# Declining Inflation Persistence in Canada: Causes and Consequences

*Rhys Mendes and Stephen Murchison, Canadian Economic Analysis Department*

- *The persistence of both core and headline CPI inflation in Canada has declined significantly relative to the 1980s.*
- *The adoption of explicit inflation targets in 1991 likely played a key role in this decline. The impact of more activist monetary policy and lower variance of long-run inflation expectations on wage- and price-setting behaviour appears to have been particularly important. This suggests that the degree of structural inflation persistence is low in Canada.*
- *The degree of structural inflation persistence has important implications for the speed with which inflation should be returned to target, the degree to which policy should be forward looking, and the relative merits of inflation- and price-level targeting. Other things being equal, price-level targeting is more effective as a stabilization tool when structural inflation persistence is low.*

Longworth (2002) documents changes to the dynamic properties of several key macroeconomic variables in Canada that occurred around the beginning of the 1990s. Noteworthy among these changes is a reduction in the level, variance, and persistence of various measures of price inflation, including the consumer price index (CPI). While each change is significant in its own right, the focus of this article is on the reduction in inflation persistence, defined here as the correlation between current and lagged inflation. In addition to updating certain estimates of inflation persistence, the article examines possible reasons for the decline that have been suggested in the economics literature. In particular, a distinction is drawn between the role played by monetary policy, through its effect on price- and wage-setting behaviour, and possible changes to the structure of the economy that are independent of monetary policy, including the distribution of shocks. Finally, a normative analysis of the desirability of low inflation persistence is provided from the viewpoints of an inflation-targeting (IT) and a price-level-targeting (PLT) central bank.

At first glance, it may seem surprising that the Bank of Canada should be concerned about inflation persistence or its causes. After all, the Bank's mandate is to maintain the level of inflation close to the midpoint of the target range. The extent and causes of inflation persistence can be very important, however, in determining the optimal way to achieve the Bank's current mandate of inflation control.

By definition, a variable that is persistent responds more sluggishly in the short run, other things being equal. This is analogous to the difference in manoeuvrability between a speedboat and an ocean liner. Since an ocean liner has a great deal of momentum because of its enormous mass, there is a considerable lag before changes to its intended path are fully reflected in its actual path. For a central bank that

regards inflation as highly inertial for reasons unrelated to the conduct of monetary policy, that policy must be set based on a projection of where inflation will be in the future, rather than on its current level. This is precisely because policy actions will have their maximum impact on inflation several periods after the action is initiated.

Inflation persistence, as well as its underlying causes, is relevant not only to the Bank's achievement of its current inflation target; it is also very significant for determining what the ideal target should be. Since the Bank is currently exploring the potential benefits of replacing its current inflation target with a target for the price level, the issue is of particular interest.

Finally, inflation persistence is relevant not only for central banks. If prices and wages (or any other contract specified in nominal terms) are adjusted only periodically, then knowing the degree of inflation persistence is relevant when deciding the best price or wage to set, when given the opportunity to do so. For instance, if inflation has recently been high and is known to be persistent, households will negotiate a higher nominal wage, since high inflation is likely to persist into the future, eroding the real purchasing power of their wage through time. This can create a vicious circle, whereby persistence tends to beget even greater persistence because of the important role played by expectations. In this example, higher wages raise firms' costs, which will be partly reflected in higher prices. Therefore, price inflation in the future will be higher for longer.

This article begins with a comparison of persistence estimates for total and core CPI inflation for the periods 1980–90 and 1991–2009. Possible explanations for the observed decline are then reviewed, including changes to the structure of the economy, changes in the distribution of shocks, and the establishment of a credible inflation target by the Bank of Canada in 1991. The implications of low inflation persistence for the conduct of monetary policy are then considered for both inflation-targeting and price-level-targeting regimes.

## Revisiting Estimates of Inflation Persistence

Longworth (2002) focuses on changes to the persistence of inflation between the 1980s and 1990s. This is a natural division, given that the Bank of Canada adopted an explicit target for inflation at the beginning of the 1990s.[1] In addition to theoretical arguments linking the conduct of policy to the behaviour of inflation, formal statistical tests tend to support the early 1990s as the period in which the changes began to occur.[2]

**Table 1** summarizes changes in the estimated degree of persistence for total and core CPI inflation, and both series are plotted in **Chart 1**. Persistence is estimated for both the year-over-year change and the quarterly change in each price index.[3] For quarterly (year-over-year) inflation, persistence is defined by the correlation between current inflation and inflation lagged one (four) quarter(s). The key message is that the degree of persistence displayed by both core and headline CPI inflation has declined significantly, relative to the 1980s. These results are qualitatively similar to recent estimates in Benati (2008) and Levin, Natalucci, and Piger (2004).[4] Benati (2008), in particular, emphasizes that quarterly inflation in Canada now appears to display no persistence whatsoever. This means that, on average, the current-period rate of inflation is uninformative for predicting the rate of inflation in the next period.

## Why Has Persistence Declined?

### Sources of inflation persistence

A natural starting point for discussing inflation dynamics is the price Phillips curve, which generally models inflation as a function of lagged inflation, one or more relative prices, and a measure of capacity pressures, such as the unemployment or output gap. In recent years, one particular variant of this model, referred to as the New Keynesian Phillips curve (NKPC) has taken on particular prominence at central banks and among academics, primarily because it can be rationalized

1 In February 1991, the Bank of Canada (in a joint statement with the Minister of Finance) announced the introduction of an inflation-reduction target. The period between 1982 and 1990 has been labelled *the search for a new nominal anchor*, since the Bank determined in 1982 that it would no longer target M1 (Thiessen 2000).

