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Special Issue

Recent Research on Inflation Targeting

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Introduction

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Roman Antoninianus

David Bergeron, Curator, Currency Museum

The introduction of a new coin is always a momentous event. While sometimes it marks a transition, such as Canada's move from a 1-dollar paper note to a dollar coin (the "loonie"), at other times it reflects more complex changes in the economy. The coin introduced in ancient Rome in 215 AD during the reign of Caracalla (211–17) is a classic example of the latter. Faced with a dwindling supply of silver to mint coins to pay his troops, Caracalla reduced the silver content of all coins and authorized the minting of a new denomination worth two denarii. The new coin featured the distinctive portrait of the emperor wearing the radiate crown, a convention for double denominations. Not knowing the coin's actual name in antiquity, modern numismatists call it the *antoninianus*, based on a reference in the *Historia Augusta*, a collection of biographies of the Roman emperors.

Despite its inflated cash value, the intrinsic value of the antoninianus, which is about the size of a Canadian 25-cent coin, was equivalent to only 1.5 denarii. The debasement of silver coins, including the antoninianus, immediately sparked inflation as merchants adjusted their prices to reflect the coins' depreciated value. Hoarding of old coins containing higher amounts of silver made the problem worse. Antoninianii continued to be struck for a short period following Caracalla's reign, but were abandoned in 219 AD by the Emperor Elagabulus to slow inflation, which was by then out of control. The coin, now containing even less silver, was reintroduced in 238 AD. As the Roman economy continued its collapse, the antoninianus was issued with progressively less silver, and by the time of the Emperor Aurelian (270–75 AD) it was mostly bronze. Aurelian undertook an important reform of the imperial currency to restore its appearance and reputation. He returned order to operations at the mints, especially the main one in Rome; established fixed rates of exchange (thus stabilizing prices); and, most importantly, restored the precious metal content of coins.

Yet, over time, imperial coinage could not resist the effects of inflation, and the antoninianus was again heavily debased. Under Diocletian's monetary reform between 286 and 296 AD, new denominations were struck, and the antoninianus became an insignificant bronze coin. After Constantius I, antoninianii ceased to be minted altogether. The six coins pictured on the cover clearly demonstrate the deterioration of the antoninianus in less than a century, from a fine silver piece to a dismal bronze coin. From left to right are the antoninianii of Caracalla, Gordian III (238–44 AD), Philip II (244–49 AD), Aurelian (270–75 AD), Diocletian (284–305 AD), and Constantius I (305–306 AD).

The coins form part of the National Currency Collection of the Bank of Canada. Photography by Gord Carter, Ottawa.

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Recent Research on Inflation Targeting

John Murray, Guest Editor

The inflation targeting framework that Canada introduced in 1991 has played a significant role in the exceptional economic performance that the country has experienced in recent years. Understanding the factors that have contributed to the success of the current inflation-targeting framework, and investigating the various ways in which it might be improved in the future, are an important part of the Bank of Canada's medium-term research program. This special issue reports on some of the results of this research program, and examines inflation targeting from several different angles. We plan to provide similar updates on a regular basis in the run-up to the 2011 renewal of the inflation-targeting agreement.

In “The Costs of Inflation in New Keynesian Models,” Steve Ambler describes three new channels in New Keynesian models through which inflation affects economic welfare. These channels were absent from traditional analyses, and may have caused researchers to underestimate the costs associated with variable inflation, even at relatively low levels of inflation. The article concludes with a preliminary assessment of the quantitative importance of the new channels and their significance for monetary policy.

The article by Marc-André Gosselin, “Central Bank Performance under Inflation Targeting,” looks at the various factors that contribute to successful inflation targeting. Using a panel of 21 inflation-targeting countries over the period 1990Q1–2007Q2, he finds that the ability of central banks to hit their targets varies considerably. Some of these differences can be explained by exchange rate fluctuations, fiscal deficits, and differences in financial development. Others are explained by differences in the targeting framework itself and the manner in which it is implemented.

Stephen Murchison and Claude Lavoie look at one of the most important factors that must be considered if countries are thinking about lowering the target level of inflation much below 2 per cent—the zero interest bound. Targeting inflation rates that are too low, the authors note, may restrict the ability of monetary policy to respond to economic shocks by limiting the amount by which interest rates can be eased. The size of the shocks hitting an economy, the formation of inflation expectations, and the conduct of monetary policy are also seen to exert an important influence on the risks of hitting the zero interest bound. The evidence that the authors review suggests that the probability of encountering the zero bound when average inflation is at least 2 per cent is relatively small.

The special issue finishes with a comparison of inflation targeting and price-level targeting, in the context of a small open economy subject to sizable terms-of-trade shocks. The article by Donald Coletti and René Lalonde, “Inflation Targeting, Price-Level Targeting, and Fluctuations in Canada’s Terms of Trade,” summarizes recent research that compares the ability of price-level targeting and inflation targeting to stabilize the macro economy when confronted with shocks similar to those experienced by Canada in recent years. The authors’ preliminary results suggest that price-level targeting may represent a feasible alternative to traditional inflation targeting. Their article also provides insight into the direction of current research in this area at the Bank.

The Costs of Inflation in New Keynesian Models

*Steve Ambler**

- *Academic economists and central banks are increasingly relying on New Keynesian models for forecasting and monetary policy analysis.*
- *Central banks are using these models to refine inflation targets and to develop strategies for reducing inflation variability.*
- *As a result, it is important to understand the new channels in New Keynesian models through which inflation is costly that are absent from traditional analyses.*
- *This article reviews these channels and discusses both their quantitative importance and their significance for monetary policy.*

New Keynesian macroeconomic models have become workhorses for monetary policy analysis by academic economists and central banks.[1] The latest generation of forecasting models being developed by many central banks consists of elaborate New Keynesian models, whose distinguishing feature is the introduction of nominal rigidities via monopolistically competitive firms and / or households that set optimal prices and / or wages at infrequent intervals.[2] The incorporation of nominal rigidities constitutes a link with the old Keynesian models that were prevalent until the 1970s. Because their behavioural equations are based on explicit maximization problems solved by households and firms, they incorporate the main features of the new classical and real business cycle models developed since. New Keynesian models introduce three channels through which inflation is costly and which are absent from the traditional literature on the costs of inflation:

1. Since firms set prices at different times, there is price dispersion across firms. This price dispersion increases at higher rates of trend inflation and entails a loss of efficiency in production.[3]

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1. We briefly outline a standard New Keynesian model on pp. 7–8. Clarida, Galí, and Gertler (1999) contains a good summary of the standard New Keynesian framework.

2. Monopolistic competition refers to a particular way of modelling imperfect competition among sellers in a market. It assumes that sellers face negatively sloped demand curves for their product and take this into account when setting their prices, while taking as given not only the price set by other firms, but also total industry output and the exact price index for industry output. Monopolistic competition is a paradigm that facilitates the modelling of the effects of imperfect competition, since it abstracts completely from strategic interaction among firms. The analytical tractability of the paradigm was demonstrated by Dixit and Stiglitz (1977).

3. The traditional literature on the costs of inflation addresses the issue of price dispersion, but in a context of imperfect information in which consumers expend time and energy to seek out products that are relatively less costly. In New Keynesian models, price dispersion is costly even if there is perfect information about the prices charged by different firms.

2. Since firms set prices under monopolistic competition, their prices are higher than their marginal costs of production. The rate of trend inflation has an effect on the average markup set by firms, and therefore on the size of the distortion that results from monopoly power, which constitutes an additional source of inefficiency.[4]
3. At higher levels of trend inflation, firms' pricing decisions are relatively less sensitive to their marginal costs. Monetary policy acts via its effects on aggregate demand, which in turn is related to firms' real marginal costs. Therefore, monetary policy becomes less effective at higher rates of inflation. This leads to a higher variability of inflation, which is also costly.

With the adoption of explicit inflation targeting by more and more central banks, New Keynesian models are being used to refine inflation targets and to develop strategies for reducing inflation variability. It is therefore crucially important to understand how these new channels operate and their quantitative significance for the costs of inflation. This article reviews the three new channels, explains how they operate, discusses their quantitative importance, and examines their implications for the conduct of monetary policy.

It is crucially important to understand how these new channels operate and their quantitative significance for the costs of inflation.

The article is structured as follows. The next section very briefly reviews the traditional literature on the costs of inflation. The third section briefly presents a simplified version of a standard New Keynesian model. The fourth section explains in detail the workings of the three new channels and discusses their quantitative importance. The fifth section discusses the implications of these new channels for the conduct of monetary policy.

4. The same argument is applicable to nominal wage rigidity. The nominal wage that gives the same average markup over the opportunity cost of leisure will vary directly with trend inflation.

The Traditional Literature on the Costs of Inflation

There is a voluminous literature on the costs of inflation. It would not be fruitful to survey this literature in detail here, but a quick review will highlight the absence from the traditional literature of the channels introduced by New Keynesian models. A comprehensive summary is available in Fischer and Modigliani (1978).[5] They enumerate six types of costs, starting with an economy in which inflation is fully anticipated and where the institutional structure of the economy has fully adapted to inflation. They then gradually relax these assumptions to discuss costs that result from imperfectly anticipated inflation and from the incomplete adaptation of institutional structures to the presence of inflation.

The six costs are:

1. In a fully indexed economy in which all agents have adapted to inflation and all contracts and debt instruments (except for currency) are indexed, inflation is costly because it reduces the use of real balances, which affects "shoe leather costs." In addition, by altering the allocation of real wealth, inflation may affect capital accumulation and growth. Finally, if the unit of account for transactions is nominal, there will be resource costs of changing prices ("menu costs").[6]
2. In an economy in which the tax system is less than fully indexed, inflation creates distortions by affecting relative real after-tax rates of return.
3. In an economy in which private contracts and debt instruments are not fully indexed, inflation again creates distortions by affecting relative real rates of return.
4. In an economy in which inflation is not perfectly anticipated, shocks to inflation will cause ex ante rates of return to diverge from ex post rates of return and will in gen-

5. The more recent survey by Fischer (1994) should suffice to show that little was added to our knowledge of the costs of inflation between the publication of the article by Fischer and Modigliani and the advent of the New Keynesian approach to macroeconomic modelling.

6. Shoe leather costs refers to the costs in time and resources (including wear and tear on shoes) of walking to the bank to make cash withdrawals. Menu costs in its narrow sense refers to the costs of printing new menus with revised prices, and more generally, to the costs of printing new catalogues, posting new prices on store shelves, etc.

eral affect the distribution of income and wealth across individuals.

5. In an economy with uncertain inflation, inflation changes the risk characteristics of assets and affects the allocation of wealth.
6. Finally, attempts by governments to suppress the symptoms of inflation via wage and price controls or controls on nominal interest rates can create additional distortions.

Fischer and Modigliani mention very briefly the costs of inflation through distortions in relative prices when prices are fixed at different times by firms. Their discussion focuses on the effects of *unanticipated* inflation and the role of imperfect information: “such increased variability [in relative prices] leads to misallocation of resources, and to the absorption of resources in search and information gathering activities” (1978, 828). As discussed below, the cost of price dispersion in New Keynesian models arises even with perfect certainty and under perfect information. Fischer and Modigliani do not mention the possibility of a markup distortion. They do discuss the Phillips curve, but not the possibility that its slope may change at different rates of trend inflation.

The New Keynesian Framework

Clarida, Galí, and Gertler (1999) present a compact version of the standard New Keynesian model, which embodies nominal price rigidity only. Wages are flexible, and the labour market clears at all times: Extending the model to include nominal wage rigidity is straightforward, but leads to a more complicated system of equations.

The basic model supposes the existence of a collection of monopolistically competitive firms that produce goods that are imperfect substitutes for the goods produced by their competitors. In most versions of the basic model, the goods are intermediate inputs that are used by a competitive sector that produces a single final good.[7] The firms set their prices optimally for more than one period at a time.[8] In setting their prices, firms take into account their costs of production and the expected future path of prices over the horizon for which they fix their prices.

This basic set-up can be used, given some additional assumptions, to derive the so-called New Keynesian Phillips curve (NKPC), relating current inflation to future expected inflation and to the output gap. In the notation of Clarida, Galí, and Gertler, we have:

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} + u_t . \qquad (1)$$

The notation used is as follows: π_t is the deviation of inflation from its long-run level; x_t is the output gap, the proportional divergence between the current level of output and the level that would prevail if prices were perfectly flexible. E_t is the expectations operator conditional on information available at time *t*. u_t is a disturbance term that is tacked onto the equation (its presence cannot be directly inferred from the optimal price-setting behaviour of firms) and has the interpretation of a cost-push shock (something that generates fluctuations in inflation independently of fluctuations in the output gap). β is a parameter that measures individuals’ subjective discount rates (which also measures the weight they give as shareholders to firms’ future profits versus current profits). λ is a positive parameter that depends on the characteristics of firms’ production functions, the degree of substitutability across different types of goods, the frequency at which firms change their prices, and on β.

The additional assumptions needed to derive an NKPC of this form include the following:

- Firms have a constant probability of being able to revise their prices in any given period. Therefore, when a firm sets its price, it does not know with certainty for how long the price will remain fixed. This assumption, first used by Calvo (1983), facilitates aggregation across firms and leads to the simple functional form of the NKPC.[9]
- Either the long-run trend rate of inflation is equal to zero, or (following Yun 1996), in periods when firms do not reoptimize their prices, they can nevertheless adjust their prices at a rate determined by trend inflation. Once again, this assumption is respon-

7. Another version of the basic model makes the assumption that the goods are imperfect substitutes from the point of view of consumers who have a taste for diversity. The two different versions of the model are algebraically equivalent.

8. In the standard New Keynesian model, the reason why firms set prices for more than one period is not made explicit. This assumption is justified by appealing to menu costs of changing prices or costs of gathering the information necessary to make an informed decision concerning the firm’s output price, but these costs are most often not an explicit part of the model. The state-dependent pricing models discussed below are exceptions to this rule. In these models, the menu costs of changing prices are modelled explicitly.

9. Another widely used pricing scheme is that of Taylor (1980). Under Taylor pricing, firms keep their prices constant for a fixed number of periods. It is usually assumed that different cohorts of firms change their prices in staggered fashion.

sible for the simple functional form of the Phillips curve.

- The NKPC is derived by aggregating the optimal price-setting decisions across firms and then taking a first-order approximation of the resulting equation around the trend rate of inflation, which must be zero unless the Yun (1996) assumption is used.
- The aggregate capital stock is fixed in the short run, but capital can be reallocated instantaneously and costlessly across different firms.

Much of the discussion of the costs of inflation and of the implications of New Keynesian macroeconomics for monetary policy has taken this simple form of the NKPC for granted. This can be quite misleading, as we will argue below.

The New Keynesian model is completed by a dynamic IS curve:[10]

$$x_t = -\varphi(i_t - E_t\pi_{t+1}) + E_t x_{t+1} + g_t, \qquad (2)$$

where i_t is a short-term nominal interest rate (measured as the deviation from its long-run level), and g_t is an aggregate demand disturbance. This equation can be derived from the consumption Euler equation of the representative private agent after imposing the condition that consumption equals output minus government spending.[11]

An interest rate reaction function for the central bank can be added, assuming that the monetary policy instrument is the short-term interest rate, in which case we have a three-equation system for the three endogenous variables i_t, x_t, and π_t. Alternatively, it is possible to derive the optimal monetary policy by defining a loss function that depends on inflation and the output gap and by minimizing the loss function subject to the NKPC.[12]

The Costs of Inflation in New Keynesian Models

Inflation and relative wage and price dispersion

By considering the pricing behaviour of firms in long-run equilibrium, it is possible to show that there is a *negative* trade-off between average (trend) inflation and output in New Keynesian macroeconomic models.[13] (Note that this argument concerns the properties of the long-run equilibrium itself rather than the properties of linearizations around it.) The first author to demonstrate this result was Ascari (2004).[14]

The reasoning that leads to this negative trade-off is as follows. If firms fix their prices for several periods, their relative prices will decline over time if trend inflation is positive. Firms will front-end load their prices so that they are initially higher than the overall price level and are on average lower than the overall price level when firms are allowed to reoptimize their prices. Firms will produce less of their good than is socially optimal when they first set their prices, and as inflation erodes their relative prices, will wind up producing too much of their goods. If a social planner could allocate resources, he or she would equalize the marginal productivity of each type of good produced by the monopolistically competitive firms. Because of price rigidity, this type of equalization does not happen. The marginal social product of firms with relatively high prices is too high. The marginal social product of firms with relatively low prices is too low.

This price dispersion occurs under positive trend inflation even in the absence of aggregate uncertainty:

10. The IS curve is the relationship, in standard Keynesian models, between the interest rate and output that yields equilibrium in the goods market.

11. The Euler equation comes from the household's first-order condition for asset holdings, which yields an equation relating current consumption and expected future consumption. The basic model abstracts from investment and assumes a closed economy.

