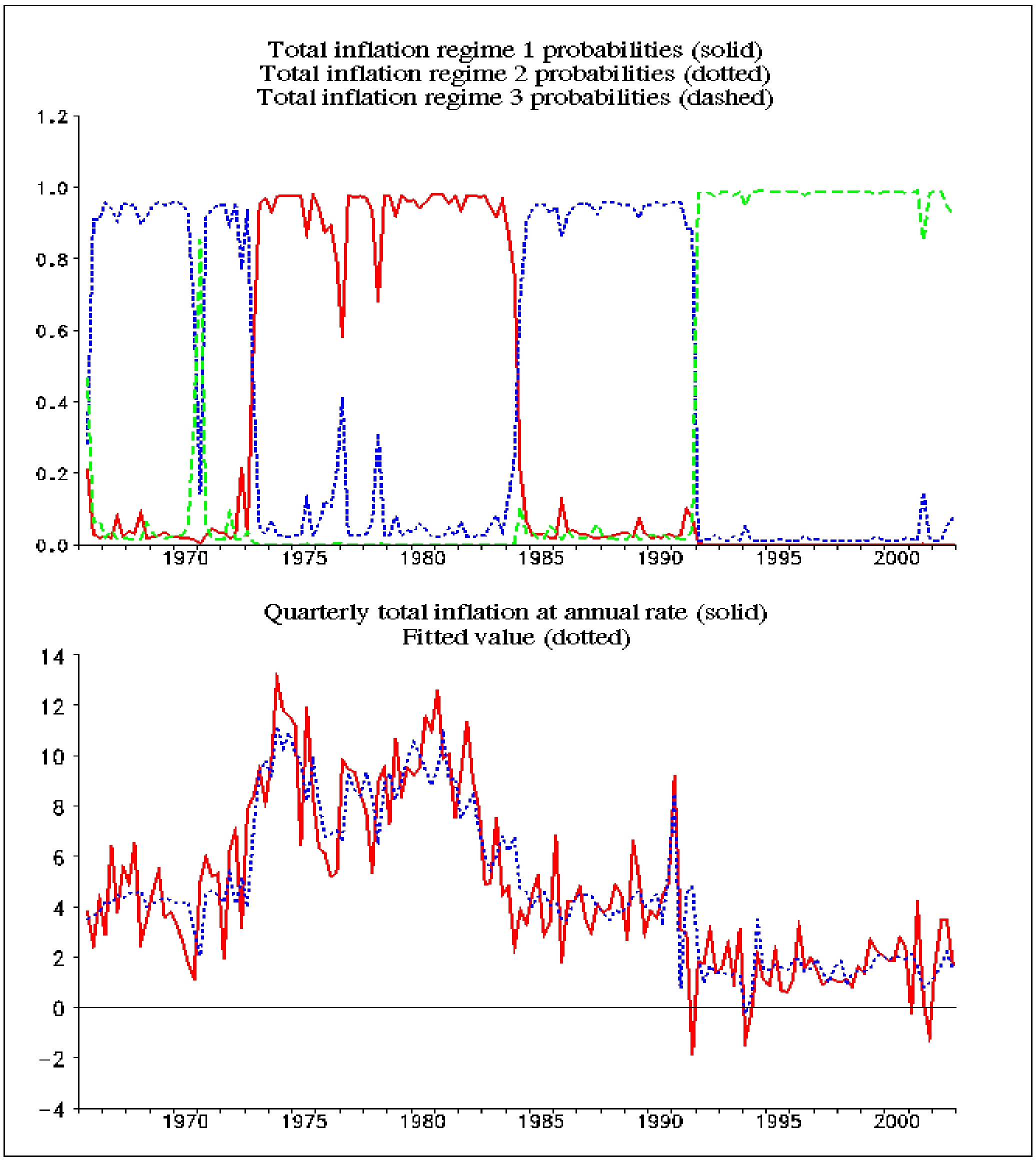


Figure 4: Fitted Value for Relative Price Dispersion Using Total Inflation