2 Qualitatively similar declines in persistence have been observed for other countries that adopted inflation targeting. Benati (2008) presents recent evidence for the United Kingdom, Sweden, Switzerland, New Zealand, and the euro area under the European Monetary Union.

3 We use quarterly data to facilitate comparison with the artificial data generated by ToTEM (discussed in the next section). Statistics reported in Longworth (2002) are based on monthly data.

4 Benati (2008) reports an estimate of -0.3 for the sum of the autoregressive parameters of an AR(p) model, whereas Levin, Natalucci, and Piger (2004) report -0.2 for the largest autoregressive root, both for the IT sample. Negative estimates may be due to an apparent negative fourth-order partial correlation in the seasonally adjusted CPI data.

**Table 1: Correlation between current and past inflation**

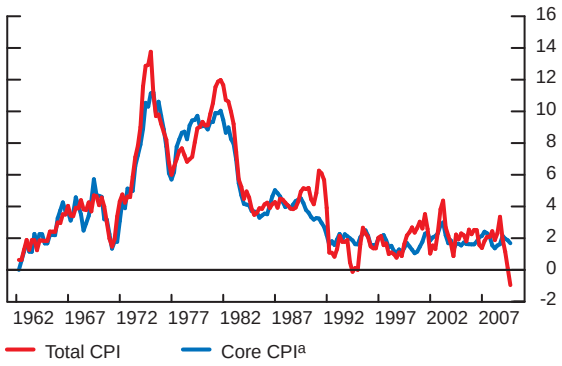
| Inflation measure | 1981Q1 to 1990Q4 | 1991Q1 to 2009Q3 |
|---|---|---|
| Total CPI | | |
| Quarterly change[a] Corr. $(\pi_t, \pi_{t-1})$ | 0.80[b] | 0.14 |
| Year-over-year change Corr. $(\pi_t, \pi_{t-4})$ | 0.79[b] | -0.13 |
| Core CPI | | |
| Quarterly change[a] Corr. $(\pi_t, \pi_{t-1})$ | 0.82[b] | 0.05 |
| Year-over-year change Corr. $(\pi_t, \pi_{t-4})$ | 0.77[b] | -0.04 |

a. Quarterly inflation is defined as $\pi_t = \ln(P_t/P_{t-1})$, whereas year-over-year is defined as $\pi_t = \ln(P_t/P_{t-4})$.

b. Indicates that the point estimate is significantly different from zero at the 1-per-cent level.

**Chart 1: Consumer price index**

Year-over-year percentage change, quarterly data




a. CPI excluding eight of the most volatile components and the effect of changes in indirect taxes on the remaining components

Source: Bank of Canada

on the basis of microeconomic theory.[5] A generic form of the NKPC is given as:

$$\pi_t = (1-\alpha_1)\pi_t^* + \alpha_1\pi_{t-1} + \alpha_2 E_t \sum_{i=0}^{\infty} \alpha_3^i \, mc_{t+i} + \varepsilon_t, \quad (1)$$

where $\pi_t$ is the quarterly rate of inflation, $\pi_{t-1}$ is the rate of inflation from the previous quarter, $\pi_t^*$ is the inflation rate expected to prevail in the distant future,[6] $mc_{t+i}$ is the real marginal cost[7] of production $i$ periods in the future relative to the average level or steady state, and $\varepsilon_t$ is a random shock term. The latter term is often interpreted as capturing movements in firms' desired markup of price over nominal marginal cost, and we also adopt this interpretation. $\alpha_1$, $\alpha_2$, and $\alpha_3$ are non-negative parameters, which are normally treated as fixed through time.

The key assumption underlying this NKPC is that individual firms do not change prices every period, but that, when given the opportunity to do so, a positive proportion of firms rationally choose a price that maximizes their expected profits.[8] Since it is known that the chosen price will remain in effect for several periods, account is taken of both current and expected *future* marginal cost, meaning that inflation is a forward-looking variable. The remaining firms are assumed to follow a simple rule of thumb (ROT), such as choosing the average price in the previous period, adjusted by the previous period's inflation rate.

From equation (1), there are four potential sources of persistence: the long-run-expectations channel (LRE), captured by $\pi_t^*$; expectations of current and future marginal cost (short-run-expectations channel (SRE)); the lagged inflation term; and the desired markup. In general, the persistence, variance, and co-movement among these variables, along with the numerical values for $\alpha_1$, $\alpha_2$, and $\alpha_3$, will determine the persistence of inflation.

The LRE channel can be interpreted as agents' perception at time $t$ of the rate of inflation to which the economy would eventually converge in the absence of future shocks. If constant through time, the LRE will not be a source of persistence. Given the historical variation in the rate of inflation in Canada (Chart 1) since the beginning of the 1980s, however, it seems reasonable to assume that $\pi_t^*$ has varied somewhat

5 The extent to which the fixed-parameter version of the NKPC can be considered micro-founded is somewhat controversial, since, among other things, the most widely used version is based on the assumption that firms do not make a rational choice to adjust their price. Rather, firms are chosen according to a lottery system that ignores how long their nominal price has been in effect.

6 Strictly speaking, the NKPC derived under the assumption of positive steady-state inflation contains several additional terms (Ascari 2004). These are not very important for explaining inflation in the NKPC, however, and are omitted for simplicity.

7 Real marginal cost refers to the cost incurred by the firm of producing an additional unit of output, divided by the price that it receives for that output. Under certain circumstances, marginal cost is proportional to average cost.