12. Woodford (2003) shows how to derive such a loss function as an approximation of the utility function of the representative agent. In solving the problem, the central bank is assumed to be able to choose the inflation rate and the output gap subject to the NKPC. The interest rate that will allow these targets to be achieved can then be backed out using equation (2).

13. Equation (1) shows that, for a given value of expected future inflation, there is a positive trade-off in the short run. By dropping time subscripts and solving for the relationship between inflation and output, the long-run trade-off also appears to be positive, and authors such as Devereux and Yetman (2002) and Blanchard and Galí (2005) have made this claim. Since the equation is based on a linear approximation, however, and variables are measured as deviations from their long-run values, the latter are, by construction, equal to zero in the long run. The equation should not be used to infer anything about the long-run trade-off in isolation from the rest of the model.

14. Buiter (2006, 2007) argues that any model in which there is a long-run trade-off between inflation and output, either positive or negative, is not well specified. He argues that the Lucas (1976) critique implies that an inflationary environment would lead firms to index their prices using rules similar to the one proposed by Yun (1996). This flies in the face of casual evidence that firms in inflationary environments do in fact fix their prices for long periods of time without indexing them to trend inflation. It also ignores the resource costs to firms of implementing the price changes implied by their indexation rules. State-dependent pricing models such as that of Dotsey, King, and Wolman (1999), in which the costs of changing prices are modelled explicitly and the average length of price rigidity is endogenous, are immune to the Lucas critique, but do not prejudge the issue of whether price dispersion varies with trend inflation in the steady state.

firms that have set their prices more recently have higher relative prices (and lower output) than firms that have not had a chance to reoptimize their prices for a longer period. Furthermore, the degree of front-end loading of prices is an increasing function of the trend rate of inflation. The steady-state spread between the firm with the highest relative price and the firm with the lowest relative price increases with the rate of trend inflation. Price dispersion is therefore an increasing function of trend inflation, and real gross domestic product (GDP) is a decreasing function of steady-state inflation. These results hold qualitatively, not only for Calvo pricing, but for any pricing scheme that has the property that average contract length is independent of the trend rate of inflation. The size of the effect of trend inflation on output is highly sensitive to the type of pricing scheme that is assumed. We take up this issue in the next subsection.

Price dispersion is an increasing function of trend inflation and causes real GDP to be a decreasing function of steady-state inflation.

The quantitative importance of price dispersion

The quantitative importance of this cost depends critically on assumptions concerning the type of wage- and price-setting. Ascari (2004) calibrates a standard new Keynesian model with realistic numerical values for its structural parameters. He shows that, under Calvo pricing, even moderate inflation has very strong effects on the steady-state level of output because of the assumption that all firms have a probability of being able to revise their price no matter how long it has been in effect. This means that there will be a small number of firms that have not revised their price for a very long time. Their relative prices are so low that they capture a large fraction of the total market. Ascari shows that with moderately high trend inflation (on the order of 15 per cent to 20 per cent inflation at annual rates, depending on the elasticity of substitution across different types of goods), steady-state output falls to zero, and there is no well-defined equilibrium. The relative price of the small number of firms that have not changed their price in a long time is so low that they capture all of aggregate demand, leaving nothing for the other firms in the economy.

Under Taylor pricing, the quantitative effects of price dispersion are smaller by an order of magnitude than under Calvo pricing. Taylor pricing holds that firms keep their prices constant for a fixed, rather than a random, number of periods. With positive trend inflation, the firms with the lowest relative prices have not changed their prices for the number of periods equal to one less than the average length of the price contract (which is the same for all firms). Under Calvo pricing, the firms with the lowest relative prices have kept their prices constant for an indefinitely long period of time, even if the *average* number of periods between price changes is relatively low.

Amano, Ambler, and Rebei (2006) extend Ascari's result to look at the effects of trend inflation outside the steady state. Since stochastic shocks can affect the dispersion of prices outside the deterministic steady state, it is necessary to use higher-order approximations of the model's equilibrium conditions in order to capture these effects: Schmitt-Grohé and Uribe (2005) show that a linearized model such as the basic New Keynesian model will, by construction, be unable to capture the effect of shocks on wage and price dispersion. Amano, Ambler, and Rebei find that Ascari's results (2004) are amplified outside of the deterministic steady state. Under Calvo pricing, stochastic shocks have quantitatively very large effects on price dispersion, and these effects increase with the rate of trend inflation. Under Taylor pricing, the effects are quantitatively very small.

The quantitative difference for price dispersion between Calvo pricing and Taylor pricing has important consequences for the welfare costs of trend inflation. Under both pricing schemes, trend inflation reduces economic welfare because of the loss of output, but the costs of trend inflation are extremely high under Calvo pricing and very mild with Taylor pricing. The quantitative impact of trend inflation under Calvo pricing is so high that Ascari (2004) and Amano, Ambler, and Rebei (2006) question the usefulness of this pricing scheme. New Keynesian models with Taylor pricing and Calvo pricing may bracket the true cost of inflation resulting from price dispersion,[15] indicating a need for empirical work to better assess the true cost of price dispersion. Researchers will first have to identify plausible empirical equivalents for the rather abstract

15. Furthermore, if the average duration of price rigidity actually decreases at higher levels of inflation, the costs of inflation resulting from price dispersion could be even lower. In models where the degree of price rigidity depends on the average rate of inflation, it would also be necessary to take account of the resource costs of changing prices to get a complete measure of the welfare costs of inflation.

intermediate goods that are used in the models.

While the effects of price dispersion under Taylor pricing are quantitatively very small, Amano et al. (2007) show that even with Taylor contracts, nominal wage rigidity can have quantitatively important effects on economic welfare. This result is compatible with Huang and Liu (2002), who show that rigid nominal wages lead to a higher degree of persistence in New Keynesian models than rigid nominal prices, and with Ambler (2006), who shows that it is easier to justify nominal wage rigidities as an equilibrium outcome in the face of small adjustment costs than it is to justify nominal price rigidities.

Finally, state-dependent pricing models such as those analyzed by Dotsey, King, and Wolman (1999) and Golosov and Lucas (2003) have the property that the average length of price rigidity reacts endogenously to changes in trend inflation.[16] The dynamics of price dispersion have not yet been analyzed in this type of model, but this is a potentially fruitful avenue for future research.[17]

Effects of trend inflation on markups

The monopolistically competitive firms in New Keynesian models face downward-sloping demand curves for their products. The most common assumption is that their demand curves have a constant elasticity of demand. If they were able to reset their prices in each period, profit maximization would entail a proportionally constant markup over their marginal costs. Since they fix their prices for several periods, their markup will vary from period to period during the price contract. With positive trend inflation, the markup will be eroded over time.

With flexible prices, monetary policy has no leverage over the markup. If nominal prices are rigid, the average markup will depend on trend inflation. The reasons for this are not obvious. Wolman (2001) distinguishes between two effects of inflation on the average markup. First, higher inflation leads firms that do adjust their prices to set a higher markup in order to protect themselves against the erosion of their relative prices from future inflation. Second, higher inflation accelerates the rate of erosion of the markup of firms whose prices remain fixed. Wolman refers to this latter effect as the erosion effect. He shows that, in a simple model with two-period price rigidity, the erosion effect dominates at very low levels of inflation, so that rising inflation decreases the average markup. At higher levels of inflation, the former effect dominates. Wolman also shows that a low, positive inflation rate minimizes the average markup in the steady state.

The average markup is directly related to trend inflation.

Another way of looking at this problem is as follows. Costs are typically convex in output. At higher rates of trend inflation, an individual firm's relative price varies more over the life of the contract. When it resets its price, the firm front-end loads the price. The firm's relative price is high initially, and therefore its output (which is determined by the demand for its product) is low. Over time, inflation erodes the relative price, which is typically below average just before the price is reset. The firm's output increases over the life of the price contract, and its marginal cost increases more than proportionally. In order to achieve the same average markup above marginal cost over the life of its price contract, the firm must initially set a higher relative price. Aside from a region for very low positive values of trend inflation where the erosion effect dominates, the average markup is directly related to trend inflation.

The quantitative importance of variable markups

The inflation rate at which the average markup is minimized depends on all of the structural parameters of the model, including the elasticity of substitution across different types of goods and the average length of the nominal price rigidity. In general, the markup-minimizing inflation rate is low, and the minimum average markup is not much lower than with a zero rate of trend inflation. With low to moderate rates of trend inflation, the average markup does not vary by much. Economic welfare is therefore not too sensitive to the rate of trend inflation over this range when looking only at the markup channel.

Inflation and the slope of the Phillips curve

As discussed above, the standard NKPC is derived under the restrictive assumption that either trend inflation is zero or firms adjust their prices at a rate equal to trend inflation even during periods when they are not allowed to reoptimize their prices. If the prices of all firms increase at the rate of trend inflation,

16. Bakhshi, Khan, and Rudolf (2004) show how to derive a Phillips curve based on a model of state-dependent pricing.

17. Golosov and Lucas (2003) show that steady-state price dispersion is affected, but not strongly, by trend inflation (see their Figure 3).

the slope of the Phillips curve is independent of trend inflation.

The assumption can be relaxed by assuming that firms are not allowed to adjust their prices during periods when they are not allowed to optimize their prices, and by dropping the assumption that trend inflation is zero. Under Calvo pricing, it is still possible to derive a fairly simple Phillips curve by aggregating across firms and linearizing around a given (non-zero) rate of trend inflation. This extended New Keynesian Phillips curve (ENKPC)[18] has the following form:

$$\tilde{\pi}_t = \beta\Pi E_t\tilde{\pi}_{t+1} + \gamma x_t + u_t + v_t, \quad (3)$$

where

$$\gamma = \left(\frac{1-\alpha\beta\Pi^{(\theta-1)}}{\alpha\Pi^{(\theta-1)}}\right)(1-\alpha\beta\Pi^{\theta}). \quad (4)$$

Here, $\tilde{\pi}_t$ is defined as the deviation of inflation from trend inflation, which is given by γ. The slope of the Phillips curve, which is given by $\Pi - 1$, now depends on the rate of trend inflation. The structural parameters on which γ depends include α, which gives the constant probability that an individual firm will not be allowed to revise its price during a given period, and θ, which gives the elasticity of substitution across the different goods produced by the monopolistically competitive firms.

Several points are worth noting about the ENKPC. First, we can recover the standard NKPC by setting $\Pi = 1$ (i.e., by assuming zero trend inflation). Second, the level of the inflation target alters the relationship between inflation and output, thereby altering the dynamics of inflation. Specifically, the output gap parameter is decreasing in Π, so a decline in the central bank's inflation objective strengthens the link between inflation and the output gap. In other words, with a lower (higher) inflation objective the current output gap has to vary less (more) to achieve a given change in inflation, all else being equal.[19] In this sense, monetary policy is more effective at lower levels of trend inflation. Not only is there an inverse relationship between trend inflation and the output gap parameter, there is also a direct relationship between trend inflation and the impact of expected inflation on current inflation.

The intuition for this last result is straightforward. The ENKPC indicates that when firms set their prices, they pay attention to expected future inflation and to real marginal cost. With low trend inflation, the most important determinant of profits is the expected evolution of real marginal cost, captured by the term for the output gap in equation (3). At higher rates of trend inflation, the evolution of inflation has a relatively more important impact on profits, and expected future inflation gets relatively more weight in firms' optimal pricing rule. Inflation becomes less sensitive to marginal cost. The ENKPC merely says that the relative weight on real marginal costs versus expected future inflation declines as trend inflation increases. Insofar as real marginal cost is directly related to the output gap, the Phillips curve becomes flatter. This means that monetary policy (which acts by affecting aggregate demand) becomes *less* effective at higher rates of inflation.

This result may seem counterintuitive, especially in light of the conjecture by Taylor (1999) that the degree of pass-through from fluctuations in marginal cost to output prices would decline with trend inflation. His result can be understood in the context of fixed menu costs for changing prices. It is as if we were to endogenize the frequency of price changes in the basic New Keynesian model, making it a direct function of the rate of trend inflation.

Monetary policy becomes less *effective at higher rates of inflation.*

The reduced effectiveness of monetary policy is a cost of inflation. Ascari and Ropele (2006) show that, under discretionary monetary policy, it is optimal for the central bank to respond less strongly to variations in inflation resulting from cost-push shocks. This can explain the empirical regularity of a direct relation between the level and the variability of inflation. Amano, Ambler, and Rebei (2005) show that this positive relationship between the average level of inflation and inflation variability holds when the central bank can precommit to the optimal monetary policy. Because of the reduced effectiveness of monetary policy at higher rates of trend inflation, this constitutes an additional cost of trend inflation in terms of economic welfare.

18. Detailed derivations of the ENKPC can be found in Ascari and Ropele (2006) and Bakhshi et al. (2003).

19. It is important to note that these results hold only for moderate rates of trend inflation such as those experienced in many industrialized countries over the past three decades. As shown by Ascari (2004), at higher levels of inflation, their output literally falls to zero with Calvo pricing.

Implications for Monetary Policy

The three channels through which inflation is costly have implications both for monetary policy in the long run (the choice of the steady-state level of inflation), and for the conduct of short-run stabilization policy (the optimal degree of price-level stability).

Optimal trend inflation in New Keynesian models

Price dispersion is minimized in the steady state when trend inflation is equal to zero. The costs resulting from the markup distortion are minimized at a low, positive rate of inflation. When choosing an optimal rate of trend inflation, the costs of these two distortions would have to be balanced at the margin. In a simple model with two-period price rigidity, Wolman (2001) shows that the price-dispersion distortion is quantitatively much more important, so that the optimal rate of trend inflation is very close to zero.

With nominal wage rigidities, a trend rate of *wage inflation* of zero would minimize welfare costs owing to wage dispersion, while a slightly positive rate of wage inflation would minimize the average markup of nominal wages over the opportunity cost of forgone leisure. With both nominal wage and nominal price rigidities, the costs of all four distortions in the steady state (price dispersion, wage dispersion, the average markup of prices over marginal costs, and the average markup of wages over the opportunity cost of leisure) would have to be balanced at the margin. If the trend rate of wage inflation equals the trend rate of price inflation, which must be the case in the absence of technological progress, this would once again give an optimal trend inflation rate very close to zero.

If the trend rate of technological progress is positive, the trend rates of wage and price inflation would have to differ so that real wages could grow along the economy's balanced growth path. The work of Amano et al. (2007) and of Ambler and Entekhabi (2006) suggests that the most costly distortion is the one resulting from wage dispersion. Balancing the costs of the two dispersion distortions and the two markup distortions at the margin would lead to an optimal trend rate of wage inflation very close to zero. Consequently, the optimal rate of price inflation would be *negative*. Amano et al. (2007) show that because of the nonlinearities inherent in the New Keynesian model, the introduction of technical progress increases the benefits of lowering the trend rate of price inflation towards zero.

The flattening of the Phillips curve at higher rates of trend inflation would also favour a trend inflation rate of zero in order to maximize the efficacy of monetary policy. Obviously, when the three channels introduced by New Keynesian models are combined with traditional channels, the optimal trend inflation rate will balance all of the costs and benefits at the margin. For example, the inability to pay interest on outside money balances will push the optimal trend inflation rate towards that implied by the Friedman rule.[20]

Optimal stabilization policy

Stochastic shocks have the effect of causing fluctuations in price and wage dispersion and in average markup. A central question in the context of New Keynesian models concerns the optimal degree of price-level variability. Earlier papers addressed this question using relatively simple versions of the New Keynesian model and concluded that price-level stability is the optimal monetary policy. This is the conclusion of Goodfriend and King (1997).[21] In their model, the trend inflation rate is taken as given and is not necessarily equal to zero. Their model actually implies that strict inflation targeting is optimal, so that past inflation surprises are accommodated by the central bank.

Goodfriend and King's model assumes only nominal price rigidity, and they characterize monetary policy as optimal if it allows the economy to attain the same equilibrium that it would under flexible prices (even though the flexible price equilibrium is suboptimal, owing to imperfectly competitive firms that set prices above their marginal costs of production). In richer settings, price stability may no longer be optimal. Erceg, Henderson, and Levin (2000) set up a model with both nominal wage and price rigidities,[22] in which the markup distortions are corrected through the use of fiscal policy. Only two distortions remain, stemming from the two types of nominal rigidity, but the central bank cannot achieve a Pareto-efficient allocation if it has only one instrument. They show that the utility of the representative private agent can be approximated with a loss function that depends on variability in price and wage inflation and the output

20. The Friedman rule stipulates that, for efficiency reasons, cash balances should carry the same real rate of return as interest-bearing assets. This holds when the inflation rate is sufficiently negative to reduce the nominal interest rate on bonds to zero.

21. Goodfriend (2002) includes a relatively non-technical summary of the main arguments of Goodfriend and King (1997).

22. Both wages and prices are set using Calvo contracts in their model.

gap. They also show that the optimal monetary policy involves some real wage adjustment and that between prices and nominal wages, it is the most flexible variable (the one with the shortest average contract length) that optimally does the most adjusting.