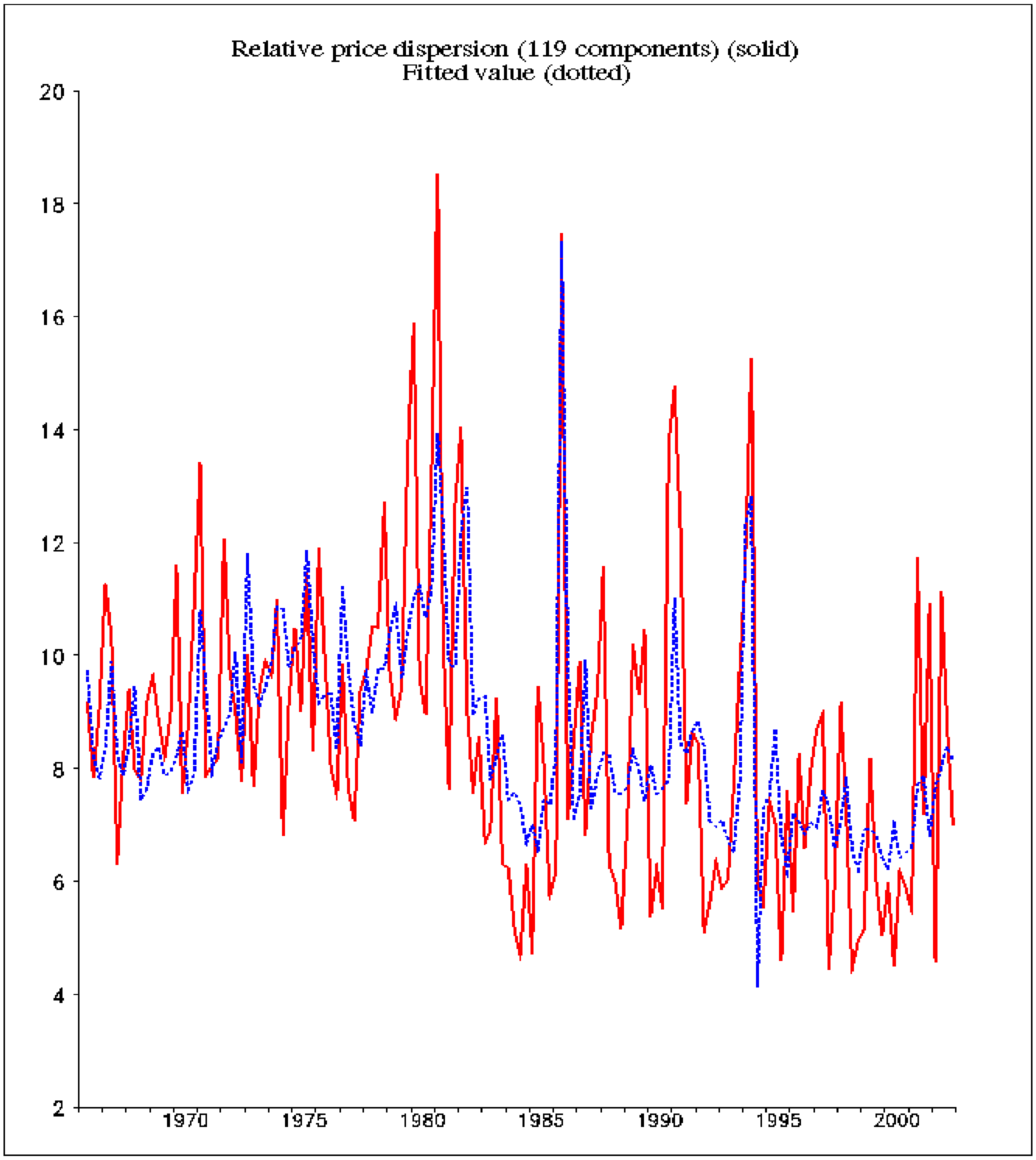


Figure 5: Transition Probabilities and Fitted Value for Core Inflation