8 The NKPC employed here follows Galí and Gertler (1999), which is an extension of the model proposed by Calvo (1983). The Calvo (1983) specification obtains when $\alpha_1 = 0$. A similar means for obtaining lagged inflation in the NKPC has been proposed by Christiano, Eichenbaum, and Evans (2005) and generalized by Smets and Wouters (2007). In these versions, all firms set prices rationally when selected to reset. Firms not chosen in a given period can, nevertheless, index their price according to the lagged rate of price inflation. These models are founded more on the premise that the cost of simply changing one's price (i.e., pure menu costs) is small, but the cost of choosing a new price optimally is not, which explains why firms change price every period but re-optimize only periodically. This model of firm behaviour has been criticized because it makes the counterfactual prediction that all prices change every period (Chari, Kehoe, and McGrattan 2009).

through time. Moreover, since firms are not likely to revise their estimate of the long-run inflation rate significantly from one period to the next, this variable will display low variance and high persistence, and this persistence will be transmitted to actual inflation through the Phillips curve.

All shocks except changes to the desired markup are transmitted to inflation via their influence on marginal cost (relative to steady state). The overall persistence of marginal cost will depend on the composition of shocks in the economy, the degree to which the economy can adjust to the shock (including the degree of price and wage flexibility), and as will be discussed in the next section, the conduct of monetary policy.

When ROT price setters are present in the economy, parameter $\alpha_1$ will be positive, and current inflation will be influenced by lagged inflation. The value of this parameter is increasing, both in the share of ROT price setters and in the weight on lagged inflation used in the rule of thumb.[9]

For the remainder of the article, we use the term *structural* or *intrinsic* to refer to persistence that comes about via the inclusion of lagged inflation in equation (1) when $\alpha_1$ is positive, as well as to any persistence inherent in the desired markup, $\varepsilon_t$. It is worth noting that our definition of structural does not correspond to the more common policy-invariance property first introduced by Lucas (1976), since we will discuss various ways in which the conduct of policy can influence $\alpha_1$.

## Potential causes of reduced persistence

### *Changes to the conduct of monetary policy*

The previous section identifies four possible sources of inflation persistence. Given that the decline in persistence in Canada appears to have roughly coincided with the Bank of Canada's adoption of an inflation target in 1991, a natural starting point is discussion of the possible channels through which a change in monetary-policy regime might influence these variables.

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The first channel is through private agents' long-run expectations for inflation, which should converge to the inflation target once the credibility of the regime has been clearly established. As the variance of $\pi_t^*$ declines, so will the persistence of inflation, since it will account for a smaller proportion of the overall variance in the level of inflation. Monetary policy can potentially influence $\pi_t^*$ in two ways. First, if long-run expectations are partially influenced by the shocks that govern short-run expectations, then policies that stabilize the latter will help to stabilize the former.[10] Second, to the extent that a central bank can demonstrate a commitment to a policy rule that is sufficiently aggressive to eventually return inflation to the target, long-run expectations should be stable, even if short-run expectations respond to shocks.[11] Persistent deviations from the rule, on the other hand, can send a signal to private agents that the central bank's long-run inflation objective has changed.

There are three main ways of inferring long-run inflation expectations, which are not directly observable. The first involves surveys of long-horizon inflation forecasts. Both the 2-year-ahead survey prepared by the Conference Board of Canada and the 6-to-10-year-ahead survey prepared by Consensus Economics suggest that long-run inflation expectations in Canada have become less volatile since the adoption of IT, and are now essentially decoupled from current economic developments. This conclusion is supported by more formal econometric evidence presented in Levin, Natalucci, and Piger (2004). The authors analyze the relationship between long-horizon inflation expectations (proxied by private sector forecasts) and current inflation for a panel of IT and non-IT countries, including Canada, and

9 In Galí and Gertler (1999), the weight on lagged inflation is set to one; i.e., there is full indexation. Amano, Mendes, and Murchison (2009) develop a model where the rule of thumb is $p_t = p_{t-1}^*(1+\pi_{t-1})^{\gamma}\mu_t$, where $p_{t-1}^*$ is the average price chosen in the preceding period, $\gamma$ is the indexation parameter, which can take on any value between 0 and 1, and $\mu_t$ is the desired (gross) markup.

10 In the limiting case, where either $\pi_t^* = \pi_t$ or $\pi_t^* = \pi_{t-1}$, the weight on lagged inflation increases to one, and inflation becomes very persistent.

11 A related strand of the literature assesses the role played by sticky long-run inflation expectations in disinflations. Erceg and Levin (2003) show that the inclusion of a perceived objective for long-run inflation, which can differ from the actual central bank objective because of imperfect credibility, can explain both the persistence of inflation and the large output costs, following a deliberate disinflation by the monetary authority. An illustration of this approach for Canada can be found in Murchison and Rennison (2006, 76).

conclude that there is no link for the IT countries from 1994 to 2003, whereas there is a positive relationship for the non-IT countries.

The second approach involves inferring long-run inflation expectations from differences between long-term nominal and real interest rates, which we will refer to as the inflation premium. Gürkaynak et al. (2006) examine the reaction of both long-term nominal interest rates and the inflation premium to unanticipated macroeconomic news in Canada and conclude that neither systematically responded from 1998 to 2005.[12] Finally, Amano and Murchison (2006) estimate the perceived level of long-run inflation for Canada using an unobserved-components model developed by Kozicki and Tinsley (1998, 2002). Their estimate suggests that the variance of long-run expectations declined by about half in the 1990s, relative to the 1980s.

*Monetary policy can influence inflation persistence via its effect on both the variance and the persistence of real marginal cost.*

Monetary policy can also influence inflation persistence via its effect on both the variance and the persistence of real marginal cost (SRE channel). From equation (1) it can be seen that current inflation depends on current and expected future real marginal cost. Therefore, if the persistence of marginal cost declines, other things being equal, so will the persistence of inflation. Taylor (2000) argues that moving from a high- to a low-inflation environment has reduced the expected persistence of changes in marginal cost and, consequently, the degree of pass-through to prices. Murchison (2009) extends Taylor's argument, suggesting that this change in persistence may be due to a change in the parameters of the central bank's policy rule.[13] In the case of Canada, if monetary policy began responding more aggressively to economic developments that threaten to push inflation away from the target, the expected persistence of real marginal cost and inflation should decline.