Schmitt-Grohé and Uribe (2005) study optimal fiscal and monetary policy in a more elaborate New Keynesian model that includes both nominal price and nominal wage rigidities (once again wages and prices are set using Calvo contracts) and other sources of distortion such as distortionary taxation. Some of the features of their model would seem to favour variable inflation as the optimal monetary policy: for example, the existence of non-indexed nominal government bonds creates an incentive to use inflation to erode the real value of government debt. Nevertheless, they find that the optimal monetary policy involves a very low volatility of prices.[23] Since wages and prices are set using Calvo contracts, this is likely to accentuate the costs of price dispersion both in the steady state and in response to stochastic shocks: Their results may not be robust to the introduction of alternative pricing schemes. In addition, they include aggregate technology shocks in their model, but technology is stationary, so that there is no wedge in the long run between price inflation and wage inflation. This feature of their model is also likely to favour price stability as the optimal monetary policy.

23. They calculate the optimal monetary and fiscal policies by assuming that the government can precommit to its announced policies and by solving for the government's optimal strategies subject to the first-order conditions of private agents.

Conclusions

New Keynesian models have immensely enriched our qualitative understanding of the costs of inflation. They will be used by central banks for the foreseeable future as forecasting tools and for analyzing the optimal conduct of monetary policy. This article argues that the quantitative importance of the impact of inflation on economic welfare depends on how nominal price and wage rigidities are modelled, which varies widely across different types of New Keynesian models. Clearly, further fine-tuning of inflation targets and of strategies to keep inflation on target in both the short and the medium term will depend on developing a better understanding of the new channels and of how important they are for quantifying the costs of inflation.

Literature Cited

Amano, R., S. Ambler, and N. Rebei. 2005. "Monetary Policy and Trend Inflation: Some Preliminary Results." Bank of Canada. Draft.

———. 2006. "The Macroeconomic Effects of Nonzero Trend Inflation." *Journal of Money, Credit and Banking* 39 (7): 1821–38.

Amano, R., K. Moran, S. Murchison, and A. Rennison. 2007. "Trend Inflation, Wage and Price Rigidities, and Welfare." Bank of Canada Working Paper No. 2007–42.

Ambler, S. 2006. "Nominal Wage Rigidity as a Microfoundation for the New Neoclassical Synthesis." Université du Québec à Montréal. Draft.

Ambler, S. and N. Entekhabi. 2006. "Technical Change, Wage and Price Dispersion, and the Optimal Rate of Inflation." Université du Québec à Montréal. Draft.

Ascari, G. 2004. "Staggered Prices and Trend Inflation: Some Nuisances." *Review of Economic Dynamics* 7 (3): 642–67.

Ascari, G. and T. Ropele. 2006. "Optimal Monetary Policy under Low Trend Inflation." University of Pavia. Draft. Available at <http://economia.unipv.it/pagp/pagine_personali/gascari/optimal_policy_2nd.pdf>.

Bakhshi, H., P. Burriel-Llombart, H. Khan, and B. Rudolf. 2003. "Endogenous Price Stickiness, Trend Inflation, and the New Keynesian Phillips Curve." Bank of England Working Paper No. 191.

Bakhshi, H., H. Khan, and B. Rudolf. 2004. "The Phillips Curve under State-Dependent Pricing." Bank of England Working Paper No. 227.

Literature Cited (cont'd)

Blanchard, O. and J. Galí . 2005. "Real Wage Rigidities and the New Keynesian Model." National Bureau of Economic Research (NBER) Working Paper No. 11806.

Buiter, W. H. 2006. "The Elusive Welfare Economics of Price Stability as a Monetary Policy Objective: Why New Keynesian Central Bankers Should Validate Core Inflation." European Central Bank Working Paper No. 609.

———. 2007. "How Robust Is the New Conventional Wisdom in Monetary Policy?: The Surprising Fragility of the Theoretical Foundations of Inflation Targeting and Central Bank Independence." Presented at the Bank of England's Chief Economists' Workshop, "Policy Challenges to Monetary Theory," 18 April 2007. Available at <http://www.nber.org/~wbuiter/konstanz.pdf>.

Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Clarida, R., J. Galí, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37: 1661–1707.

Devereux, M. B. and J. Yetman. 2002. "Menu Costs and the Long-Run Output-Inflation Trade-Off." *Economics Letters* 76 (1): 95–100.

Dixit, A. K. and J. E. Stiglitz. 1977. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review* 67 (3): 297–308.

Dotsey, M., R. G. King, and A. L. Wolman. 1999. "State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output." *Quarterly Journal of Economics* 114 (2): 655–90.

Erceg, C. J., D. W. Henderson, and A. T. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

Fischer, S. 1994. "Modern Central Banking." In *The Future of Central Banking: The Tercentenary Symposium of the Bank of England*, 262–308, edited by F. Capie, C. Goodhart, S. Fischer, and N. Schnadt. Cambridge: Cambridge University Press.

Fischer, S. and F. Modigliani. 1978. "Towards an Understanding of the Real Effects and Costs of Inflation." *Weltwirtschaftliches Archiv* 114 (4): 810–32.

Golosov, M. and R. E. Lucas, Jr. 2003. "Menu Costs and Phillips Curves." National Bureau of Economic Research (NBER) Working Paper No. 10187.

Goodfriend, M. 2002. "Monetary Policy in the New Neoclassical Synthesis: A Primer." *International Finance* 5 (2): 166–91.

Goodfriend, M. and R. G. King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy." In *NBER Macroeconomics Annual 1997*, 231–83, edited by B. S. Bernanke and J. J. Rotemberg. Cambridge: MIT Press.

Huang, K. X. D. and Z. Liu. 2002. "Staggered Price-Setting, Staggered Wage-Setting, and Business Cycle Persistence." *Journal of Monetary Economics* 49 (2): 405–33.

Lucas, Jr., R. 1976. "Econometric Policy Evaluation: A Critique." *Carnegie-Rochester Conference Series on Public Policy* 1: 19–46.

Schmitt-Grohé, S. and M. Uribe. 2005. "Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model: Expanded Version." National Bureau of Economic Research (NBER) Working Paper No. 11417.

Taylor, J. B. 1980. "Aggregate Dynamics and Staggered Contracts." *Journal of Political Economy* 88 (1): 1–23.

———. 1999. "Staggered Price and Wage Setting in Macroeconomics." In *Handbook of Macroeconomics*, 1010–50, edited by J. B. Taylor and M. Woodford. Amsterdam: North-Holland.

Wolman, A. L. 2001. "A Primer on Optimal Monetary Policy with Staggered Price-Setting." *Federal Reserve Bank of Richmond Economic Quarterly* 87 (4): 27–52.

Woodford, M. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton: Princeton University Press.

Yun, T. 1996. "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles." *Journal of Monetary Economics* 37 (2–3): 345–70.

Central Bank Performance under Inflation Targeting

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- *The inflation-targeting (IT) regime is 18 years old and is now being practised in more than 21 countries, providing enough evidence to assess the IT experience.*
- *This article analyzes the inflation record of IT central banks by looking at a broad range of factors that can influence deviations from the inflation target.*
- *The author finds that part of the cross-country and time variation in deviations of inflation from target can be explained by exchange rate movements, fiscal deficits, and differences in financial sector development. He also finds that a higher inflation target and a wider inflation-control range are associated with more variable outcomes for inflation and output.*
- *Although the literature tends to suggest that greater central bank transparency is desirable, these findings imply that transparency may not improve the accuracy of inflation targeting. Interestingly, central banks using economic models to guide policy do a better job of stabilizing inflation around the target and output around trend.*

Since inflation targeting (IT) was first adopted by the Reserve Bank of New Zealand in 1990, it has become an increasingly popular framework for monetary policy. It was adopted by the Bank of Canada in 1991, followed by the Bank of England in 1992. Since then, five other industrialized countries and 13 emerging-market economies have become inflation targeters, thereby providing sufficient evidence to assess the IT experience.

Inflation outcomes in the short run may be the result of several factors other than monetary policy, especially for small open economies like Canada's. Nevertheless, a successful IT central bank should, on average, be able to keep inflation close to its target. In this article, we analyze the performance of IT central banks in achieving their target and assess the empirical role of macroeconomic shocks, the financial environment, and the characteristics of the monetary policy framework as determinants of this performance.[1]

In theory, we should expect more transparent central banks to have a better inflation record.

There is a general consensus among economists that central bank transparency (i.e., the extent to which information related to the policy-making process is disclosed) is an important aspect of the monetary policy framework. According to the International Monetary Fund's "Code of Good Practices on Transparency in Monetary and Financial Policies" (1999) the effectiveness of policy increases if the goals and instru-

1. This article summarizes and updates Bank of Canada Working Paper No. 2007–18 by Marc-André Gosselin (published under the same title).

ments of policy are known to the public.[2] If greater effectiveness of policy is associated with higher transparency, then, all else being equal, we should expect more transparent central banks to have a better inflation record. To verify this, we test the hypothesis that greater central bank transparency reduces deviations from the inflation target.

Using a panel of 21 IT countries over the period 1990Q1–2007Q2, we find that the ability of central banks to hit their target varies considerably. Part of the cross-country and time variation in performance can be explained by exchange rate fluctuations, fiscal deficits, and differences in financial sector development. We also find that central banks opting for a higher numerical target or a larger control range tend to observe larger inflation deviations, while central banks using economic models to guide policy do a better job of stabilizing inflation around the target and output around trend. Surprisingly, regression results indicate that measures of transparency are either uncorrelated or positively correlated with inflation and output deviations. These findings could have practical applications. For instance, a better understanding of the factors behind deviations from the inflation target could be useful to central banks debating the adoption of some form of IT. It could also help IT countries to improve the design of their monetary policy framework through learning from the experience of successful IT central banks.

The Inflation-Targeting Experience

Although there is extensive literature on the economic effects of having an inflation target, very few studies examine the inflation performance of IT central banks. Roger and Stone (2005) gather a number of stylized facts on the international experience with IT. When comparing actual and targeted inflation, they find that the mean absolute deviation (MAD) has typically been about 1.8 percentage points (pp), and the deviations vary considerably across country groups. There is a greater dispersion of outcomes around inflation targets in emerging-market economies than in developed countries. Disinflating countries, on average, have tended to exceed their target, while countries with a stable target have tended to undershoot their target.

Like Roger and Stone, Albagli and Schmidt-Hebbel (2004) examine various statistics on the extent to which countries miss their inflation targets. They take the analysis one step further, however, by performing a panel regression of inflation deviations. To control for macroeconomic disturbances, Albagli and Schmidt-Hebbel include deviations of the exchange rate from its trend in their specification. They find that the higher the numerical target and the wider the control range, the more likely the inflation rate is to deviate from its target. They also find that deviations from target are negatively correlated with central bank independence and policy credibility (approximated with various measures of country risk).

Central Bank Transparency: Theory, Limits, and Evidence

Economists will generally argue that more information is better. Having a central bank more fully communicate its objectives, its assessment of economic conditions, and the expected effects of its policy actions will enhance social welfare, because agents will be better able to align their decisions with those of the central bank and the economy will adjust more smoothly. As Woodford (2005) argues, monetary policy is more effective when it is expected, since better information on the part of financial markets about central bank actions and intentions implies that the change in the policy rate required to achieve the desired outcome can be much more modest when expected future rates also move.[3] Similarly, Svensson (2005) notes that greater transparency about central banks' operational objectives (in the form of an explicit intertemporal loss function), forecasts, and communications would improve the conduct of monetary policy. In principle, more transparent central banks should thus have a better inflation record, all else being equal, since greater transparency reduces uncertainty about future policy actions. Using a small analytical model, Demertzis and Hughes Hallett (2007) show that the variance of inflation increases with the lack of central bank transparency perceived by the public.

Greater transparency may not always lead to an improvement in welfare, however. Morris and Shin (2002) show that when the level of some variable (e.g., potential output or fundamental asset prices) is highly uncertain and the central bank is unlikely to have better information than the private sector, disclosure of the associated estimate may cause financial market participants to ignore their private information and to coordinate on the noisy disclosed estimate, leading to greater volatility. Similarly, using a model where the actual and perceived degrees of transpar-

2. Jenkins (2004) and Kennedy (2008) also highlight the importance of transparency in monetary policy making.

3. It is private sector expectations of the entire future path of the policy rate that matter for the economy. These expectations feed into longer-term interest rates and asset prices, which affect private sector decisions.

ency are allowed to differ from each other, Geraats (2007) shows that the perception of opacity makes financial markets more cautious in their response to central bank communications, which may reduce the volatility of private sector expectations. Cukierman (2005) enumerates a number of cases in which the optimal level of transparency is likely to be intermediate. For instance, it can be counterproductive for a central bank to publish advance signals about potential problems in parts of the financial system. Such publication might induce a run on the banks or other unpredictable movements that would force the central bank to take more expansionary steps than if the information were temporarily withheld. There might also be a compelling case for keeping the discussions of the monetary policy committee secret when there are disagreements within the committee. Mishkin (2004) argues that announcement of the central bank's objective function will complicate the communication process and weaken support for the central bank's focus on long-run objectives. In addition, some forms of increased transparency may not be feasible. Macklem (2005) points out that the complete state-contingent monetary policy rule is too complex for a central bank to derive or communicate anytime soon.[4]

The empirical literature on central bank transparency often tries to identify the effects of a precise change in disclosure practices by individual central banks on specific economic or financial variables. For instance, Parent, Munroe, and Parker (2003) find that the introduction of a schedule of dates for policy interest rate announcements increased the predictability of the Bank of Canada's interest rate decisions and the financial markets' understanding of Canadian monetary policy.[5] Chortareas, Stasavage, and Sterne (2002) show that the publication of more detailed central bank forecasts reduces average inflation in a cross-section of 82 countries. Although most empirical studies conclude that greater central bank transparency is beneficial, their primary limitation is that the findings for individual

4. The state-contingent monetary policy rule represents the central bank's optimal rule of conduct under all possible future contingencies for the direction the economy will take.

5. Muller and Zelmer (1999) come to similar conclusions with respect to the introduction of the Bank of Canada's *Monetary Policy Report* in 1995.

Measuring Central Bank Transparency

Transparency is a qualitative concept for which few precise measures exist. It is typically measured either for a very limited number of central banks or at a single point in time. Researchers usually look at three factors: whether the central bank provides prompt public explanations of its policy decisions; the frequency and form of forward-looking analysis provided to the public; and the frequency of bulletins, speeches, and research papers.

Based on such information, Eijffinger and Geraats (2006) construct comprehensive indexes that distinguish between five aspects of transparency relevant for monetary policy making: political, economic, procedural, policy, and operational transparency. Among the nine countries covered by the indexes, the most transparent institutions are the Reserve Bank of New Zealand, the Swedish Riksbank, and the Bank of England. The Bank of Canada ranks fourth.

Dincer and Eichengreen (2007) extend the indexes of Eijffinger and Geraats, using a sample that covers 100 central banks for every year from 1998 to 2005. Consistent with Eijffinger and Geraats, they find that the Reserve Bank of New Zealand, the Swedish Riksbank, and the Bank of England were the most transparent central banks in 2005. The Bank of Canada ranks fifth, right behind the central bank of the Czech Republic. They also find that the trend towards greater transparency has been widespread, since no institution has moved in the direction of less transparency over this period.

Although these measures quantify the degree of openness of central banks based on the information provided, they do not necessarily reflect the extent to which the public understands the monetary authority's actions and signals. Central bank transparency may not be effective unless it can be appreciated by the public and incorporated into its economic behaviour. This issue motivated Kia and Patron (2004) to compute a market-based transparency index. Their index uses daily data on the federal funds and Treasury bill rates over the period 1982–2003 and has the advantage of reflecting what market participants understand from the Federal Reserve's actions and signals. Their definition of transparency is much narrower, however, since it only relates to day-to-day policy rate expectations.

cases cannot be easily generalized. Moreover, it is difficult to identify the impact of increased transparency on the basis of a time series when there may only be one significant change in disclosure practices in the sample period. Dincer and Eichengreen (2007) overcome these issues by constructing time-varying transparency indexes for the majority of the world's central banks (see Box, p. 17). They find that transparency has a broadly favourable, though relatively weak, impact on inflation and output variability.

Although most empirical studies conclude that greater central bank transparency is beneficial, their primary limitation is that the findings for individual cases cannot be easily generalized.