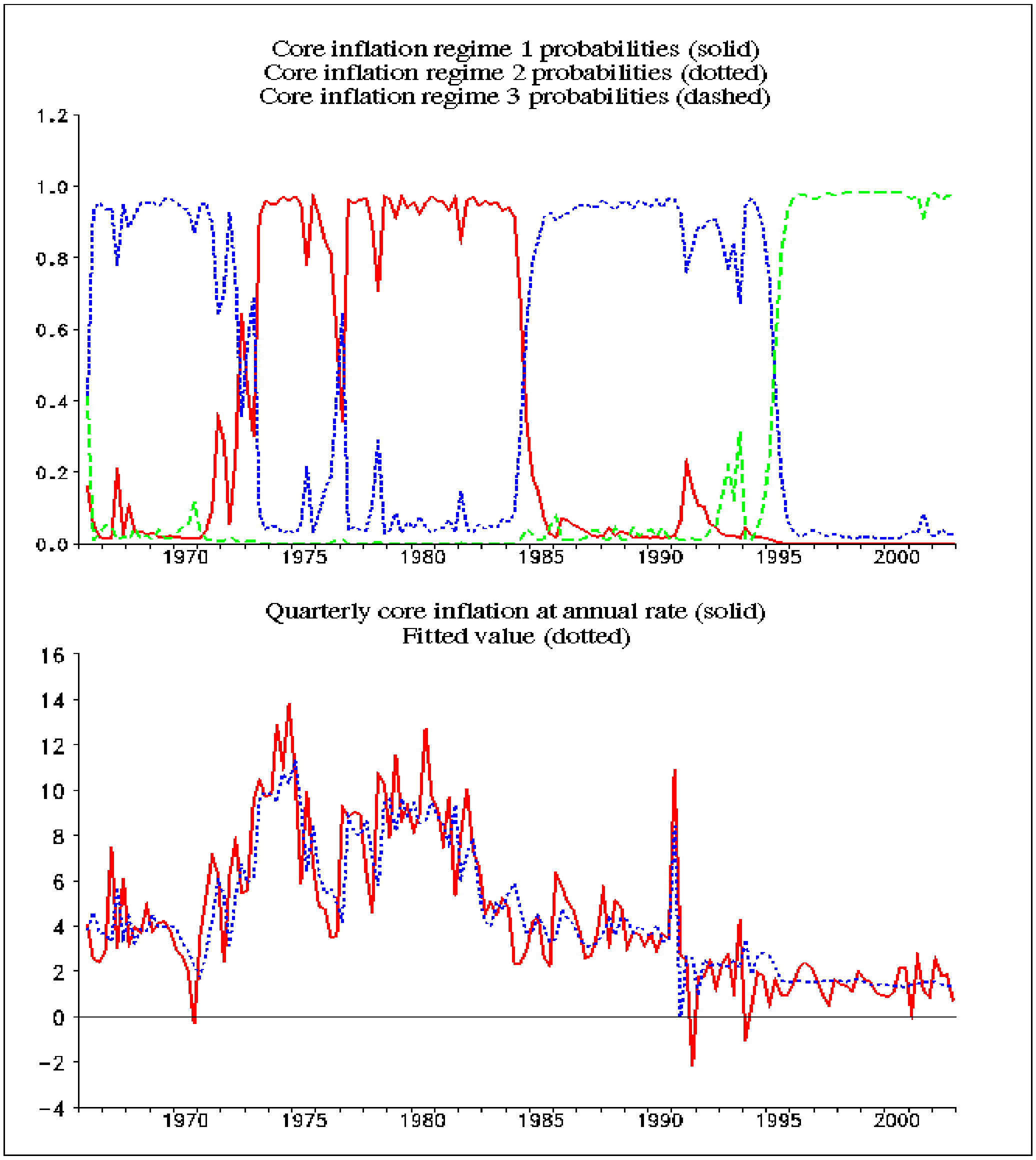


Figure 6: Fitted Value for Relative Price Dispersion