To understand the link between the *variance* of marginal cost and inflation persistence, we must first recall that the NKPC distinguishes between shocks that are transmitted to inflation through marginal cost, including demand and productivity shocks, and shocks to firms' desired markup of price over marginal cost, $\varepsilon_t$. Since there is no particular reason to think that the persistence of marginal cost and the desired markup should be identical, their contribution to inflation persistence will depend on their relative variance. The intuition for this is straightforward; for example, if all of the variance in inflation were driven by marginal cost, only the persistence of marginal cost would matter. In this way, the variances of each variable are like weights that determine their influence on the properties of inflation. Since measures of real marginal cost are usually found to be much more persistent than the desired markup, a decline in the variance of marginal cost relative to $\varepsilon_t$ will reduce inflation persistence.[14]

Provided that the variance of markup shocks is not too high, a more aggressive policy rule will also reduce the variance of output and marginal cost.[15] For instance, since marginal cost is heavily influenced by wages, its response to a shock will depend importantly on the size of the wage reaction. If households expect monetary policy to respond aggressively to keep inflation close to the target, then the desired change in nominal wage and marginal cost will be smaller.

A hypothetical example of the persistence and variance channels for monetary policy is shown in **Chart 2**. The Bank of Canada's main projection model for Canada, ToTEM, is used to simulate the reaction of marginal cost and quarterly (at annual rates) CPI inflation to an unanticipated increase of 1 per cent in foreign aggregate demand, under two different calibrations of a simple monetary-policy rule given by:

$$R_t = \rho R_{t-1} + (1-\rho)\left[R^* + \lambda\left(\varphi_\pi(E_t\pi_{t+k} - \pi^T) + \varphi_y(ygap_t)\right)\right], \quad (2)$$

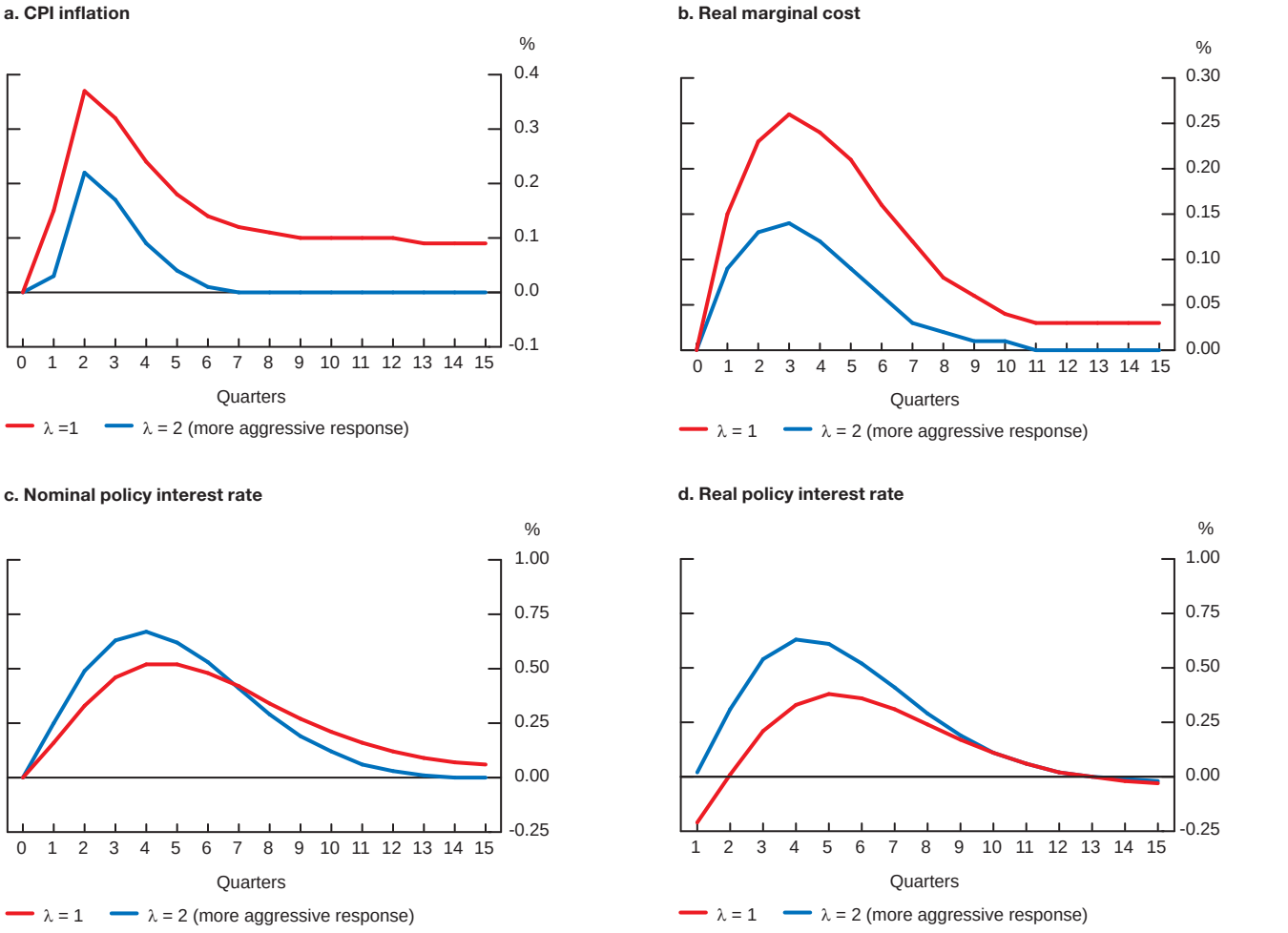
12 Owing to data limitations, the authors do not compare the pre- and post-IT behaviour of inflation expectations in Canada.