Inflation Performance under Inflation Targeting

To analyze the inflation performance of central banks under IT, we look at deviations of the rate of consumer price inflation from targeted inflation (year-over-year, quarterly). Although some central banks emphasize a core rate of inflation, we use total inflation as measured by the consumer price index (CPI), which is the most widely understood and used measure of inflation and is always used to define the official target variable. Total CPI inflation does not abstract from the potential effects of changes in indirect taxes on the recorded inflation rate, however. This is a caveat to our measure of performance, since short-run movements in inflation caused by changes in indirect taxes are not an indicator of monetary policy performance.[6] This drawback also applies to previous studies. For central banks using a range for targeting inflation, the midpoint of the band is used as the numerical objective. This is a realistic assumption, since targeting the midpoint of the range maximizes the probability of keeping inflation within the band.[7]

The sample includes 21 IT economies: eight industrialized countries (Australia, Canada, Iceland, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom) and 13 emerging-market economies (Brazil, Chile, Colombia, the Czech Republic, Hungary, Israel, the Republic of Korea, Mexico, Peru, the Philippines, Poland, South Africa, and Thailand).[8] Each country's inflation target, or target range, and regime starting dates are taken from Mishkin and Schmidt-Hebbel (2007). For most countries, these data cover both a declining inflation target period (i.e., disinflation) and a period when the inflation target is stable. The sample starts at various dates (depending on the individual regimes) and ends in the second quarter of 2007.[9]

The inflation performance of industrialized economies as a group is rather good, with about two-thirds of target deviations smaller than 1 pp (Chart 1). There is no bias overall, since 50.2 per cent of the deviations are positive and 49.8 per cent are negative. Target misses of more than 2 pp occur very rarely. The average of the MAD from the target is about 1 pp (Table 1). Switzerland ranks first, with inflation deviating from the target by only 0.38 pp, on average. The United Kingdom has a very good performance, with a MAD of 0.66 pp. Canada comes third, with a MAD of 0.80 pp, which means that, on average, inflation deviations have been smaller than the 1 per cent band on either side of the target. Iceland, with the most limited IT experience among industrialized economies, is the worst performer, with inflation missing the target by 2.13 pp, on average. Looking at the transparency rankings (DE rank) of Dincer and Eichengreen (2007), there is no obvious link between our MAD rankings and the degree of transparency, which could suggest a weak

6. Changes in indirect taxes can sometimes have a significant impact on a central bank's ability to hit the target (Bank of Canada 1991). Nevertheless, we use headline CPI because price series that account for the effect of changes in indirect taxes are not readily available for the countries sampled. Yet we were able to obtain CPI measures adjusted for the introduction of the Goods and Services Tax for Australia and excluding the effect of changes in indirect taxes in the case of Canada. If there were large effects of changes in indirect taxes in the other countries in the sample, our performance rankings could be biased in favour of Australia and Canada.

7. Paulin (2006) notes that, in practice, IT central banks tend to downplay the role of the edges of the range, viewing them primarily as a communication tool to provide clarity on the degree of tolerance with respect to the variance of inflation. The Bank of England is an exception since, whenever the target is missed by more than one percentage point, the Governor of the Bank must write an open letter to the Chancellor explaining the reasons why inflation has increased or fallen to such an extent and what the Bank proposes to do to ensure that inflation returns to the target.

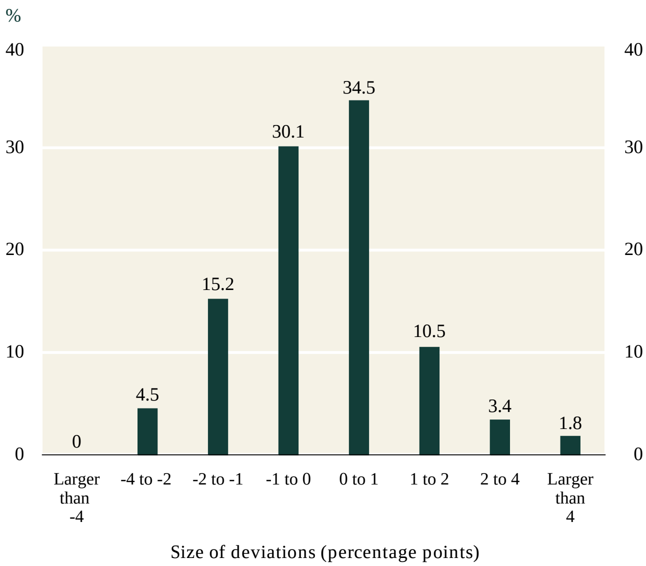
8. We did not include the euro area because the European Central Bank does not consider itself an inflation targeter. Albagli and Schmidt-Hebbel (2004) and Roger and Stone (2005) also exclude the euro area from their sample. The Slovak Republic, Indonesia, Romania, and Turkey moved to IT in 2005–06.

9. See Gosselin (2007) for details on the IT parameters, e.g., starting dates, disinflation periods, numerical values, and definition of range.

Chart 1

Distribution of Inflation Deviations from Target

Industrialized economies



correlation between inflation performance and transparency.

As in Roger and Stone (2005), we find that central banks tend to exceed their inflation target during disinflation periods. Canada is an exception to this, however, with inflation below the target by 1.06 pp, on average.[10]

10. Excluding the effect of the tobacco tax reduction in 1994.

This could reflect the Bank of Canada's determination to err on the side of tight monetary policy in the early stages of IT.

There is very little bias around the target during stable IT periods, especially in Australia, Canada, Switzerland, and the United Kingdom. Norway and Sweden have tended to undershoot their objective, while Iceland is the main overshooter. If we exclude Iceland, the average bias falls from 0.82 to -0.07 pp and from 0.07 to -0.16 pp during declining and stable IT periods, respectively.

The persistence of inflation deviations, as measured by the half-life of a 1 pp deviation from the target, is consistent with the typical impulse-response functions from vector autoregression estimates. Deviations are the least persistent in Norway and Switzerland (half-life of 1.4 quarters) and the most persistent in Sweden and Australia (half-life of 4 and 6 quarters, respectively). Large target misses, measured by the number of times that inflation diverged from the target by more than 2 pp, never occurred in Switzerland and the United Kingdom. They are more frequent in Australia, New Zealand, and Iceland, which could reflect a greater exposure to commodity-price shocks. Although Canada might have been affected by such shocks, it managed to record only four large target misses. For countries using target bands, we also report the number of times that inflation has been outside the control range during periods of stable IT. By this metric, Canada has the best performance among industrialized countries, since inflation outcomes have been beyond the edges of the target band in only 12 out of 46 quarters. The Australian performance is weaker,

Table 1

The Inflation-Targeting Performance of Industrialized Economies

	IT start	MAD (pp)	MAD rank	DE rank	Bias (declining target)	Bias (stable target)	Persistence (quarters)	Large deviations	Beyond bands
Australia	1994Q3	0.85	4	6		-0.05	5.97	7	29/52
Canada	1991Q1	0.80	3	4	-1.06	-0.02	2.91	4	12/46
Iceland	2001Q1	2.13	8	8	2.59	1.66	2.89	10	-
New Zealand	1990Q1	0.99	5	1	0.93	0.42	3.02	7	15/38
Norway	2001Q1	1.03	6	7		-0.56	1.40	4	-
Sweden	1995Q1	1.08	7	2		-0.85	3.95	5	24/50
Switzerland	2000Q1	0.38	1	5		-0.06	1.43	0	-
United Kingdom	1992Q1	0.66	2	3		0.02	2.78	0	-
Average	-	0.99	-	-	0.82	0.07	3.04	4.63	43%

Sources: Author's calculations and Dincer and Eichengreen (DE) (2007)

Notes: MAD = mean absolute deviation of actual inflation from target; DE rank = transparency rankings in 2005 (industrialized IT countries only); bias = mean of inflation deviations; persistence = half-life of a 1 percentage point (pp) inflation deviation (computed using autoregressive coefficients); large deviations = absolute inflation deviations greater than 2 pp; beyond bands = number of times that inflation is outside of the control range during stable IT periods with year-over-year inflation outside of the range more than half of the time.[11]

The performance of inflation-targeting regimes is relatively weaker and much more dispersed in emerging-market economies (Chart 2 and Table 2). Only 43 per cent of deviations for the group lie between -1 and +1 pp, and about 33 per cent of deviations are larger than 2 pp. The average of the MAD is 0.86 pp higher than for industrialized countries. The worst performers are Brazil, Israel, and South Africa, while Chile, the Republic of Korea, and Thailand have MADs comparable to those for industrialized countries. Disinflation periods are much more common in emerging-market economies. On average, there is a small negative bias around the inflation target, but the figure is skewed by the large undershooting in the Republic of Korea. There are significant cross-country differences, with Brazil and Hungary both exceeding their target by an average of 1.9 pp, and Colombia and the Republic of Korea undershooting their targets by averages of 1.5 and 3.0 pp, respectively. Bias is smaller during stable IT periods. The persistence of inflation deviations is higher for emerging-market economies, with an average half-life of 3.83 quarters compared with 3.04 quarters for industrialized countries. Persistence is particularly high for the Philippines and low in Peru. Large inflation deviations are frequent, especially in Brazil, Israel, and Poland. Although the control range

11. Note, however, that the control range is narrower for Australia (between 2 and 3 per cent). Assuming a target band width comparable to that of the other industrialized countries reduces the frequency of target-range misses from 29 to 16 out of 52.

Chart 2

Distribution of Inflation Deviations from Target

Emerging-market economies

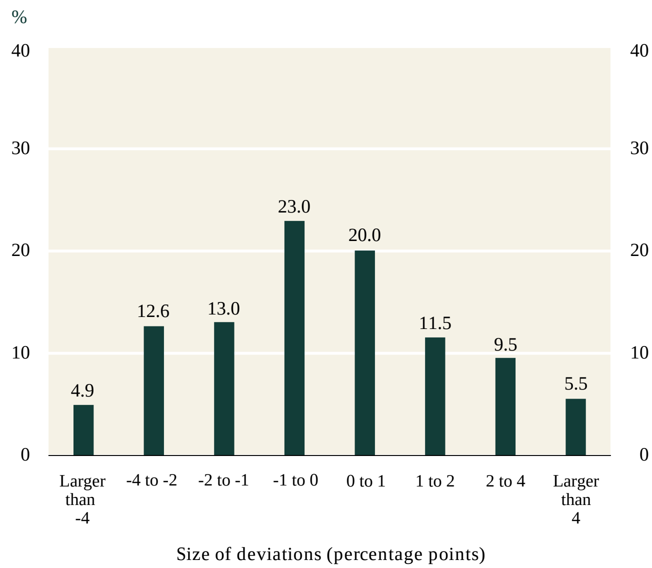


Table 2

The Inflation-Targeting Performance of Emerging-Market Economies

	IT start	MAD (pp)	MAD rank	DE rank	Bias (declining target)	Bias (stable target)	Persistence (quarters)	Large deviations	Beyond bands
Brazil	1999Q1	3.00	13	4	1.92		4.15	17	-
Chile	1991Q1	1.02	1	7	0.66	-0.27	2.05	8	6/26
Colombia	1999Q1	1.75	6	8	-1.53		4.59	14	-
Czech Republic	1998Q1	2.01	8	1	-0.95		2.34	14	-
Hungary	2001Q1	2.08	9	3	1.90		3.40	11	-
Israel	1992Q1	2.26	11	5	-1.14	-1.25	2.29	33	14/18
Korea, Republic of	1998Q1	1.16	2	5	-3.00	-0.03	3.99	6	15/30
Mexico	1999Q1	1.56	4	9	0.15	1.20	2.70	5	11/18
Peru	1994Q1	1.57	5	6	0.63	-0.67	1.16	13	10/22
Philippines	2001Q1	1.92	7	2	0.27		10.14	13	-
Poland	1998Q1	2.22	10	6	-1.13	-0.45	4.20	17	10/14
South Africa	2001Q1	2.31	12	4		0.61	4.18	10	12/26
Thailand	2000Q1	1.21	3	6		0.74	4.68	4	6/30
Average	-	1.85	-	-	-0.20	-0.02	3.83	12.7	46%

Sources: Author's calculations and Dincer and Eichengreen (DE) (2007)

Notes: MAD = mean absolute deviation of actual inflation from target; DE rank = transparency rankings in 2005 (emerging-market IT countries only); bias = mean of inflation deviations; persistence = half-life of a 1 percentage point (pp) inflation deviation (computed using autoregressive coefficients); large deviations = absolute inflation deviations greater than 2 pp; beyond bands = number of times that inflation is outside of the control range during stable IT periods is generally larger, occasions when the target band is missed are somewhat more prevalent, on average, in these countries.

Switzerland and the United Kingdom obtain the best performance among industrialized IT countries.

Putting these various performance metrics together, it appears that Switzerland and the United Kingdom obtain the best performance among IT countries. Within the group of emerging-market IT countries, Chile and Thailand have the best records. The magnitude, persistence, and frequency of inflation deviations vary considerably across countries, perhaps because of the diversity of exogenous economic shocks, institutions, and monetary policy frameworks that characterize these economies. We will attempt to quantify the contribution of these factors.

Empirical Determinants of Deviations from the Inflation Target

We extend the work of Albagli and Schmidt-Hebbel (2004) by examining a more extensive set of factors that determine central bank performance under IT. One of our contributions is to try to account for transparency and other institutional measures specific to central banks, which helps us to determine what makes a successful IT central bank. As well, since the financial system is a key component of the monetary policy transmission mechanism, we also try to control for the financial environment. Krause and Rioja (2006) find that a more highly developed financial system improves the efficiency of monetary policy. Given this, we should expect central banks' success in hitting the inflation target to increase with the degree of financial market sophistication.

We follow Albagli and Schmidt-Hebbel and define central bank performance under IT as the absolute value of the difference between consumer price inflation and either the target or the centre of the control band. However, we broaden the definition of performance by also considering specifications in which performance is measured as a weighted average of the absolute value of deviations of inflation from the target and of output from potential (i.e., the central bank's loss function). This is a reasonable exercise, since the monetary policy objective typically includes not only the stability of inflation around the target, but also the stability of the real economy. Where a supply shock shifts output and inflation in opposite directions, for example, some central banks may be willing to tolerate a one-time price-level movement rather than a disturbance in output.

Using the sample previously described, we regress absolute inflation deviations (or the bank's loss function) on the characteristics of the monetary policy framework and on control variables representing the macroeconomy and the financial environment. The set of macroeconomic control variables includes lags of the absolute value of deviations of output, the exchange rate, and the relative price of oil (all relative to their trend, as in Albagli and Schmidt-Hebbel). In addition to various measures of country risk, we use the lagged fiscal deficit relative to GDP to account for the dependence of successful disinflations on fiscal reforms, especially in emerging-market economies.[12] Control variables representing the financial environment can be grouped into those that capture the degree of financial market development (index of financial market sophistication and stock market capitalization, or turnover, relative to GDP) and those that reflect the health of the banking sector (e.g., indexes of bank financial soundness or strength or market share of state-owned banks).

The characteristics of the monetary policy framework can be grouped into three categories: IT parameters, transparency, and other possible explanatory variables. The first category includes the level of the inflation target, the width of the target range, and the policy horizon (i.e., the period over which inflation is expected to return to the target). Instead of trying to build measures of central bank transparency such as those described in the Box on p. 17, we use the indexes of Dincer and Eichengreen (2007).[13] We also experiment separately with various proxies of the degree of openness of monetary institutions in their communications with the public, such as the number of inflation reports published per year, the provision of quantitative

12. Since inflation in smaller and more open economies is likely to be more exposed to foreign economic developments, we also try openness to trade and country size as variables to explain deviations from the inflation target. The macroeconomic control variables are lagged to avoid the issue of simultaneity.

13. We did not consider the measures of Kia and Patron (2004) and Eijffinger and Geraats (2006), since the former relies on daily data, making it virtually impossible to reproduce for many countries, while the latter covers only nine industrialized countries and does not vary over time.

forecasts, and the publication of minutes or voting records of monetary policy committee (MPC) meetings. These measures should exhibit enough variation across time and countries to properly identify transparency effects.[14] Finally, although not directly related to the concept of transparency, we investigate the role of the frequency of official MPC meetings, the use of economic models (with more than 10 equations) to guide policy, the size of the MPC, and central bank independence.[15]

Several estimation results based on various econometric specifications, such as cross-section, pooled, and fixed-effects panel regressions, and regressions of instrumental variables, as well as a variety of definitions of the central bank's loss function, are reported in Gosselin (2007).[16] Table 3 summarizes and updates the main empirical findings.