Using Core Inflation

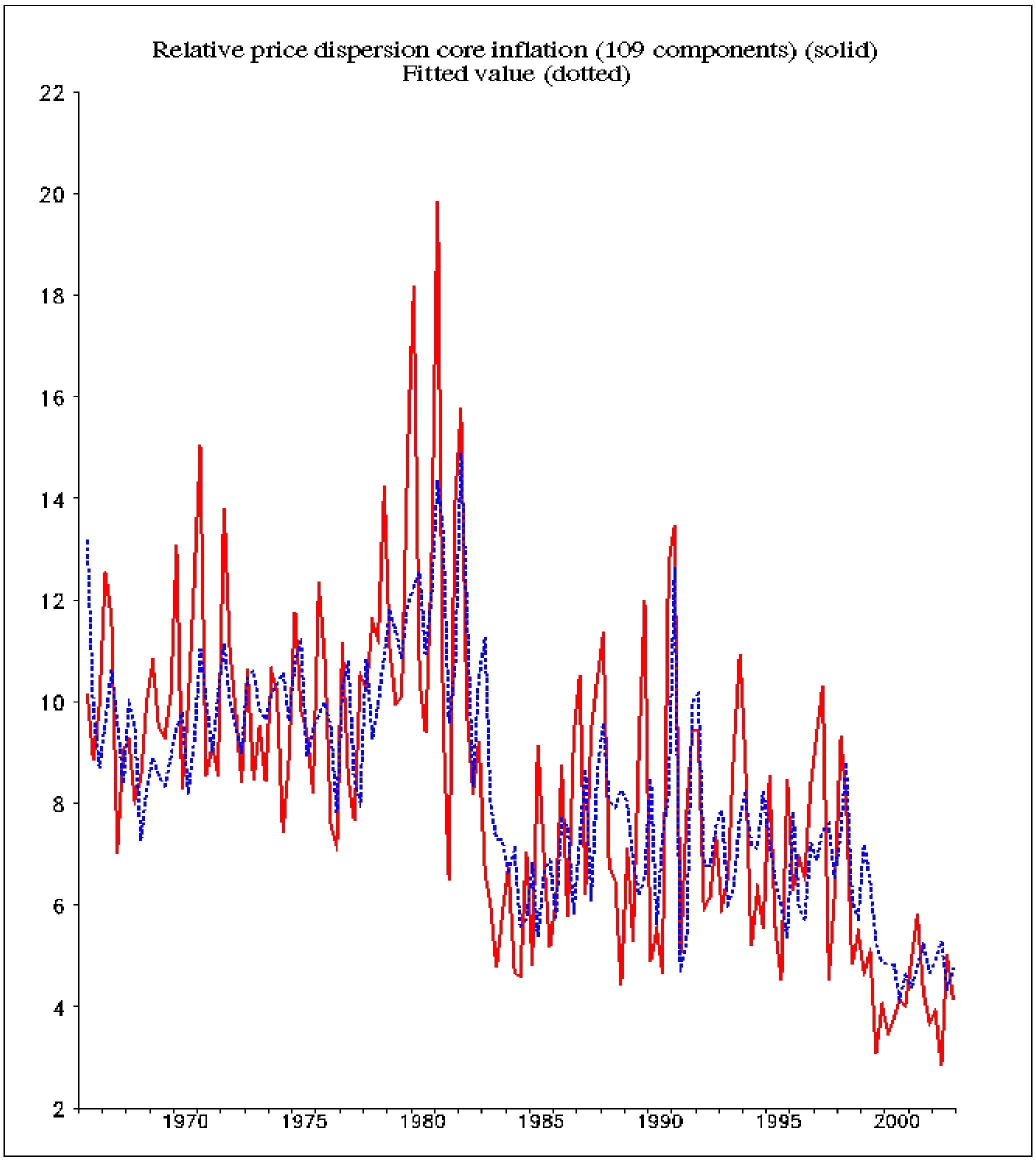
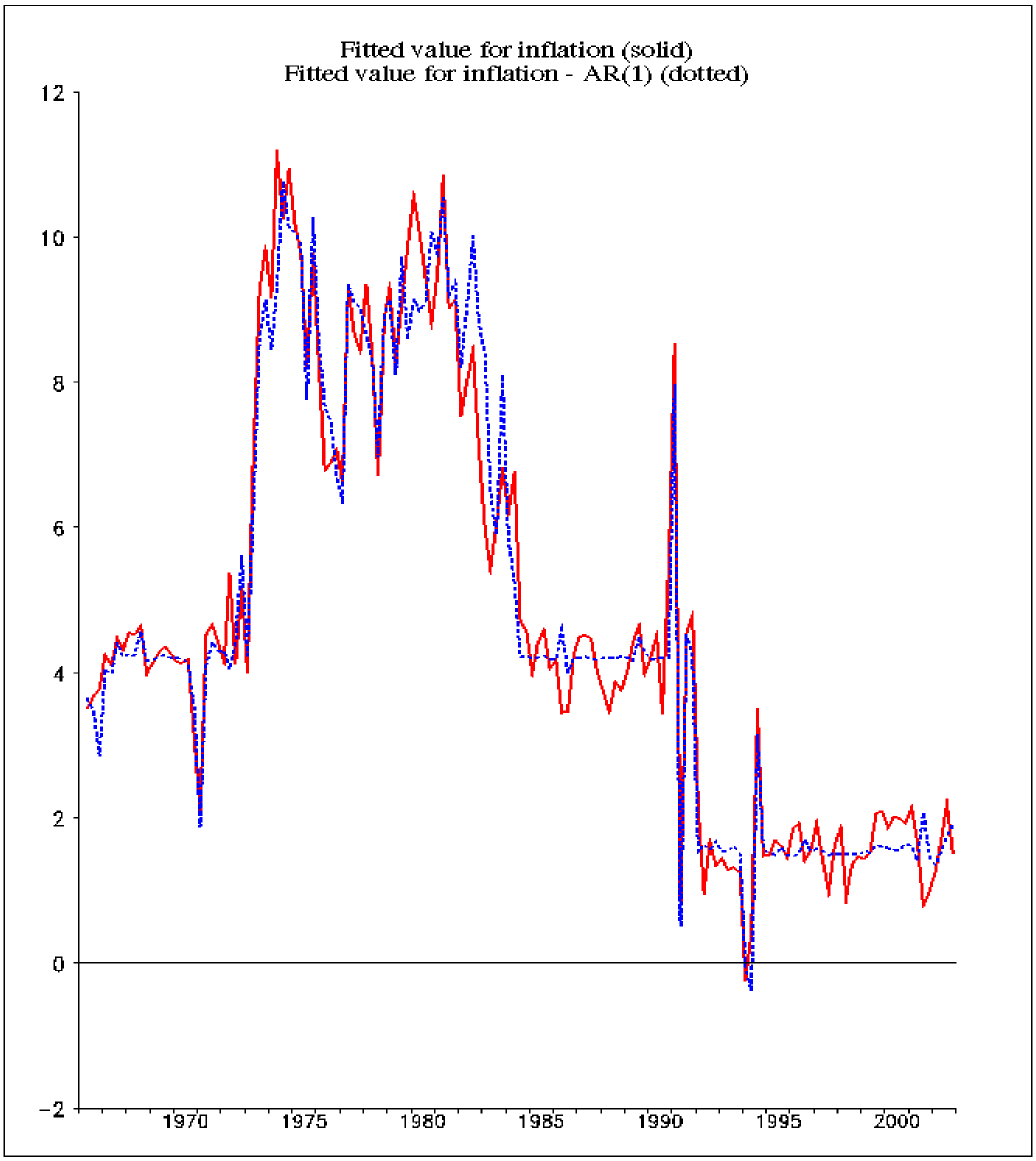