13 Carlstrom, Fuerst, and Paustian (2009) study the link between policy aggressiveness, the relative variance of technology shocks, and inflation persistence in an NKPC for the United States.

14 The first-order autocorrelation coefficient for the discounted sum of future marginal costs in ToTEM from 1981Q1 to 2009Q3 is 0.93, whereas the equivalent coefficient for the desired markup is just 0.27.

15 When faced with a markup shock, monetary policy stabilizes inflation through its influence on marginal cost, making monetary policy a source of variance in marginal cost. As a result, if inflation is predominantly driven by markup shocks, or if the central bank is concerned mainly with stabilizing inflation, increasing the aggressiveness of the policy response could increase the variance of marginal cost.

**Chart 2: Results of different policy responses to a foreign-demand shock of 1 per cent in ToTEM**




Source: Bank of Canada

where $R_t$ is the policy interest rate in period $t$, $R^*$ is the long-run steady-state level of interest rates, $E_t\pi_{t+k}$ is the period $t$ expectation of inflation in period $t+k$, $\pi^T$ is the inflation target, and $ygap_t$ is the output gap. $\rho$, $\varphi_\pi$, and $\varphi_y$ are fixed parameters that determine the degree of interest rate smoothing and the sensitivity of the policy rate to deviations of inflation from target and to the output gap, respectively.[16] Note that $k$ determines the degree to which policy is forward looking and is referred to as the "feedback horizon."

In the first scenario, the parameter $\lambda$, whose value influences proportionately the policy response to inflation and to the output gap, is set to one. In the second scenario, $\lambda = 2$, meaning that the central bank adjusts the policy interest rate by twice as much in response to a given level of expected inflation or of the output gap, relative to the first scenario.

An increase in foreign real GDP generates an increase in demand for Canadian exports and a depreciation of the exchange rate, both of which put upward pressure on inflation and the output gap. In the first scenario, the policy interest rate is increased by a maximum of about 50 basis points by the end of the first year. In the second scenario, the rate increases faster and by more, so that the increase is almost 70 basis points after one year. Overall, the nominal interest rate is higher in the second scenario for the first two years. For a given expected rate of inflation, a higher nominal interest rate will translate into a higher *real* rate, which acts to temper the rise in domestic demand and inflation in Canada. Thus, a virtuous circle is created

16 The values $\varphi_\pi = 1.1$, $\varphi_y = 0.6$, and $k = 0$ are taken from Murchison (2009).

in the second scenario, whereby lower expected inflation generates a higher real interest rate, which puts additional downward pressure on inflation.

The difference in the magnitude of the policy response explains the smaller increase in marginal cost (reduced variance) and the faster return to its pre-shock level (slightly reduced persistence). Since the discounted sum of future marginal costs is reduced, the peak response of inflation is nearly cut in half, and inflation is back to its pre-shock level in two years, whereas inflation remains above the target for several years in the first scenario.

To roughly quantify the link between the two expectations channels (LRE and SRE) and the conduct of monetary policy, ToTEM is again used to simulate the level of inflation persistence for different calibrations of the monetary policy rule described by equation (2). The horizontal axis in **Chart 3** gives the coefficient $\lambda$, which ranges from 1.0 to 3.0, in the monetary policy rule. The lowest value corresponds to the value estimated in Murchison (2009) for the 1970–83 period, and is similar to the rule presented in Gagnon and Ihrig (2001).[17]

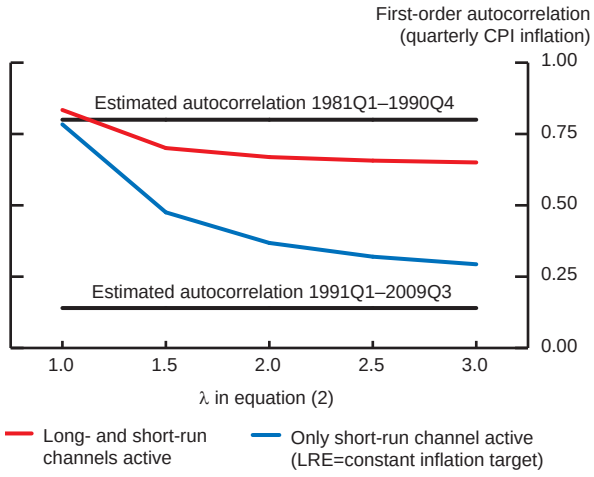
Chart 3 shows a modestly negative relationship between the aggressiveness of monetary policy and inflation persistence when the variance of long-run inflation expectations, $\pi_t^*$, is set equal to its historical value from 1981 to 1990.[18] When the LRE channel is active and monetary policy is largely passive (far left), ToTEM matches the persistence of quarterly inflation over the 1981–90 period (0.8) quite closely. As policy becomes more aggressive, the persistence of marginal cost (via the SRE channel) declines, and the overall persistence of inflation declines by a moderate amount. When long-run expectations are not well anchored, however, the extent to which policy can reduce persistence through the SRE channel is quite limited.

When the variance of $\pi_t^*$ is set to zero, which is a reasonable depiction of long-run inflation expectations since the establishment of a credible inflation target in Canada, the negative relationship between policy aggressiveness and persistence is much more pronounced. Estimated policy rules are subject to considerable parameter uncertainty, but based on Lam and Tkacz (2004), we judge a value of 2 for $\lambda$ to be a reasonable calibration for the 1990s. If we further

17 We are aware of no estimated policy rules for Canada over the 1981–90 period.

18 The calibration of $\pi_t^*$ in ToTEM is discussed in Murchison and Rennison (2006, 48). Movements in long-run expectations are driven by persistent deviations from the policy rule.