Among the macroeconomic control variables, we find that higher variability of the exchange rate and larger fiscal deficits increase the magnitude of deviations of inflation from the target. The statistical significance of the exchange rate is not a surprise, given that most of the countries in the sample are small open economies. The output gap is statistically insignificant, consistent with evidence of a flattening of the Phillips curve during the 1990s. The insignificance of oil prices is more of a surprise, however, especially given that we are looking at total inflation.[17] The various measures of country risk examined by Albagli and Schmidt-Hebbel are not statistically significant either, presumably because this notion is already captured by other elements in

Table 3

Key Determinants of Central Bank Performance and Their Correlation with Inflation Deviations or the Central Bank's Loss Function

	Inflation deviations	Loss
Macroeconomic variables		
Output deviations	ns	+
Exchange rate deviations	+	+
Oil-price deviations	ns	+, small
Country risk premium	ns	ns
Fiscal deficit/GDP	+	+
Financial environment variables		
Degree of financial market development		
Financial market sophistication	ns	ns
Stock market capitalization/GDP	ns	ns
Stock market turnover/GDP	ns	ns
Banking-sector health		
Soundness index of private banks	-	ns
Financial strength of private banks	-	ns
Market share of state-owned banks	ns	+, small
Institutional variables		
IT parameters		
Inflation-target level	+	+
Size of inflation-target range	+	+
Inflation-control horizon	-, small	ns
Transparency		
Dincer and Eichengreen (DE) index	ns	ns
Number of inflation reports per year	ns	ns
Provision of quantitative forecasts	ns	ns
Publication of MPC minutes	+	+
Other		
Frequency of official MPC meetings	ns	-, small
Use of models	ns	-
Size of MPC	-, small	ns
Central bank independence	-	ns

Notes: + and - indicate statistically significant positive and negative coefficients; *ns* corresponds to insignificant coefficients; *small* is added when the effect is statistically significant but economically small. The central bank's loss function is a weighted average of the absolute value of deviations of inflation from the target and of output from potential. MPC = monetary policy committee

the equation, such as the variable for the fiscal deficit. Regressions of the central bank's loss function produce similar results, except that lags of the absolute value of the output gap are now statistically significant. Oil-price deviations are positively correlated with loss, but the impact is small.

There is no statistical evidence of a relationship between central bank performance and the degree of financial market development. However, in line with Krause and Rioja (2006), we find some evidence that the health

14. For instance, the transparency indexes of Dincer and Eichengreen (2007) take values of 6, 7, 7.5, 8, 9, and 9.5 for Switzerland, and 4, 4.5, and 5.5 for Mexico.

15. Some of the characteristics of the monetary policy framework exhibit time variation, which allows us to introduce them in conjunction with country-fixed effects. For instance, the number of Monetary Policy Reports per year published by the Bank of Canada changed from two to four in 2000. As well, the dummy variable for the publication of minutes or voting records of MPC meetings takes the value of 1 *if* and *when* this situation applies to a central bank. Gosselin (2007) provides the exact definition and source of all the explanatory variables that were considered potential determinants of inflation-target deviations and the central bank's loss function and reports selected descriptive statistics of the variables representing the monetary policy framework.

16. While some specifications incorporate country-fixed effects, we do not control for a number of country-specific effects that may be quite important, including: the weight of energy in the CPI basket times the elasticity of domestic energy prices with respect to the world price of oil (which may depend on taxes and regulation), the percentage of workers whose wages are formally indexed to the CPI, and the basket weight of regulated prices that are changed more than once a year.

17. A larger but barely statistically significant impact of oil could be obtained by multiplying the oil-price variable by a measure of how much oil the country uses.

of the private banking sector is positively correlated with meeting targets more consistently, since the soundness and financial strength of private banks are both negatively correlated with inflation deviations. The only control variable representing the financial environment that is statistically significant in regressions of loss is the market share of state-owned banks. The coefficient is positive, indicating that countries with less development in the private banking sector tend to have more variable output and inflation outcomes relative to targets.

Several interesting findings concern the role played by the characteristics of the monetary policy framework. Consistent with Albagli and Schmidt-Hebbel, we find that a higher value for the inflation target is associated with larger deviations. The size of the control range has the expected positive sign, presumably because countries that define their targets in a less-restrictive manner are more likely to deviate from the range's centre. Though by an economically small amount, a longer inflation-control horizon reduces target misses, which could suggest that by paying more attention to longer-term objectives, the monetary authority is better able to anchor the private sector's expectations for inflation. Surprisingly, there is no statistical relationship between the Dincer and Eichengreen (2007) transparency indexes and performance. This result could have been expected, however, given the absence of correlation between our MAD rankings and the transparency rankings, as we saw in Table 1. With regard to our transparency proxies, we do not find evidence of a link between performance and either the number of inflation reports published per year or the provision of quantitative forecasts, which is contrary to the findings of Chortareas, Stasavage, and Sterne (2002). Moreover, we find that central banks publishing the minutes or voting records of their MPC meetings tend to miss their objective by more than those that do not. This could be because minutes and voting records sometimes expose disagreements within the MPC, thereby complicating communications with the public.[18] Another explanation for these findings could be that the requirement for transparency may act as a constraint on policy by reducing flexibility and introducing bureaucracy. Central banks with larger MPCs have a slightly better inflation performance, consistent with the principle that, with some obvious limits, the greater the number of board members, the broader the range of experiences and perspectives, and hence the better their ability to deal with uncertainty and to process information (Berger, Nitsch, and Lybek 2006).[19] We also find that independent central banks obtain significantly better inflation outcomes, which probably reflects a stronger ability to commit to price stability (Cukierman, Webb, and Neyapti 1992).

We obtain similar results with respect to the central bank's loss function. A higher level and a wider control range for the inflation target are both associated with larger monetary policy losses. The fact that the range variable remains positive and statistically significant in the loss regressions suggests that the benefits of lower output variance do not offset the costs of higher inflation volatility when central banks choose a wider control range. As with the regressions of inflation deviations, the publication of minutes is harmful to performance. Though by a small amount, we find that a greater frequency of official MPC meetings is associated with lower loss. This reduction could be the result of better-timed policy decisions or transparency benefits, in that more frequent meetings allow the central bank to convey its view to the public with greater efficiency. Finally, we find that central banks using models to guide the conduct of policy obtain significantly lower losses, highlighting the importance of economic models in making monetary policy (Coletti and Murchison 2002).

Conclusion

To recapitulate, our empirical analysis reveals that inflation and output deviations are positively correlated with exchange rate movements and fiscal deficits, negatively correlated with private banking sector health and central bank independence, and positively or not correlated with transparency. Furthermore, we find that deviations increase with the level of the inflation target and the width of the control range but decline if economic models are used to guide policy. What makes a successful IT central bank? To minimize deviations of inflation from target and of output from trend, IT central banks would benefit from having a low numerical target and a relatively narrow control range, confidential MPC meetings, economic models

18. Another disadvantage of releasing minutes or voting records is that knowledge by committee members that their positions and arguments will become public information within a short period of time may inject short-term political and personal career factors into their deliberations and voting behaviour, which is likely to contaminate the monetary policy process with considerations other than the public interest (Cukierman 2005). Similarly, Kennedy (2008) argues that there is a need to protect the integrity of some internal policy deliberations, since the public release of policy advice and policy recommendations could stifle the free debate and consensus building that is necessary for sound policy making.

19. We also experimented with squared transformations of some variables to see whether there is an optimal level of transparency; the results were qualitatively similar.

to guide policy decisions, and independence from the government.

Transparency may not improve the accuracy of inflation targeting.

Our findings that transparency may not improve the accuracy of inflation targeting should be interpreted cautiously, however. Although the empirical results suggest that greater transparency could reduce the central bank's ability to hit the inflation target, it is important to keep in mind that central bank transparency is extremely difficult to measure accurately. The indexes used in this article attempt to measure and quantify all the information provided to the public by central banks, but do not necessarily reflect the extent to which the public understands the monetary authority's actions and signals. Nor do they capture the degree to which this information is incorporated into the public's economic behaviour. Therefore, given the rudimentary nature of these indexes of transparency, our results should be interpreted as preliminary until better measures are obtained.

Literature Cited

Albagli, E. and K. Schmidt-Hebbel. 2004. "By How Much and Why Do Inflation Targeters Miss Their Targets?" Presented at the conference, *Strategies for Implementing Monetary Policy in the Americas: The Role of Inflation Targeting*, held by the Federal Reserve Bank of Atlanta, 4 October. Available at <http://www.economia.puc.cl/seminarios/SECHI/cursos/Albagli%20Schmidt-Hebbel%20July%202004.pdf>.

Bank of Canada. 1991. "Targets for Reducing Inflation: Further Operational and Measurement Considerations." *Bank of Canada Review* (September): 3–23.

Berger, H., V. Nitsch, and T. Lybek. 2006. "Central Bank Boards Around the World: Why Does Membership Size Differ?" International Monetary Fund (IMF) Working Paper No. 06/281.

Chortareas, G., D. Stasavage, and G. Sterne. 2002. "Does It Pay to Be Transparent? International Evidence from Central Bank Forecasts." *Federal Reserve Bank of St. Louis Review* 84 (4): 99–117.

Coletti, D. and S. Murchison. 2002. "Models in Policy-Making." *Bank of Canada Review* (Summer): 19–26.

Cukierman, A. 2005. "The Limits of Transparency." Presented at the 2006 Allied Social Science Associations Annual Meeting, 7 January. Available at <http://www.aeaweb.org/annual_mtg_papers/2006/0107_1015_0903.pdf>.

Cukierman, A., S. B. Webb, and B. Neyapti. 1992. "Measuring the Independence of Central Banks and Its Effect on Policy Outcomes." *The World Bank Economic Review* 6 (3): 353–98.

Demertzis, M. and A. Hughes Hallett. 2007. "Central Bank Transparency in Theory and Practice." *Journal of Macroeconomics* 29 (4): 760–89.

Dincer, N. N. and B. Eichengreen. 2007. "Central Bank Transparency: Where, Why, and with What Effects?" National Bureau of Economic Research (NBER) Working Paper No. 13003.

Eijffinger, S. C. W. and P. M. Geraats. 2006. "How Transparent Are Central Banks?" *European Journal of Political Economy* 22 (1): 1–21.

Geraats, P. M. 2007. "The Mystique of Central Bank Speak." *International Journal of Central Banking* 3 (1): 37–80.

Gosselin, M.-A. 2007. "Central Bank Performance under Inflation Targeting." Bank of Canada Working Paper No. 2007–18.

International Monetary Fund (IMF). 1999. "Code of Good Practices on Transparency in Monetary and Financial Policies: Declaration of Principles." Available at <http://www.imf.org/external/np/mae/mft/code/index.htm>.

Literature Cited (cont'd)

Jenkins, P. 2004. "Communication: A Vital Tool in the Implementation of Monetary Policy." Remarks to the FMAC / FMA-USA Joint Conference, Toronto.

Kennedy, S. 2008. "Transparency: The More, The Better?" Speech to l'Association des femmes en finance du Québec, Montréal, Quebec, 8 January.

Kia, A. and H. Patron. 2004. "Market-Based Monetary Policy Transparency Index, Risk and Volatility—The Case of the United States." Carleton University. Manuscript. Available at <http://www.carleton.ca/economics/cep/cep04-07.pdf>.

Krause, S. and F. Rioja. 2006. "Financial Development and Monetary Policy Efficiency." Draft. Available at <http://www.economics.emory.edu/Working_Papers/wp/krause_06_13_paper.pdf>.

Macklem, T. 2005. "Commentary: Central Bank Communication and Policy Effectiveness." In *The Greenspan Era: Lessons for the Future*, 475–94. Proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City in Jackson Hole, Wyoming, 25–27 August. Kansas City: Federal Reserve Bank of Kansas City.

Mishkin, F. S. 2004. "Can Central Bank Transparency Go Too Far?" In *The Future of Inflation Targeting*, 48–65, edited by C. Kent and S. Guttman. Proceedings of a conference held at the H. C. Coombs Centre for Financial Studies, Kirribilli, Australia, 9–10 August. Reserve Bank of Australia.

Mishkin, F. S. and K. Schmidt-Hebbel. 2007. "Does Inflation Targeting Make a Difference?" National Bureau of Economic Research (NBER) Working Paper No. 12876.

Morris, S. and H. S. Shin. 2002. "Social Value of Public Information." *American Economic Review* 92 (5): 1521–34.

Muller, P. and M. Zelmer. 1999. "Greater Transparency in Monetary Policy: Impact on Financial Markets." Bank of Canada Technical Report No. 86.

Parent, N., P. Munro, and R. Parker. 2003. "An Evaluation of Fixed Announcement Dates." *Bank of Canada Review* (Autumn): 3–11.

Paulin, G. 2006. "Credibility with Flexibility: The Evolution of Inflation-Targeting Regimes, 1990–2006." *Bank of Canada Review* (Summer): 5–18.

Roger, S. and M. Stone. 2005. "On Target? The International Experience with Achieving Inflation Targets." International Monetary Fund (IMF) Working Paper No. 05/163.

Svensson, L. E. O. 2005. "Optimal Inflation Targeting: Further Developments of Inflation Targeting." Presented at the conference, *Monetary Policy under Inflation Targeting*, held by the Banco Central de Chile, 20 October. Available at <http://www.bcentral.cl/eng/conferences-seminars/annual-conferences/pdf/2005/Svensson.pdf>.

Woodford, M. 2005. "Central-Bank Communication and Policy Effectiveness." In *The Greenspan Era: Lessons for the Future*, 399–474. Proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City in Jackson Hole, Wyoming, 25–27 August. Kansas City: Federal Reserve Bank of Kansas City.

The Zero Bound on Nominal Interest Rates: Implications for Monetary Policy

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- *The lower bound on nominal interest rates is typically close to zero, since households can earn a zero rate of return by holding bank notes.*
- *The average inflation rate, the size of the shocks hitting an economy, the formation of inflation expectations, and the conduct of monetary policy itself all influence the risk of hitting the zero bound. The balance of evidence suggests a small risk of encountering the zero bound when average inflation is at least 2 per cent.*
- *Central banks considering an inflation target much below 2 per cent must factor in possible difficulties that the zero bound on nominal interest rates might present for the conduct of monetary policy.*

Price stability is generally viewed among both academics and practitioners as the most appropriate long-run objective for monetary policy. In Canada, the benefits of low, stable, and predictable inflation are clear. Since the Bank of Canada adopted an explicit inflation target in 1991, both the level and volatility of short- and long-maturity interest rates have declined. In addition, real growth has been higher and more stable than in previous decades (Longworth 2002). Monetary policy aimed at achieving low and stable inflation, in conjunction with sound fiscal policy, has resulted in a stronger, more resilient economy that is better equipped to weather shocks.

Canada's strong economic performance since the adoption of a 2 per cent inflation target raises the question of whether the Bank of Canada should lower the target further. Even when measurement error is factored into the consumer price index (CPI) (see Rossiter 2005), 2 per cent inflation does not correspond to true price stability. Targeting a rate of inflation closer to zero may further reduce resource misallocations resulting from inflation uncertainty and reduce the frequency of price changes, thereby lowering menu costs.[1] In addition to the possible transition costs associated with a reduction in the target, however, two main arguments have traditionally been advanced against the idea of targeting a very low rate of inflation. The first stems from the concern that it may be more difficult to adjust real wages downwards when inflation is low because this would also entail a

1. Interpreted literally, the term menu costs refers to the costs associated with having to reprint menus each time a restaurant updates its prices. The term is typically used more broadly to describe costs associated with changing prices in general.

reduction in the nominal wage, and workers may be reluctant to accept such reductions (Akerlof, Dickens, and Perry 1996; Fortin 1996; and Fortin et al. 2002).[2] The second argument is that central banks could encounter difficulties conducting monetary policy in a very low-inflation environment because nominal interest rates cannot go below zero (Summers 1991).

Canada's strong economic performance since the adoption of a 2 per cent inflation target raises the question of whether the Bank should lower the target further.

Recent experience in Japan, in which nominal short-term interest rates remained close to zero for more than seven years and real annual growth in gross domestic product (GDP) averaged just 1.7 per cent over the same period, suggests that the zero interest rate bound remains a significant and relevant practical issue for monetary policy.

In this article, we examine the impact of the zero bound on nominal interest rates, the likelihood that the constraint will bind, the ways that monetary policy can reduce this likelihood, and alternative policies to stimulate the economy when the zero bound binds. We begin by reviewing the underlying mechanism of the zero-bound problem and then assess the risk of hitting the zero bound, including the potential implications. In the following section, we review the main factors that influence this risk, with special emphasis on the role played by monetary policy design. We then discuss some policy alternatives that are available to the central bank for stimulating the economy when interest rates are stuck at zero. In the final section, we draw some conclusions on the general implications of the zero bound for monetary policy in Canada.

Why Are Nominal Interest Rates Bounded at Zero?

Central banks typically implement monetary policy by adjusting a very short-term nominal or "money" interest rate, such as the overnight rate in Canada. The nominal interest rate on an asset refers to the rate of return expressed in money terms, so a one-year, $100 bond with a rate of 6 per cent will pay the holder $106 at maturity. But in an economy with positive inflation, the purchasing power of money will decline over the course of that one-year period. The actual increase in the purchasing power of goods and services associated with the bond is referred to as the real interest rate. This relationship is summarized by the Fisher identity: The real interest rate is equal to the nominal interest rate minus the expected inflation rate:

Real Rate = Nominal Rate - Expected Inflation

Since households in the economy derive utility from the purchases of goods and services, it is the real rate of interest that is most relevant to their economic decisions. Therefore, monetary policy actions will influence demand only to the extent that adjustments to the nominal interest rate feed through to the real interest rate. In the case of an inflation-targeting central bank like the Bank of Canada, the task of monetary policy is to reduce real short-term interest rates when economic events, or shocks, occur that cause inflation to fall below the target and, symmetrically, to raise real interest rates when shocks cause inflation to go above the target.