Figure 7: Fitted Value for Total Inflation (Markov regime-switching Phillips curve versus AR(1))



Appendix A

Estimation Results for the Inflation Equation (total)

Parameters	Coefficients	Standard errors	T-stats
P_{11}	0.978	0.018	55.18
P_{12}	0.966	0.022	44.75
P_{13}	0.990	0.011	87.43
C_{11}	6.15	1.18	5.22
C_{12}	4.08	0.49	8.35
C_{13}	1.81	0.29	6.25
ϕ_1	0.28	0.13	2.21
ϕ_2	0.07	0.11	0.59
ϕ_3	-0.18	0.14	-1.32
σ_1^2	3.16	0.71	4.45
σ_2^2	1.64	0.30	5.43
σ_3^2	1.14	0.24	4.82
β_1	0.30	0.14	2.14
β_2	-0.14	0.12	-1.13
β_3	0.03	0.12	0.27
δ_1	-0.05	0.03	-1.44
δ_2	-0.02	0.03	-0.82
δ_3	-0.00	0.03	-0.00
θ_1	0.02	0.01	1.72
θ_2	0.01	0.01	1.95
θ_3	0.01	0.00	2.11
D_{11}	3.57	0.64	2.23
D_{12}	-1.42	0.75	-5.40
Pseudo-adjusted R^2		0.74	