**Chart 3: Inflation persistence and monetary policy in ToTEM**




Source: Bank of Canada

assume that this value has not changed significantly since 2000, then ToTEM predicts that the persistence of inflation should have declined from about 0.8 in the 1980s to about 0.35 since 1991.

To summarize, ToTEM ascribes an important role to more activist monetary policy and a somewhat smaller role to reduced variability in long-run inflation expectations. The influence of monetary policy via both the long-run and short-run expectations channels explains the majority of the decline in inflation persistence in ToTEM, suggesting that high inflation persistence is not intrinsic to the Canadian economy. This result is consistent with Benati (2008), who obtains an estimate of $\alpha_1 = 0.19$ for Canada over the IT period. Nevertheless, the full extent of the decline in overall persistence cannot be explained by changes to the behaviour of LRE and SRE alone in ToTEM, since the point estimate for quarterly CPI inflation for the 1991–2009 sample is 0.14, whereas ToTEM predicts a value close to 0.35 when $\lambda = 2$. This suggests that other factors may have contributed to the decline. We next examine possible links between monetary policy and the parameters of the NKPC in equation (1).

The coefficients of the NKPC are typically assumed to be invariant to the conduct of monetary policy. But major regime changes, such as the adoption of an inflation target, may cause these parameters to change, which will influence inflation persistence. The direction of the change is not clear, however, since there are potentially offsetting effects. For instance, Dotsey, King, and Wolman (1999) argue that the move from an environment of high to low trend inflation will

lead firms to change prices less frequently. The intuition for this result is quite simple: in a world with positive trend inflation and sticky prices, firms can no longer achieve their desired relative price each period because inflation causes it to decline through time.[19] The higher the rate of trend inflation, the larger is the average difference between optimal and actual relative prices, meaning larger forgone profits for firms. Therefore, firms will have an incentive to change prices more frequently in a high-inflation environment and less frequently when inflation is low.[20]

When prices become stickier, the parameter $\alpha_2$ in equation (1) declines, and, hence, price inflation responds more slowly to differences between nominal marginal cost and the price level (real marginal cost). As a result, the gap takes longer to close, meaning that real marginal cost becomes more persistent. To summarize, to the extent that low and stable inflation leads to greater nominal rigidity in goods and labour markets, inflation will tend to become more persistent, other things being equal.

A similar argument can be made for the labour market. As wages become stickier, a firm's marginal cost will tend to become more persistent, since wages are an important component of overall costs. However, stickier wages will also tend to reduce the variance of marginal cost. Therefore, the overall impact of inflation persistence will depend on which of these offsetting effects dominates.

In contrast, Minford (2004), Minford, Nowell, and Webb (2003), and more recently, Amano, Ambler, and Ireland (forthcoming) study a labour market in which households that do not re-optimize their wage in a given period can still index their nominal wage to the previous period's rate of inflation. This form of indexation is intended to loosely mimic so-called cost-of-living-adjustment (COLA) clauses, and acts as imperfect insurance against unanticipated shocks that affect households' real wage. The authors find that in an environment of lower inflation variance and persistence, households find it optimal to reduce the extent of indexation. Equivalently, this means that a lower proportion of households find it optimal to have wage indexation built into their labour contract. While the focus of these papers is on the benefits of PLT compared with IT, the basic argument would appear to hold generally for policy regimes that produce greater economic stability.

*In an environment of lower inflation variance and persistence, households find it optimal to reduce the extent of indexation.*

To summarize, research using theoretical models predicts that monetary regimes that reduce the level and variance of inflation will result in an increase to the average duration of nominal price and wage contracts and a decrease in the rate at which households index wages to lagged inflation. Labour market data from Human Resources Development Canada support both of these predictions for Canada. For instance, the average life of private sector wage settlements was 28 months over the 1981–90 period and rose to 39 months for the period 1995 to 2009, while the average share of private sector wage settlements with COLA clauses declined from 31 per cent to 20 per cent for the same sample periods. Other things being equal, longer nominal price contracts will tend to make inflation more persistent, while a reduction in nominal wage indexation will have the opposite effect, and the effect of longer wage contracts is ambiguous.

### *Causes unrelated to monetary policy*

While the move to a transparent, easily understood, and credible target for monetary policy in Canada no doubt played an important role in the decline of inflation persistence, other plausible explanations have been suggested in the literature; most notably, the *structural change* and the *good luck* arguments. While typically employed to explain the so-called Great Moderation, elements of these arguments also apply to the issue of inflation persistence.[21] This stems from the fact that a reduction to the variance of real marginal cost will reduce inflation persistence.

*A reduction to the variance of real marginal cost will reduce inflation persistence.*

19 Assuming that prices are not indexed to steady-state inflation each quarter.

20 Provided that the cost of changing prices does not depend importantly on the trend rate of inflation.

21 The term "Great Moderation" dates back to work by Kim and Nelson (1999), McConnell and Perez-Quiros (2000), and Stock and Watson (2003a), which together document a decline in the variance of inflation and output growth in the United States. Although the timing of the declines differs somewhat, similar reductions in variance have been observed for several other countries, including Canada (Longworth 2002).

McConnell and Perez-Quiros (2000), among others, argue that structural change, primarily in the form of improvements to inventory-management technology, reduced the variance of inventory investment, and hence, of output growth in the United States, beginning around 1984. For Canada, however, the evidence is less clear cut. The decline in the variance of output growth, which does coincide roughly with the decline in inflation persistence (Debs 2001), appears to have been driven by a combination of lower variance in the growth rate of goods consumption and of residential investment, which is more difficult to link directly to structural change. The role played by inventory investment appears to be less important (Debs 2001), and where evidence of a break has been found (Liu and Painchaud 2002), the timing of the change (1983) does not coincide with reduced inflation persistence.