This suggests that the normal conduct of monetary policy involves a degree of variation in the level of short-term interest rates over a business cycle. Of course, the larger the shock, all else being equal, the larger will be the adjustment to interest rates that is required to return output to potential and inflation to the target over a reasonable time horizon. In response to a significant deterioration in economic conditions, a deep recession, for example, the central bank may wish to lower the nominal interest rate below zero. Since households can always earn a zero rate of return by holding bank notes, however, no rational person would willingly agree to purchase a security yielding a negative nominal return. In practice, therefore, the lower bound on nominal interest rates is typically very close to zero,[3] and this bound may prevent a central bank from reducing the real interest rate sufficiently to return the economy to its potential level over the desired time horizon.[4]

2. Crawford and Wright (2001) argue that while downward nominal wage rigidities exist, the magnitude of their real effects is extremely small.

3. Technically, the lower bound would literally be zero only in a world where there are no costs to holding cash. As discussed in Yates (2004), to the extent that there are variable costs associated with holding money, such as monitoring and storage costs, then the lower bound on nominal interest rates would be slightly negative.

4. For a comprehensive review of the literature on the zero bound on nominal interest rates, see Yates (2004) and Amirault and O'Reilly (2001).

Whether the zero bound causes significant short-run damage to an economy will depend on what happens once interest rates reach zero. In a benign scenario, with no further negative shocks, low real interest rates may gradually return output to potential and inflation to the target, albeit more slowly than desired. Suppose, instead, that a significant negative shock to demand hits the economy, and the central bank finds itself unable to further reduce real interest rates. Recalling the Fisher identity, if the nominal rate is stuck at zero, any shock that lowers inflation expectations will raise the real interest rate. A deflationary spiral occurs when high real interest rates depress demand, which further reduces inflation expectations, and so on. The result can be a long period of weak demand growth and deflation.

Historical Estimates of the Risk of Hitting the Zero Bound

While there is no debating the existence of a lower bound on nominal interest rates, its relevance to policy-makers depends entirely on the probability that it will limit the central bank's ability to reduce real interest rates. Owing to limited historical experience with interest rates close to the zero bound, probability estimates are typically computed via simulations with economic models.

In practice, the lower bound on nominal interest rates is typically very close to zero.

Results for Canada are reported by Lavoie and Pioro (2007); Babineau, Lavoie, and Moreau (2001); Black, Coletti, and Monnier (1998); and Cozier and Lavoie (1994). For an average inflation rate of 2 per cent and an average real interest rate of 3 per cent, probability estimates of the nominal interest rate equalling zero range from about 1 per cent to 4 per cent. In addition, Lavoie and Pioro (2007) report that, with an inflation target of 2 per cent, the probability of falling into a deflationary spiral is effectively zero (see Table 1). As we discuss in the next section, these probabilities depend importantly on a number of factors, including the average rate of inflation in the economy. Therefore, for a central bank considering an inflation target that is significantly lower than 2 per cent, the threat of the zero bound cannot be ignored.

Factors That Influence the Risk of Hitting the Zero Bound

The factors affecting the probability of hitting the zero bound can be divided into two categories: those that influence the mean, or average, level of the interest rate and those that affect its volatility, or variation, around that mean. As we discuss in detail below, the conduct of monetary policy in general can have an important bearing on both the mean and the variance of nominal interest rates.

With an inflation target of 2 per cent, the probability of falling into a deflationary spiral is effectively zero.

Beginning with the first set of factors, the Fisher identity discussed in the previous section stipulates that the average nominal interest rate over a given period of time is equal to the average real interest rate plus the average expected inflation rate, where the latter should be approximately equal to the inflation target, provided the target is viewed as credible. The lower the inflation target, the lower will be the nominal interest rate, on average, and the higher will be the likelihood that the zero bound is encountered. Lavoie and Pioro (2007) estimate that targeting zero, rather than 2 per cent, inflation would increase the likelihood of hitting the zero bound approximately threefold, from 3.8 to 12.1 per cent (see Table 1). Moreover, not only does the likelihood increase as the inflation target is reduced, but it increases at an increasing rate, meaning that the

Table 1

Performance of Various Policy Rules under Inflation Targeting

Average (targeted) inflation rate	Degree of history-dependence	Probability of hitting zero bound	Probability of deflationary spiral
2 per cent	Low	17.0	0.0
	High	3.8	0.0
0 per cent	Low	35.4	0.2
	High	12.1	0.2

Note: Results taken from Lavoie and Pioro (2007) relationship is non-linear. Consequently, the constraint created by the zero bound on nominal interest rates has been used as an argument against targeting a very low level of inflation, typically below 1 or 2 per cent.

The second set of factors that are important for determining the probability of hitting the zero bound are those that affect the variability of short-term nominal interest rates. As discussed in the previous section, central banks adjust short-term interest rates in an effort to achieve their target(s) in response to unexpected economic developments or shocks. Therefore, the degree of variation in short-term nominal interest rates generated by monetary policy actions will depend on the variability of the shocks faced by the economy. All else being equal, the higher the variance of shocks, the more volatility is required in interest rates in order to achieve the target.

While the variance of economic shocks is clearly an important determinant of interest rate volatility, it is not the sole factor. The manner in which private sector expectations are formed, coupled with the means by which monetary policy actions are implemented and communicated, can have a significant influence on the variability of short-term interest rates for a given variance of shocks and the central bank's objective.

Central banks have direct control over a very short-term nominal rate, such as the overnight rate, whereas it is the market-determined real interest rate across the yield curve that is most relevant to aggregate demand and inflation. The impact on the economy of a given change in the nominal short rate will depend, therefore, on the extent to which it is reflected in longer-maturity real rates. Thus, for a given maturity, the Fisher identity indicates that the response of the real rate can be greater than, equal to, or less than the change in the nominal rate, depending on whether inflation expectations rise, remain the same, or decline in response to the change.

The link between short- and long-maturity interest rates is provided by what is commonly referred to as the expectations theory of the term structure. This theory posits that, in the absence of uncertainty, the current rate of return on an *n*-period bond should equal the average expected rate of return on one-period bonds over the next *n* periods, provided the bonds are equivalent in every other respect.[5] Therefore, according to the expectations theory of the term structure, the response of longer-maturity interest rates to a change in monetary policy will depend on how long the change is expected to last. All else being equal, movements in short-term interest rates that are perceived by the market to be long lasting will exert a greater influence on longer-term nominal rates.

When we combine the Fisher identity with the expectations theory of the term structure, we see that, for a given reduction in the policy interest rate, longer-maturity real interest rates will decline by more if the reduction is perceived to be long lasting and if inflation expectations rise. From the point of view of a central bank wishing to avoid the zero bound, this is the best-case scenario, since even a small reduction in the nominal interest rate can be highly stimulative to the economy.

Central banks seeking to minimize the probability of encountering the zero bound should credibly commit to a history-dependent monetary policy.

On the basis of this reasoning, Woodford (1999) argues that central banks seeking to minimize the probability of encountering the zero bound should credibly commit to a history-dependent monetary policy, i.e., the central bank must convince the public that interest rate reductions implemented today will remain in place well into the future. In other words, the current level of the short-term policy interest rate will be highly correlated with its level in previous periods. Clearly, this will act to lower longer-maturity nominal interest rates through the expectations theory of the term structure. Provided that private sector inflation expectations are forward looking in nature,[6] however, such a history-dependent policy will also act to raise longer-term inflation expectations, thereby further reducing the real interest rate. The reasoning is straightforward: Interest rate cuts that are viewed as long lasting will be more stimulative to the economy and will therefore raise expectations of future inflation more than cuts that are perceived as highly transitory.

5. The assumption of no uncertainty is somewhat unrealistic, but does not alter the fundamental point that changes in longer-term interest rates tend to reflect expected changes in short-term rates over the same horizon. In reality, longer-maturity instruments tend to incorporate a term premium.

6. Inflation expectations are said to be forward looking if they are based on a particular view of the future state of the economy, such as the future level of demand relative to long-run supply. This contrasts with adaptive expectations, whereby agents base their view of future inflation on the level of inflation over the recent past.

In the context of policies that are set according to a mathematical rule, a simple strategy for incorporating history-dependence is to set the current level of the short-term interest rate partly as a function of its lagged value. For instance, the famous Taylor rule (1993), which posits that interest rates respond to the current level of inflation (relative to the target) and the current level of output relative to potential output, can be modified to permit a role for the lagged interest rate, thereby introducing additional inertia. Using the Terms-of-Trade Economic Model (ToTEM), Lavoie and Pioro (2007) show that increasing the weight on the lagged interest rate from 0.3 to 0.8 reduces the probability of encountering the zero bound on nominal interest rates from 17 per cent to less than 4 per cent when the average inflation rate is 2 per cent (see Table 1), a significant decline.

To summarize, if expectations are forward looking, then a central bank that can credibly commit to history-dependence can effectively trade off the average size of interest rate changes against the duration of the change. This will reduce the volatility of short-term nominal interest rates and reduce the probability of hitting the zero bound. An oft-cited example of such central bank communications is the statement by the Federal Reserve in 2003 that, “In these circumstances, the Committee believes that policy accommodation can be maintained for a considerable period” (FOMC 2003). Of course, the extent to which such statements influence private sector expectations will depend critically on their perceived credibility.

One special case of a history-dependent monetary policy is a price-level target (Woodford 1999; Eggertsson and Woodford 2003). Unlike an inflation target, where the central bank sets monetary policy to return the rate of change in the price level to some pre-specified level, a price-level target involves returning the price level itself to either a fixed level or a time-varying path. Under inflation targeting, bygones are bygones in the sense that the central bank makes no explicit attempt to make up for past deviations of inflation from the target.

To see why the distinction is important for the issue of the zero bound, consider a situation in which the central bank targets 2 per cent inflation but, because of weak demand, current inflation is below the target. If the central bank’s inflation target is credible, agents’ medium-term inflation expectations will be about 2 per cent, since they believe that the central bank will take whatever actions are necessary to achieve their target. Now consider the same situation, but instead of the central bank targeting 2 per cent inflation, they target a price level that increases by 2 per cent each year. With inflation currently below 2 per cent, the price level will fall below the desired level. Consequently, to return the price level to its targeted path, the central bank will have to allow inflation to exceed 2 per cent for a period of time. If this policy is viewed as credible by the public, medium-term inflation expectations will be higher under a price-level target than under an inflation target, meaning that the real interest rate will decline by more. In this sense, the adoption of a price-level target represents a commitment to a policy of history-dependence.

The above discussion suggests that adopting a target path for the price level can effectively allow the central bank to achieve a lower average rate of inflation in the economy without increasing the likelihood of encountering the zero bound on nominal interest rates. Using a small, forward-looking New Keynesian model, Wolman (1998) demonstrates that the optimal rate of inflation is very low, even when an explicit account of the implications of the zero bound is factored in. Wolman finds that when a policy of targeting the price level is followed and inflation expectations are forward looking, the constraint on nominal interest rates imposes essentially no constraint on real interest rates. Similarly, Wolman (2005) shows that price-level targeting combined with forward-looking price-setting behaviour implies that the real implications of the zero bound for monetary policy are very small.

Adopting a target path for the price level can allow the central bank to achieve a lower average rate of inflation without increasing the likelihood of encountering the zero bound.

It has also been shown that taking pre-emptive actions to prevent the zero-bound constraint from binding will also limit its implications. Results from Lavoie and Pioro (2007) and Kato and Nishiyama (2005) suggest that central banks should implement a more aggressive interest rate response when expected inflation falls below its desired level and the nominal interest rate approaches the zero lower bound.

To summarize, for a given variance of economic shocks, there is a higher likelihood that, in a very low inflation environment, the zero-bound constraint will restrict the ability of policy-makers to respond to changes in output and inflation. Taken in isolation, this would suggest that a lower average level of inflation would lead to more frequent and deeper periods of weak economic activity.[7] Central banks can reduce the incidence of the constraint on the zero bound, however, by credibly committing to a monetary policy that is highly inertial or history-dependent, meaning that policy changes tend to be very long lasting. When inflation expectations are highly forward looking and monetary policy is regarded as credible, central banks can exploit the expectations channel as a means of stabilizing the economy without inducing additional volatility in short-term interest rates. One special case of a history-dependent monetary policy is a commitment by the central bank to a target for the path of the price level. Recent research suggests that very low average rates of inflation can be achieved without significant distortions arising from the zero-bound constraint when such a policy is adopted.

Policy Options at the Zero Bound

There are various alternatives to stabilize output and inflation when the interest rate reaches zero and the standard policy tool (lowering the policy interest rate) is no longer available. Alternatives to the interest rate channel suggested in the literature can be divided into three groups: increasing liquidity, affecting expectations, and taxing currency holdings.

Even when the interest rate is zero, central banks can continue to increase the monetary base and liquidity in the economy, using one of several possible mechanisms. First, the central bank could print money to finance tax cuts or additional government spending (Feldstein 2002). With a tax cut, the impact on aggregate demand and inflation expectations will depend on the proportion of the tax cut that is saved. If consumers believe that the policy change is temporary, or will be reversed at some point in the future (Goodfriend 2000), the impact on private consumption might be quite small.[8] In addition, adjusting tax and spending instruments takes time and may not be an effective way to quickly counteract the zero bound in the very short run.

A second possibility would be for the central bank to purchase long-term bonds or private equities, which would lead to a reduction in the liquidity premium embodied in longer-maturity interest rates. Third, the central bank could buy foreign currency assets. This will cause a depreciation of the domestic currency, which will stimulate the economy (Bernanke 2000; Meltzer 2001). A devaluation of the currency may not be possible, however, if the home country's major trading partners are also confronted with the zero-bound problem and attempt to follow the same strategy.

The second group of policy alternatives attempts to influence real interest rates through inflation expectations. A price-level target or a high inflation policy could then be announced when the zero bound is hit. However, a promise to target a higher inflation rate or to bring the price level back to its targeted level will not affect expectations if private sector agents doubt the central bank's ability, when constrained by the zero bound, to deliver on that promise. Similarly, a high-inflation policy may not affect expectations if agents believe that the monetary authority will return to a low-inflation regime once the constraint created by the zero bound no longer binds. In other words, the public may believe that the central bank will eventually renege on its promise of higher inflation once the benefits have been fully realized.

The announcement of a commitment to higher inflation may thus need to be accompanied by actions that support it. For example, Svensson (2001) proposes establishing, for a period of time, a target path for the price level that corresponds to positive inflation (inflation expectations) and is reinforced by an announced devaluation of the currency.

The final alternative to be considered is a tax on currency holdings (Gesell 1934; Keynes 1936; Buiter and Panigirtzoglou 2001; and Goodfriend 2000). The zero bound on short-term interest rates exists because people have the option of holding cash, which bears a zero nominal rate of return. Any means by which this rate of return can be lowered below zero will correspondingly lower the effective floor on nominal interest rates. One possibility would be to tax cash. This policy could potentially have large social costs, however, and its success would depend on the feasibility of enforcement.

Conclusion

The consensus in the literature is that the risk of encountering the zero lower bound on nominal interest rates is small at an average rate of inflation of 2 per cent or higher, but increases quickly as average inflation falls below 2 per cent. The size of the shocks hitting the economy, the way in which inflation expectations are

7. This statement ignores any potential benefits of lower average inflation.

8. Expanding the monetary base proved largely ineffective in Japan during the period when nominal interest rates were close to zero.

formed, and the manner in which monetary policy actions are implemented and communicated are all critical factors in the calculation of the risks.

Probability estimates based on variances from historical data may be misleading. There is a vast and interesting literature documenting a reduction in the variance of inflation and output growth in Canada and many other countries over the past two decades or so, the so-called "great moderation." Although the exact cause of this decline is still not known with certainty, it may mean that the risk of hitting the zero bound is lower than reported in the literature. At the same time, as noted in Yates (2004), if we are uncertain about the probability of hitting the zero bound, it may be prudent to assume that our estimates of that probability are too small, rather than too large.

The implications of the zero bound are also lower when monetary policy is credible and expectations are well anchored. The adoption of a regime that targeted price levels could further minimize the risk of hitting the zero bound, but it does not provide a foolproof means of escaping it. In the end, without a perfect alternative to the interest rate channel, central banks choosing an inflation objective must weigh the costs generated by greater output and inflation variability if the zero bound binds vs. the benefits of lower average inflation. The policy choice should thus depend on a careful analysis of these costs and benefits based on the social preferences associated with them.

Literature Cited

Akerlof, G. A., W. T. Dickens, and G. L. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* 1: 1–59.

Amirault, D. and B. O'Reilly. 2001. "The Zero Bound on Nominal Interest Rates: How Important Is It?" Bank of Canada Working Paper No. 2001-06.