Appendix B

Estimation Results for the RPD Equation Using a Lower Level of Disaggregation (37)

Version with expected inflation		Pseudo-adjusted $R^2 = 0.37$	
Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	3.51	0.56	6.26
α_1	0.20	0.08	2.64
α_2	0.08	0.07	1.20
γ	0.22	0.07	3.22
η	0.01	0.05	0.25
φ	0.02	0.01	3.10
τ	10.93	1.75	6.27
D_{21}	1.43	2.02	0.71
D_{22}	5.37	1.02	5.28
C_σ	2.49	0.45	5.52
ρ_1	0.14	0.13	1.05
ρ_2	0.18	0.02	1.44
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		6.88	3.84
Ljung-Box test[a]		Probability	
$Q(1)$		0.32	
$Q(2)$		0.60	
$Q(3)$		0.58	
$Q(4)$		0.69	
$Q^2(1)$		0.93	
$Q^2(2)$		0.53	
$Q^2(3)$		0.74	
$Q^2(4)$		0.87	
Version with inflation uncertainty		Pseudo-adjusted $R^2 = 0.35$	
Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	2.76	0.75	3.66
α_1	0.19	0.08	2.41
α_2	0.08	0.07	1.16
γ	0.22	0.07	3.26
η	0.01	0.05	0.21
λ	0.71	0.37	1.89
τ	10.92	1.77	6.16
D_{21}	1.72	2.01	0.85
D_{22}	5.36	1.00	5.36
C_σ	2.39	0.45	5.33
ρ_1	0.17	0.13	1.34
ρ_2	0.19	0.13	1.44
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		6.25	3.84
Ljung-Box test[a]		Probability	
$Q(1)$		0.68	
$Q(2)$		0.81	
$Q(3)$		0.45	
$Q(4)$		0.61	
$Q^2(1)$		0.92	
$Q^2(2)$		0.36	
$Q^2(3)$		0.53	
$Q^2(4)$		0.66	

[a] We use standardized errors.

Appendix C

Estimation Results for the Inflation Equation (core)

Parameters	Coefficients	Standard errors	T-stats
P_{11}	0.972	0.024	41.24
P_{12}	0.977	0.018	54.26
P_{13}	0.989	0.014	71.99
C_{11}	4.39	1.04	4.22
C_{12}	2.40	0.51	4.73
C_{13}	1.48	0.22	6.84
ϕ_1	0.45	0.12	3.70
ϕ_2	0.33	0.13	2.49
ϕ_3	-0.04	0.13	-0.35
σ_1^2	4.22	0.89	4.74
σ_2^2	2.43	0.45	5.26
σ_3^2	0.36	0.09	4.15
β_1	0.44	0.15	3.00
β_2	0.24	0.13	1.84
β_3	-0.08	0.10	-0.74
δ_1	-0.04	0.04	-1.05
δ_2	-0.02	0.03	-0.72
δ_3	-0.00	0.01	-0.35
D_{11}	5.24	1.26	4.17
Pseudo-adjusted R^2		0.69	

Appendix D

Estimation Results for the RPD Equation Using Core Inflation

Version with expected inflation		Pseudo-adjusted $R^2 = 0.52$	
Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	1.63	0.57	2.83
α_1	0.31	0.07	4.65
α_2	0.08	0.06	6.41
γ	0.04	0.04	0.95
η	0.03	0.06	0.45
φ	0.02	0.01	2.39
D_{21}	3.62	1.55	2.33
C_σ	3.54	0.60	5.88
ρ_1	0.17	0.13	1.25
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		0.06	3.84
Ljung-Box test		Probability	
$Q(1)$		0.40	
$Q(2)$		0.49	
$Q(3)$		0.60	
$Q(4)$		0.69	
$Q^2(1)$		0.92	
$Q^2(2)$		0.71	
$Q^2(3)$		0.87	
$Q^2(4)$		0.05	