The good luck argument is based on the notion that the variance of adverse shocks has declined, and as a result, the variance of endogenous variables, such as output growth and inflation, has also declined. To apply the good luck argument to the issue of inflation persistence, it must be true that the relative variance of those shocks that cause persistent inflation movements has declined. Carlstrom, Fuerst, and Paustian (2009) use a New Keynesian model, similar to that given by equation (1), to demonstrate that a reduction in the relative variance of technology shocks, which are transmitted to inflation through real marginal cost, could explain reduced inflation persistence. They also present evidence for the United States that indicates a reduction to the relative variance of technology shocks.

More generally, several authors have presented VAR-based evidence of a structural break in shock variances for the United States that coincides with the Great Moderation.[22] The difficulty with the good luck argument is that a structural break in the behaviour of monetary policy may itself explain the decline in these variances. If the model does not correctly control for other changes, such as the behaviour of the central bank's policy rule, they will show up in the model's error terms. This point is developed extensively in Benati and Surico (2009), who show that structural VAR-based methods will tend to indicate a spurious reduction in shock variances, even when the only change to the underlying structural model is an increase in the responsiveness of monetary policy to inflation fluctuations.

22 See Stock and Watson (2003b), Primiceri (2005), Sims and Zha (2006), Gambetti, Pappa, and Canova (2008).

## Implications for the Conduct of Monetary Policy in Canada

Low structural persistence in inflation has potentially important implications for the conduct of monetary policy. For example, Levin and Williams (2003) show that the performance of monetary policy rules can be very sensitive to the level of structural inflation persistence. Similarly, Walsh (2003) demonstrates that targeting the price level yields benefits only if the degree of inflation persistence is sufficiently low. These authors provide examples of a general principle: the degree of persistence in structural inflation should be a key factor in the design of monetary policy.

Of particular interest are the implications of low inflation persistence for inflation-targeting (IT) and price-level-targeting (PLT) regimes. When monetary policy targets inflation, changes in structural persistence can have implications for the optimal speed with which inflation should be returned to target, as well as the degree to which policy should be forward looking. Inflation persistence can also alter the relative merits of IT and PLT. However, it is important to consider that structural inflation persistence, as we define it, can also be policy-regime dependent. In particular, behavioural changes could lead to higher structural persistence in inflation under PLT than under IT.

### Inflation targeting

Canada adopted an IT regime in February 1991. When inflation deviates from 2 per cent, the Bank of Canada aims to return it to target within 18 to 24 months.[23] This is known as the "inflation-target horizon."[24]

Low structural inflation persistence implies a shorter optimal target horizon.[25] Consider the optimal response to a positive markup shock in the NKPC. If the central bank cares about variance in both inflation and the output gap, it will choose to offset only part of the shock's impact on inflation by reducing aggregate demand and marginal cost. As the weight on lagged

23 The policy of bringing inflation back to target within a horizon of 18 to 24 months is generally appropriate, although specific occasions may arise in which a somewhat shorter or longer time horizon might be considered. For example, Basant Roi and Mendes (2007) demonstrate that, in the face of a large and persistent asset-price shock, it may be appropriate to take a somewhat longer view of the inflation-target horizon.

24 For an overview of issues related to the Bank's inflation-target horizon see Coletti, Selody, and Wilkins (2006).

25 Batini and Nelson (2001) introduce and formalize the concept of an optimal target horizon.

inflation declines, the cumulative loss in output required to comply with a given target horizon will diminish. That is, less movement in output is required to stabilize inflation when persistence is lower. Thus, reduced persistence implies that the central bank can return inflation to target more quickly without incurring the cost of additional variance in the output gap. This, in turn, implies that the optimal target horizon shortens as the degree of structural inflation persistence declines.

*Low structural inflation persistence implies a shorter optimal target horizon.*

More formally, Steinsson (2003) shows that, as the proportion of forward-looking firms increases, it becomes optimal to undo a greater fraction of the impact of shocks on the long-run price level. Recall that, under inflation targeting, a central bank stabilizes the rate of change of prices (inflation), but not the level of prices. This implies that shocks that move inflation away from target temporarily will have a permanent effect on the price level (known as price-level drift). Steinsson finds that greater forward-looking behaviour, and thus decreased inflation persistence, is associated with lower optimal price-level drift.

Amano, Mendes, and Murchison (forthcoming) decompose the sources of optimal price-level drift. They note that a reduction in the number of rule-of-thumb (ROT) firms has two effects on the NKPC: (i) it decreases the weight on lagged inflation ($\alpha_1$), and (ii) it increases the weight on future demand conditions ($\alpha_2$ and $\alpha_3$). Both of these changes serve to make inflation more responsive to demand conditions. Thus, when there are fewer ROT firms in the economy, monetary policy can return inflation to target, following a markup shock, with less disruption to the real economy.

Similarly, a reduction in the weight of lagged inflation in the ROT reduces the influence of lagged inflation in the NKPC. Since lagged inflation cannot be influenced by current policy, a reduction in the coefficient on lagged inflation enhances the ability of monetary policy to simultaneously stabilize inflation and aggregate demand.[26]

Inflation persistence also has an important impact on the degree to which monetary policy should be forward looking. Monetary policy in an inflation-targeting regime is often characterized by a simple inflation-forecast-based (IFB) rule of the form given by equation (2). The feedback horizon, $k$, is inversely related to the degree of structural persistence in inflation. If inflation is intrinsically persistent, then monetary policy must be forward looking to avoid taking action too late. All else being equal, the more persistent is inflation, the longer it takes for policy to have its maximum impact on inflation. If policy does not react until the full impact of inflation is observed, then the peak impact of the policy response will occur after the effects of the shock have already begun to dissipate, meaning that policy will be behind the curve. This, in turn, will tend to destabilize output. Thus, the feedback horizon should be longer in environments with higher structural persistence in inflation.