Babineau, B., C. Lavoie, and N. Moreau. 2001. "Risques et conséquences d'atteindre la borne inférieure du taux d'intérêt nominal de court terme." Department of Finance Working Paper No. 2001–22.

Bernanke, B. S. 2000. "Japanese Monetary Policy: A Case of Self-Induced Paralysis?" In *Japan's Financial Crisis and Its Parallels to US Experience*, 149–66, edited by R. Mikitani and A. S. Posen. Special Report 13. Washington, D.C.: Institute for International Economics.

Black, R., D. Coletti, and S. Monnier. 1998. "On the Costs and Benefits of Price Stability." In *Price Stability, Inflation Targets, and Monetary Policy*, 303–42. Proceedings of a conference held by the Bank of Canada, May 1997. Ottawa: Bank of Canada.

Buiter, W. H. and N. Panigirtzoglou. 2001. "Liquidity Traps: How to Avoid Them and How to Escape Them." In *Reflections on Economics and Econometrics: Essays in Honour of Martin M. G. Fase*, 13–58, edited by W. F. V. Vanthoor and J. Mooij. De Nederlandsche Bank NV.

Cozier, B. and C. Lavoie. 1994. "Is There a Floor to Nominal Interest Rates? Evidence and Implications for the Conduct of Monetary Policy." Paper presented at Canadian Economics Association Meeting, University of Calgary, June.

Crawford, A. and G. Wright. 2001. "Downward Nominal-Wage Rigidity: Micro Evidence from Tobit Models." Bank of Canada Working Paper No. 2001-7.

Eggertsson, G. B. and M. Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 1: 139–211.

Federal Open Market Committee (FOMC). 2003. "Statement." 16 September. Available at <http://www.federalreserve.gov/boarddocs/press/monetary/2003/20030916>.

Feldstein, M. 2002. "The Role for Discretionary Fiscal Policy in a Low Interest Rate Environment." National Bureau of Economic Research (NBER) Working Paper No. 9203.

Fortin, P. 1996. "The Great Canadian Slump." *Canadian Journal of Economics* 29 (4): 761–87.

Fortin, P., G. A. Akerlof, W. T. Dickens, and G. L. Perry. 2002. "Inflation and Unemployment in the U.S. and Canada: A Common Framework." Département des sciences économiques, Université du Québec à Montréal Working Paper No. 20-16.

Literature Cited (cont'd)

Gesell, S. 1934. *The Natural Economic Order: A Plan to Secure an Uninterrupted Exchange of the Products of Labor, Free from Bureaucratic Interference, Usury and Exploitation* [1929]. Translated from the 6th German edition by P. Pye. San Antonio, TX: Free-Economy Publishing Co.

Goodfriend, M. 2000. "Overcoming the Zero Bound on Interest Rate Policy." *Journal of Money, Credit and Banking* 32 (4): 1007–35.

Kato, R. and S.-I. Nishiyama. 2005. "Optimal Monetary Policy When Interest Rates Are Bounded at Zero." *Journal of Economic Dynamics and Control* 29 (1–2): 97–133.

Keynes, J. M. 1936. *The General Theory of Employment, Interest and Money.* London: Macmillan.

Lavoie, C. and H. Pioro. 2007. "The Zero Bound on Nominal Interest Rates: Implications for the Optimal Monetary Policy in Canada." Bank of Canada Discussion Paper No. 2007-1.

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

Meltzer, A. H. 2001. "Monetary Transmission at Low Inflation: Some Clues from Japan in the 1990s." *Monetary and Economic Studies* 19 (S-1): 13–34.

Rossiter, J. 2005. "Measurment Bias in the Canadian Consumer Price Index." Bank of Canada Working Paper No. 2005-39.

Summers, L. 1991. "How Should Long-Term Monetary Policy Be Determined?" *Journal of Money, Credit and Banking* 23 (3): 625–31.

Svensson, L. E. O. 2001. "The Zero Bound in an Open Economy: A Foolproof Way of Escaping from a Liquidity Trap." *Monetary and Economic Studies* 19 (S-1): 277–312.

Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195–214.

Wolman, A. 1998. "Staggered Price Setting and the Zero Bound on Nominal Interest Rates." Federal Reserve Bank of Richmond *Economic Quarterly* 84: 1–22.

——. 2005. "Real Implications of the Zero Bound on Nominal Interest Rates." *Journal of Money, Credit and Banking* 37 (2): 273–96.

Woodford, M. 1999. "Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?" In *New Challenges for Monetary Policy,* 277–316. Proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, 26–28 August.

Yates, T. 2004. "Monetary Policy and the Zero Bound to Interest Rates: A Review." *Journal of Economic Surveys* 18 (3): 427–81.

Inflation Targeting, Price-Level Targeting, and Fluctuations in Canada's Terms of Trade

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- *Despite numerous successes, inflation targeting (IT) has some notable shortcomings. In particular, it does not define the future path of the price level, which may result in costly uncertainty for the economy.*
- *Price-level targeting (PLT) reduces future price-level uncertainty, but it is not clear whether this comes at the expense of increased macroeconomic instability, including that caused by large and persistent shocks to Canada's terms of trade.*
- *Research suggests that, compared with IT, PLT delivers a reduction in consumer price inflation and nominal interest rate variability at the expense of slightly higher output-gap variability.*
- *These results are highly sensitive to the interaction between the relative incidence of different macroeconomic shocks and the extent to which price setting is forward looking.*

In November 2006, the Government and the Bank of Canada announced the renewal of Canada's inflation-control agreement (Bank of Canada 2006). Under the terms of this five-year agreement, the Bank of Canada is committed to maintaining the year-over-year change in the consumer price index at the 2 per cent midpoint of a 1 to 3 per cent target range. This is the fourth consecutive inflation-control agreement since the announcement of the inflation-reduction targets in 1991. At that time, Canada followed New Zealand to become the second country in the world to introduce inflation targets; since then, more than 21 countries have followed suit. The Canadian and international experience with inflation targeting (IT) suggests that the policy has been a major success. Perhaps the most significant testament to this is that, despite numerous challenging macroeconomic developments, no country has abandoned the arrangement (Svensson 2008).

Despite significant achievements—lower average inflation rates, less inflation variability, more firmly anchored inflation expectations, and less variability in output relative to capacity—IT has notable shortcomings. In particular, IT does not require a credible commitment to long-run stability in the price level. In practical terms, shocks to the price level under IT are simply accommodated and thus not reversed. As shown in Chart 1, when an economy is facing random shocks, uncertainty about the future price level rises without limit as the planning horizon increases, even though uncertainty around the inflation rate is capped at its unconditional variance. Price-level uncertainty is particularly problematic for risk-averse economic agents who enter into imperfectly indexed, long-term

Chart 1

Stylized Confidence Intervals under Inflation Targeting

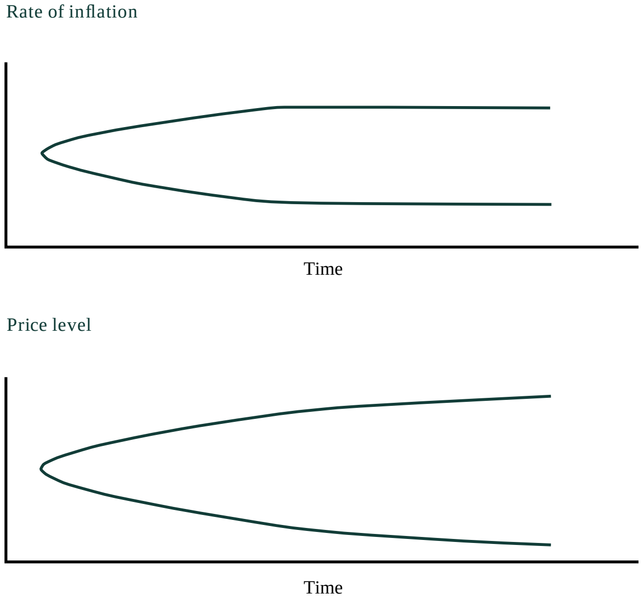
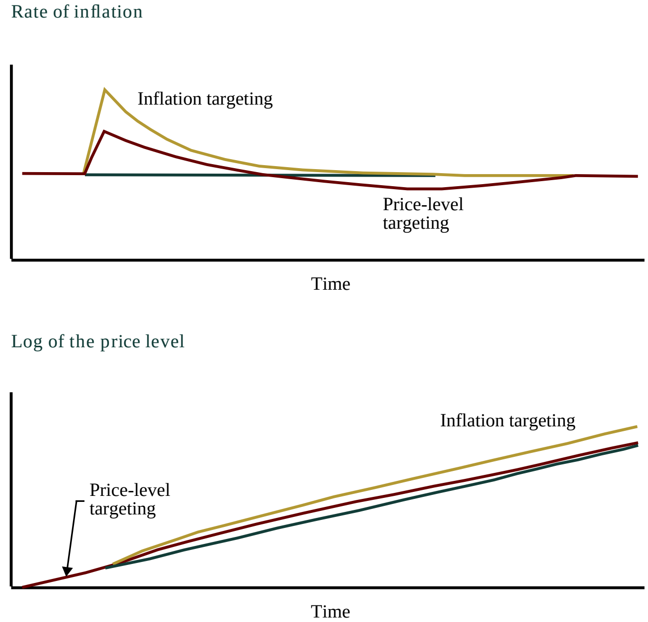


Chart 2

Inflation Targeting vs. Price-Level Targeting



nominal contracts (e.g., mortgages).[1] Although the quantitative significance of price-level uncertainty remains an open question, it is considered, conceptually at least, a weakness of inflation targeting.[2]

An alternative monetary policy strategy that directly addresses the issue of price-level uncertainty is price-level targeting (PLT). PLT differs from IT in that the central bank makes an explicit commitment to meet a publicly announced numerical target for the price level rather than an inflation target. Intuitively, the difference between IT and PLT is that, under inflation targets, shocks to the price level are accommodated, while under price-level targets shocks to the price level are reversed. The difference between the behaviour of PLT and IT for a positive shock to prices is shown in Chart 2. By focusing on the price-level target, central banks can reduce the uncertainty associated with the future level of prices.

The price-level target could be specified as a constant or it could be allowed to grow at some predetermined rate, e.g., 2 per cent, as in Chart 2. It has been argued that allowing the price-level target to grow reduces both the likelihood of hitting the zero lower bound on nominal interest rates (see Lavoie and Murchison, this issue) and of encountering the potentially destabilizing effects of deflation when compared with a constant target.

Critics of PLT have traditionally argued that it would lead to increased macroeconomic variability in both inflation and output.

In recent years, several important papers have compared the relative merits of IT and PLT; summaries of the literature can be found in Ambler (2007) and Côté (2007). Briefly, critics of PLT have traditionally argued that it would lead to increased macroeconomic variability in both inflation and output, since returning the price level to its target necessitates greater variability in the inflation rate than does simply returning inflation to target. Greater inflation variability combined with the presence of nominal rigidities in the economy implies that there must also be greater variability in the real side of the economy. Others have responded that, under certain conditions, PLT could in fact deliver more macro stabilization than does IT (Woodford 1999). This view relies heavily on the assumption that expectations of future inflation are forward looking and take into account, among other factors, the state-

1. It is important to note as well that the impact of price-level uncertainty is regressive. Low-income individuals cannot easily hedge this uncertainty.

2. In an alternative strand of the literature it is argued that, in the face of productivity shocks, an unvarying and hence "certain" price level is detrimental to economic agents who enter into nominal contracts (Selgin 1997).

ments and actions of a highly credible central bank. Under PLT, inflation expectations act as a powerful stabilizer, limiting the response of price- and wage-setters to shocks that have consequences for inflation.

This article provides a relatively non-technical summary of a recent Bank of Canada paper that compares the relative ability of PLT and IT to stabilize the macro economy when confronted by shocks similar to those seen in recent history.[3] The first part of the article explains the methodology, while the second section focuses on overall results, followed by a discussion of a number of sensitivity analyses. The third section pays special attention to the role played in the analysis by shocks to Canada's terms of trade. Our interest in terms-of-trade shocks comes about because, under PLT, persistent movements in the terms of trade could require significant declines in other relative prices in order to bring the average price level to target. In the presence of nominal rigidities, this could induce increased output variability. This argument is accentuated by the difference in price rigidities, which are greater in the non-traded goods sector of the economy than in the traded goods sector. The article concludes by highlighting future research.

Methodology

Coletti, Lalonde, and Muir (henceforth CLM 2008a, b) study the relative ability of PLT and IT to stabilize the macroeconomy in a state-of-the-art, multi-country, dynamic general-equilibrium model. CLM use a stripped-down version of the International Monetary Fund's Global Economy Model (GEM) (Pesenti 2008). The version of GEM used by CLM features two countries—Canada and the United States—and two sectors, tradable and non-tradable goods. Non-tradable goods are assumed to cover all services except financial services. All other goods are assumed to be tradable goods.

A key assumption of the study is that several differentiated tradable (and non-tradable) goods are being produced in each country.[4] Product differentiation gives firms some market power, which allows them to set a price that is above their marginal cost of production. Product differentiation also allows for the possibility that the basket of goods produced in Canada for export to the United States will be different from those produced by U.S. firms for export to Canada, leading to a meaningful distinction between the terms of trade and the real exchange rate.[5] Other important features of the model include nominal rigidities in the form of both wage and price rigidity. The model also allows for a form of indexing of inflation to past inflation, which can be thought of as reflecting the existence of rule-of-thumb price-setters who base their expectations of future inflation on last period's inflation outcomes. Real rigidities, including habit-formation in consumption and leisure and adjustment costs in investment, help to generate the observed persistence in movements in the real economy.

The study compares the ability of simple IT and PLT rules to stabilize the macroeconomy under the assumption that the two-country model would be hit by shocks similar in size to those seen in Canada and the United States over the 1983–2004 period.[6] The authors assume that the central bank cares principally about stabilizing the variability of output relative to production capacity and the variability of consumer price inflation.[7] More formally, the central bank seeks to minimize the following quadratic loss function:

$$\bar{L} = \sigma_{\pi}^2 + \sigma_{ygap}^2 + 0.1 \cdot \sigma_{\Delta R}^2 , \qquad (1)$$

where σ_{π}^2, σ_{ygap}^2, and $\sigma_{\Delta R}^2$ are the unconditional variances of the gap between consumer price inflation (π) and the target inflation rate (π^T), the output gap (*ygap*), and the change in the policy interest rate (ΔR).[8] The quadratic functional form is consistent with the notion that central banks view large deviations from the targets as disproportionately more costly than small variations. The weights on the various elements in the function imply that the central bank cares equally

3. This summary is based in part on Coletti, Lalonde, and Muir (2008a), which is forthcoming in a special issue of IMF Staff Papers on the International Monetary Fund's Global Economy Model (GEM) and its applications (2008). For a more complete technical description, see Coletti, Lalonde, and Muir (2008b).

4. Similarly, it is also assumed that workers offer differentiated skills to the labour market, as in Erceg, Henderson, and Levin (2000). For a more thorough non-technical description of the model, see CLM (2008b).

5. One notable shortcoming of the model is that it does not explicitly incorporate a commodities sector. Commodities are particularly important for understanding the evolution of Canada's terms of trade. This is an area for future work.

6. Although all shocks are considered to be temporary, they can be quite persistent (e.g., productivity shocks). Specific details on the shocks can be found in CLM (2008a, b).

7. An alternative approach to evaluating the merits of different monetary policy frameworks is to choose rules that maximize the welfare of the model's representative consumer. An important advantage of this approach is that it allows us to analyze which variables should be stabilized by monetary policy. On the downside, it also means that the welfare function will be model specific.

8. The output gap is the difference between the economy's actual output and the level of output that it can achieve with existing capital, the level of total factor productivity, and the trend in total hours worked.

about inflation and the output gap. The small weight on the change in the policy rate eliminates rules that cause the nominal interest rate to hit the zero lower bound more than five per cent of the time.[9]

We assume that the central bank commits to setting the contemporaneous policy interest rate, R, according to the simple rule:

$$R_t = \rho R_{t-1} + (1-\rho)R^* + \varphi_p(E_t p_{t+k} - \eta E_t p_{t+k-1} - p^T_{t+k} + \eta p^T_{t+k-1}) + \varphi_y(ygap_t), \quad (2)$$

where R^* reflects the sum of the average real short-term interest rate and the trend inflation rate, p denotes the logarithmic level of consumer prices, and E_t denotes expectations made in period t.[10] For IT, $\eta = 1$ while for PLT, $\eta = 0$. The central bank chooses the weight on interest-rate smoothing (ρ), the degree to which it reacts to expected deviations of consumer price inflation (or the price level) from target (φ_p), the degree to which it reacts to the output gap (φ_y), and the degree to which policy is forward looking (k) to minimize the objective function given in (1).