Version with inflation uncertainty		Pseudo-adjusted $R^2 = 0.51$	
Parameters	Coefficients	Standard errors	T-stats
C_{rpd}	1.25	0.58	2.13
α_1	0.30	0.07	4.32
α_2	0.40	0.07	5.97
γ	0.03	0.04	0.66
η	0.01	0.07	0.08
λ	0.41	0.21	1.93
D_{21}	4.27	1.45	2.96
C_σ	3.45	0.63	5.45
ρ_1	0.21	0.15	1.41
Wald test		Statistics	C.V.(0.05)
$\gamma = \eta$		0.12	3.84
Ljung-Box test		Probability	
$Q(1)$		0.27	
$Q(2)$		0.40	
$Q(3)$		0.48	
$Q(4)$		0.56	
$Q^2(1)$		0.94	
$Q^2(2)$		0.89	
$Q^2(3)$		0.96	
$Q^2(4)$		0.05	

Bank of Canada Working Papers
Documents de travail de la Banque du Canada

Working papers are generally published in the language of the author, with an abstract in both official languages. ***Les documents de travail sont publiés généralement dans la langue utilisée par les auteurs; ils sont cependant précédés d'un résumé bilingue*****.**

2005

2005-27	Inflation Dynamics and the New Keynesian Phillips Curve: An Identification-Robust Econometric Analysis	J.-M. Dufour, L. Khalaf, and M. Kichian
2005-26	Uninsured Idiosyncratic Production Risk with Borrowing Constraints	F. Covas
2005-25	The Impact of Unanticipated Defaults in Canada's Large Value Transfer System	D. McVanel
2005-24	A Search Model of Venture Capital, Entrepreneurship, and Unemployment	R. Boadway, O. Secrieru, and M. Vigneault
2005-23	Pocket Banks and Out-of-Pocket Losses: Links between Corruption and Contagion	R.H. Solomon
2005-22	The Effects of the Exchange Rate on Investment: Evidence from Canadian Manufacturing Industries	T. Harchaoui, F. Tarkhani, and T. Yuen
2005-21	The Effectiveness of Official Foreign Exchange Intervention in a Small Open Economy: The Case of the Canadian Dollar	R. Fatum and M.R. King
2005-20	La fonction de production et les données canadiennes	P. Perrier
2005-19	Bank Failures and Bank Fundamentals: A Comparative Analysis of Latin America and East Asia during the Nineties using Bank-Level Data	M. Arena
2005-18	Lines of Credit and Consumption Smoothing: The Choice between Credit Cards and Home Equity Lines of Credit	S. Dey
2005-17	Risk Perceptions and Attitudes	M. Misina
2005-16	Endogenous Central Bank Credibility in a Small Forward-Looking Model of the U.S. Economy	R. Lalonde
2005-15	Learning-by-Doing or Habit Formation?	H. Bouakez and T. Kano
2005-14	Labour Market Adjustments to Exchange Rate Fluctuations: Evidence from Canadian Manufacturing Industries	D. Leung and T. Yuen
2005-13	Efficiency and Economies of Scale of Large Canadian Banks	J. Allen and Y. Liu
2005-12	Do Exchange Rates Affect the Capital-Labour Ratio? Panel Evidence from Canadian Manufacturing Industries	D. Leung and T. Yuen

Copies and a complete list of working papers are available from:
Pour obtenir des exemplaires et une liste complète des documents de travail, prière de s'adresser à :

Publications Distribution, Bank of Canada
234 Wellington Street, Ottawa, Ontario K1A 0G9
E-mail: publications@bankofcanada.ca
Web site: http://www.bankofcanada.ca

Diffusion des publications, Banque du Canada
234, rue Wellington, Ottawa (Ontario) K1A 0G9
Adresse électronique : publications@banqueducanada.ca
Site Web : http://www.banqueducanada.ca