As Batini and Haldane (1999) note, the optimal feedback horizon tends to be closely related to the length of time it takes for a change in monetary policy to have its peak impact on inflation. At this horizon, the cumulative change in demand conditions required to stabilize inflation is minimized. If the feedback horizon is shorter than this, then policy must induce greater movements in aggregate demand to return inflation to target.

## Price-level targeting

Recent research suggests that price-level targeting may have beneficial properties relative to inflation targeting. In particular, PLT can yield a lower variance in both inflation and the output gap. This result is, however, sensitive to assumptions about the degree of inflation persistence.

PLT outperforms IT in a forward-looking environment because it induces stabilizing movements in expected future demand conditions—a term in the NKPC. As Ambler (2009) explains, stabilizing the price level after a positive markup shock requires a period of below-average inflation. The anticipation of this drop reduces the initial impact of the shock on inflation. This improves the short-run trade-off between inflation and output stabilization.

This result does not necessarily hold in a more general environment in which some firms use simple rules of thumb to set prices. For example, Coletti, Lalonde, and Muir (2008) show that as the proportion of ROT firms rises above 50 per cent, IT is preferred to PLT. Nevertheless, calibrating the NKPC to match the

**26** This is also true for a decline in the persistence of markup shocks.

degree of inflation persistence in Canada during the inflation-targeting era implies that only a small proportion of firms follow simple rules of thumb (Benati 2008; Murchison and Rennison 2006). This lends support to the idea that PLT can yield material improvements over IT for economic stability in Canada.

The benefits of PLT also depend crucially on the assumption that economic agents understand the policy regime. In the period immediately following a switch from IT to PLT, economic agents may not fully appreciate the differences between the two regimes. If firms do not understand PLT, they will not take account of its effect on future demand conditions when setting prices. Kryvtsov, Shukayev, and Ueberfeldt (2008) show that, in this situation, PLT can lead to worse outcomes than IT. The reason is simple: failure to correctly understand the policy regime cuts off the expectations channel. Thus, the speed with which economic agents learn to understand the new regime is an important factor in assessing the merits of moving from IT to PLT.

*The benefits of PLT depend crucially on the assumption that economic agents understand the policy regime.*

Gaspar, Smets, and Vestin (2007) study the transition from IT to PLT in an environment in which economic agents learn about the new regime through econometric estimation. The rate at which agents learn depends on the information they can glean from observed data. The authors show that the speed of learning is faster, and the transition costs smaller, if the degree of structural inflation persistence is lower.

Given these results, it is tempting to conclude that ROT behaviour is not a concern for PLT in Canada. A potential risk to this conclusion is that it treats the importance of ROT behaviour as fixed across policy regimes. Amano, Mendes, and Murchison (2009) show that a major regime change may lead firms to revisit their decision to follow a simple ROT. Firms likely choose to do so in order to economize on the costs of gathering information and of rationally forecasting future economic conditions. Their willingness to follow an ROT will depend on how well that rule performs in terms of profitability relative to the profits associated with forward-looking behaviour.

These authors show that PLT may improve the relative performance of simple ROTs by reducing the variance of inflation and output. This could lead to an increase in the number of ROT price-setters that would undermine the performance of PLT. Thus, it may be inappropriate to treat the proportion of ROT firms as constant across policy regimes.

This result reinforces the point that, when evaluating alternative policy regimes, it is crucial to carefully consider the underlying reasons for observed economic behaviour. As this example demonstrates, taking into account the behavioural responses of economic agents can cause a source of structural persistence to become regime dependent. Though it is difficult to predict the precise nature and magnitude of behavioural responses, it is nonetheless valuable to analyze the risks they pose.

## Conclusion

In contrast to the 1970s and 1980s, the past two decades in Canada have been characterized by very low inflation persistence, and the timing of the reduction appears to coincide with the formal adoption of inflation targeting by the Bank of Canada. Theoretical explanations for the observed decline include good monetary policy, structural change, and the good luck argument. Good monetary policy has been linked to a decoupling of long-term inflation expectations from current economic conditions, as well as to lower variance in inflation and output, since monetary policy now actively responds to economic developments in order to maintain price stability. Simulations with ToTEM suggest that changes to the conduct of monetary policy can explain most, but not all, of the observed decline in inflation persistence. These results also suggest that the underlying degree of structural persistence in inflation in the Canadian economy is low. Other things being equal, this means that monetary policy in Canada need not be as forward looking as it would need to be if persistence was high. It also means that the optimal time horizon over which inflation should return to the target, following a disturbance, is shorter than would otherwise be the case.

For a central bank considering the relative merits of price-level versus inflation targeting, recent research suggests that low structural persistence in inflation will tend to favour the former. Moreover, the transition period to a price-level-targeting regime, when the private sector may still be learning about the precise nature of the change, appears to be less costly when structural inflation persistence is low.

As central banks continue their search for better policy frameworks, it is crucial that account be taken of the profound economic changes that a new policy regime can bring about. Just as inflation targeting brought about a significant change in the properties of inflation and output growth in Canada, so too could other monetary policy regimes. To accurately compare and rank various policy alternatives, behavioural responses must be considered. Recent research at the Bank of Canada has begun to focus on possible changes to the nature of price-setting behaviour in a price-level-targeting regime. Future work will focus on extending this approach to other aspects of private sector behaviour.

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