The model's parameters were chosen to allow it to closely replicate some of the key features of the Canadian and U.S. economies.[11] Of particular significance is the model's ability to replicate the persistence of consumer price and wage inflation over the sample period. The calibration is notionally consistent with assuming that about 40 per cent of firms and consumer-workers (rule-of-thumb agents) form inflation expectations based exclusively on last period's inflation rate. The remaining 60 per cent (forward-looking agents) are assumed to form their inflation expectations in a more forward-looking manner by taking into account all of the available information, including the structure of the economy, the realization of shocks, and the behaviour of the central bank.

9. This calculation is based on the assumption that the average real interest rate equals 3 per cent and the trend inflation rate equals 2 per cent.

10. Our analysis is restricted to consumer prices in the monetary reaction function. It may be preferable to target an alternative price index (e.g., non-tradable goods prices), particularly in the case of PLT. Examining which index is best to target is the subject of ongoing research.

11. Real data are detrended using a Hodrick-Prescott (H-P) filter with a stiffness parameter of 10,000. All Canadian nominal variables are detrended using the inflation target after 1991 and the implied inflation target calculated from the Bank of Canada's staff economic projection over the 1983–90 period (Amano and Murchison 2005). All U.S. nominal variables are detrended using an estimate of the implied inflation target in the United States (Lalonde 2005).

Results

Based on a set of macroeconomic shocks similar to those seen over the 1983– 2004 period, CLM show that PLT generates slightly greater macroeconomic stability than IT in terms of minimizing the weighted average of consumer price inflation, the output gap, and nominal interest rate variability in Canada (Table 1). To be more precise, PLT delivers a reduction in the variability in consumer price inflation and nominal interest rates at the expense of slightly higher variability in the output gap.

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From Table 1, we can also see that the quantitative difference between the two monetary policy frameworks is quite small (0.5 per cent) when measured relative to the gain in moving from an historical Taylor (1993) rule to the optimized IT rule.[12] It is important to remember, however, that the preferred IT rule puts a very high weight on interest-rate smoothing (Table 2). All else being equal, as this weight approaches 1, the inflation-targeting central bank acts increasingly like a price-level targeter. A weight of 1 on the lagged inter-

Table 1

Macroeconomic Stabilization

	Inflation targeting (IT)	Price-level targeting (PLT)
Loss function*	2.15	2.13
Incremental benefit**	–	0.5%
Standard deviations of key variables under the optimized rules		
Consumer price inflation	0.50	0.41
Output gap	1.34	1.37
Interest rate (change)	1.09	1.02

* Because of rounding, the results for the aggregate loss function may not correspond to the sum of its parts.

** Incremental benefit of moving from the optimized IT simple rule to the optimized PLT simple rule relative to the gain from moving from the historical Taylor rule to the optimized IT simple rule.

12. See CLM (2008b) for further details on the Taylor rules used to calibrate the model over history.

Table 2

The Optimized Simple Policy Rules

	Inflation targeting (IT)	Price-level targeting (PLT)
k	2	3
ρ	0.97	0.85
φ_p	2.44	3.74
φ_y	0.70	0.85

est rate would imply that nominal interest rates would continue to rise as long as inflation remained above target, resulting in a reversal of the initial shock to the price level. It is also interesting to note that the amount of interest rate smoothing suggested by the model is much greater than that typically found in empirical estimates of simple IT rules.[13]

To better understand the robustness of these results, CLM conduct two main sensitivity analyses. The first confirms findings in the existing literature that the relative ability of PLT versus IT to stabilize the macroeconomy depends on the degree to which prices are determined in a forward-looking manner. The more forward-looking price-setting becomes, the easier it is for the central bank to make a credible commitment to use PLT to reduce inflation variability without inducing excessive cycling in the real economy. We calculate that if the proportion of rule-of-thumb price- and wage-setters were increased from 40 per cent to 50 per cent, IT would be preferred to PLT. Based on more recent data, however, it is more reasonable to assume that a lower proportion of agents would form inflation expectations based on lagged inflation. In fact, focusing on the very low level of persistence in price and wage inflation over the inflation-targeting period in Canada would lead us to conclude that the proportion of rule-of-thumb price- and wage-setters was likely closer to zero than to 40 per cent. Even more convincing evidence from Levin, Natalucci, and Piger (2004) shows that, over the 1994–2003 period, private sector inflation expectations in Canada (and other inflation-targeting countries) have been decoupled from lagged inflation. In addition, the proportion of nominal wage contracts in Canada with a cost-of-living adjustment to past inflation has declined to about 10 per cent in recent years, from about 25 per cent in the 1980s (Fay and Lavoie 2002).[14] Such a reduction in the proportion of rule-of-thumb price- and wage-setters would strengthen the case for PLT.

The relative performance of the alternative monetary policy frameworks is also found to depend on an important interaction between the proportion of rule-of-thumb price- and wage-setters and the relative incidence of shocks. Specifically, as long as there is a significant proportion of rule-of-thumb price- and wage-setters, the relative importance of the different shocks to the economy matters for the overall results.

In the base-case calibration, PLT is preferred to IT in the case of shocks to the economy that cause consumer price inflation and the output gap to move in the same direction, such as domestic demand shocks and all foreign shocks (type A shocks).[15] On the other hand, IT generates more macroeconomic stability than PLT for shocks that cause inverse movements in inflation and the output gap, such as domestic price / wage shocks (type B shocks).[16]

Although the cumulative output gap is larger under PLT, the PLT output gap has a smaller variance than that under IT.

The intuition for this result comes from considering type A and type B shocks under the assumption that there are no rule-of-thumb price- and wage-setters. First, consider a positive shock to domestic prices (a type B shock) under PLT (see Chart 3). The central bank's commitment to a target path for the price level implies that future inflation rates must be lower under PLT than under IT. As a result, the initial rise in inflation is lower than that under IT. The reduction in inflation volatility is not merely the result of the central bank's announcement of a target path for the price level. To generate the reduction in inflation volatility, the central bank creates relatively more cumulative

13. The reasons for this are interesting in their own right, but are beyond the scope of this article.

14. In addition, Amano, Ambler, and Ireland (2008) show that the degree of indexation of nominal wage contracts to lagged inflation would be lower under PLT than under IT.

15. For example, a positive U.S. demand shock leads to higher Canadian exports, a positive Canadian output gap, higher Canadian import prices, and a rise in Canadian inflation. Alternatively, a negative U.S. price (or positive U.S. productivity) shock in the non-tradable goods sector leads to a rise in the demand for labour in the United States, a higher wage, and a rise in the price of traded goods produced in the United States. In turn, a rise in U.S. traded-goods prices leads to both an increase in Canadian import prices and positive excess demand in Canada, owing to a rise in exports to the United States.

16. More formally, price and wage shocks are shocks to the degree of competition in product and labour markets.

Chart 3

A Positive Price Shock

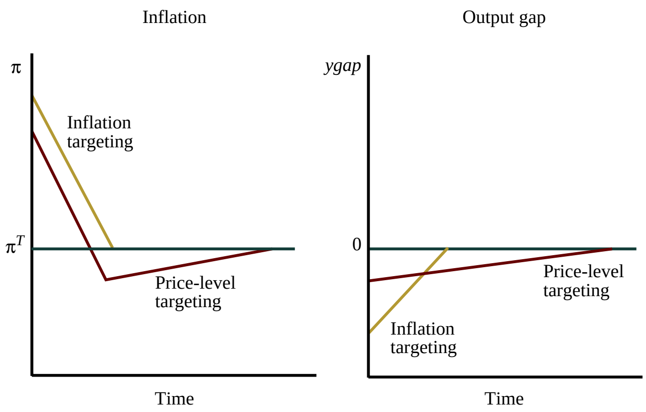
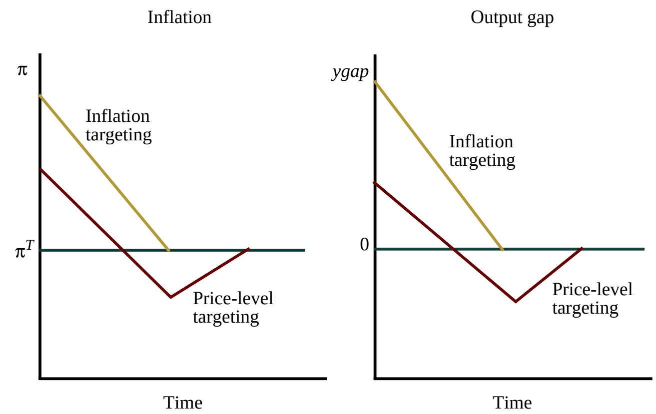


Chart 4

A Positive Demand Shock



excess supply under PLT than under IT. In fact, as long as the price level is above the target, PLT requires excess supply. Under PLT, all else being equal, the central bank will find it optimal to create less initial excess supply that lasts longer relative to IT. Taken together, this means that although the cumulative output gap is larger under PLT, the PLT output gap has a smaller variance than that under IT.[17]

Now consider a positive demand shock (a type A shock). Once again, the initial rise in inflation under PLT is smaller than under IT as a result of the central bank's commitment to a target path for the price level (Chart 4). The commitment to PLT also means that the central bank must create excess supply at some time in the future under PLT, but not under IT. In addition, the initial jump in the output gap under PLT is also smaller than it is under IT. Consequently, both the cumulative output gap and the variance of the output gap under PLT are smaller than they are under IT.

In the absence of rule-of-thumb price- and wage-setting, the relative benefits of PLT versus IT are larger for type A shocks than for type B shocks. As the proportion of rule-of-thumb price- and wage-setters rises, the central bank has an increasingly difficult time reducing inflation variability without incurring a relatively large increase in output-gap variability. When the proportion of rule-of-thumb price- and wage-setters reaches about 40 per cent, as in CLM, PLT delivers better results for both output and inflation variability in type A shocks, but IT is preferred in type B shocks. As a result, the overall assessment of the relative ability of PLT and IT to stabilize the macroeconomy depends, among other factors, on the relative incidence of type A and type B shocks.

17. Recall that the variance squares the output gap.

Terms-of-Trade Shocks

We now turn our attention from the aggregate results to the specific issue of large and persistent shocks to the terms of trade. A nation's terms of trade are the price of its exports relative to the price of its imports. The evolution of Canada's terms of trade since 1961 is shown in Chart 5. Since Canada is a relatively small country on the global stage, the prices of both its imports and exports are heavily (but not exclusively) determined by developments outside of Canada. Historically, Canada's terms of trade have been most influenced by fluctuations in the world price of its key (net) exports, energy and non-energy commodities,[18] as well as movements in the world price of its key (net) imports, computers and peripheral equipment (Amano, Coletti, and Murchison 2000). More recently, falling prices of imported consumer goods from emerging economies have also boosted Canada's terms of trade (Duguay 2006; Macdonald 2007).[19]

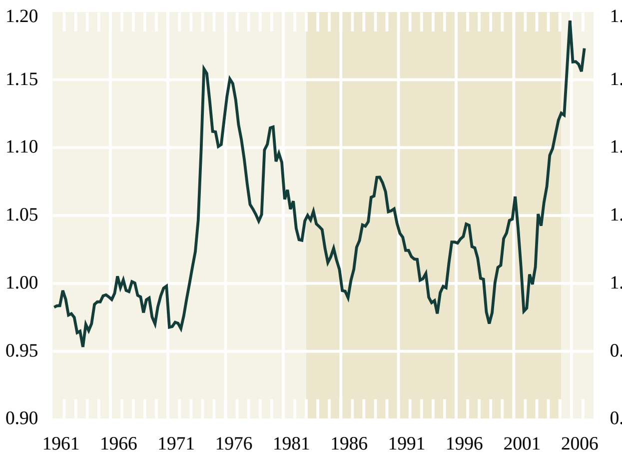
18. Commodity production represents about 11 per cent of Canadian gross domestic product (GDP), and commodity exports account for 45 per cent of the dollar value of our total exports (Duguay 2006).

19. In some cases, however, the source of the terms-of-trade shock could emanate from Canada itself. For example, there are some sectors in which developments in Canada are able to influence international prices because of the large market share enjoyed by Canadian producers (e.g., North American natural gas prices). Alternatively, Canadian producers can also face a downward-sloping demand curve in international markets because they produce a relatively differentiated product (e.g., certain automobile models, telecommunications equipment, and aircraft and transportation equipment).

Chart 5

Terms of Trade for Canada

Sample period is 1983 to 2004



Improvements in Canada's terms of trade are generally thought to have an important positive influence on the economy.[20] All else being equal, higher terms of trade means that the price of the goods Canadians sell to foreigners has gone up relative to the price Canadians pay to foreigners for their goods. On balance, Canadians receive a net transfer of wealth from our trading partners, which has two important implications for the behaviour of Canadians. First, it means that our real purchasing power has increased, thereby allowing a higher level of consumption. Second, it also means that Canadians will tend to consume relatively more imports than domestically produced goods. An improvement in the terms of trade also affects the relative level of activity in different sectors of the economy as labour and capital move into the sectors where the returns are higher.

Our special interest in terms-of-trade shocks stems from their importance for the Canadian economy and the fact that monetary policy under PLT and IT would respond differently to these shocks. Under IT, the central bank would largely ignore the initial change in the aggregate consumer price level caused by the change in the terms of trade and instead focus on returning aggregate inflation to its target. This response might involve a relatively modest change in policy interest rates with implications for the aggregate output gap and for production levels in both the tradable and non-tradable goods sectors.

20. A notable exception would be a terms-of-trade improvement resulting from a negative supply shock in a sector in which Canada enjoys important market power.

In contrast, under PLT, movements in the terms of trade could require significant changes in other relative prices in order to return the average consumer price level to target. The added inflation volatility could induce increased output variability, especially since price rigidities in the non-traded goods sector are greater than those in the traded goods sector.

Under PLT, movements in the terms of trade could require significant changes in other relative prices in order to return the average consumer price level to target.

Recall, however, that there are offsetting forces at play under PLT. As discussed earlier, a credible commitment to PLT can serve to reduce the variability of inflation relative to IT. The quantitative importance of this channel depends negatively on the proportion of rule-of-thumb price- and wage-setters and positively on the proportion of type A shocks.

It therefore becomes important to identify the sources of terms-of-trade shocks in order to quantify the relative strengths of the competing forces under PLT. An historical analysis with the stripped-down, two-country version of the GEM suggests that most of the variability in Canada's terms of trade is caused by foreign shocks, which generate a positive correlation between the output gap and consumer price inflation in Canada. In particular, the main shocks are: i) U.S. consumption shocks, ii) U.S. import shocks, and iii) exchange rate shocks.[21] Consequently, the authors find that the stabilizing effect of a credible commitment to PLT dominates the other forces at play. As a result, they conclude that PLT delivers better macroeconomic stability than does IT for shocks to Canada's terms of trade.

Conclusions and Future Work

The Bank of Canada research by Coletti, Lalonde, and Muir reviewed in this article suggests that macroeco-

21. This result may be sensitive to the specification and calibration of the model as well as to the historical time period under consideration. For example, the 1983–2004 period studied here largely ignores the large rise in Canada's terms of trade over the 2003–07 period that was driven by strong demand for commodities from emerging Asia, as well as the two major supply-driven world-oil-price shocks of the early 1970s and early 1980s. The implications of these events for the relative merits of IT and PLT are currently being studied.

nomic stability under PLT would be slightly better than under IT. In addition, when the analysis is restricted to the basket of shocks that have been identified as the most influential for the determination of Canada's terms of trade over the 1983–2004 period, PLT is found to deliver slightly better macroeconomic stability. An important result is that the relative ability of PLT and IT to stabilize the macroeconomy is quite sensitive to the fraction of rule-of-thumb wage- and price-setters in the economy and the relative incidence of the different types of shocks that can hit the economy.

Because of several important uncertainties in the analysis, the results of this research should be interpreted as merely indicative. In particular, the structure and calibration of the model are imperfect approximations of the actual economy. In addition, the relative incidence of future shocks could be very different than that seen over the 1983–2004 sample.

Considerable research is being done at the Bank of Canada to improve our understanding of the relative merits and costs of price-level targeting. This work includes extensions of the analysis reported here that focus on the special role that terms-of-trade shocks could play. Specifically, research is currently being done to study the impact of: i) including a formal commodity-producing sector in the analysis,[22] ii) examining whether the results are sensitive to allowing for permanent shocks to the terms of trade, and iii) reconsidering which index would be best to target under PLT. Lastly, since large and persistent movements in the terms of trade generate significant shifts in production and employment across different sectors and geographical regions in the economy, there is considerable interest in better understanding the implications of the relative merits of PLT and IT in incorporating the costs of reallocating capital and labour across sectors.

22. This analysis is being conducted with the Bank of Canada's version of the GEM, BoC-GEM (Lalonde and Muir 2007). BoC-GEM differs significantly from the stripped-down version of GEM used in CLM. Most notably, BoC-GEM incorporates five regions as well as energy and non-energy commodities sectors.

Literature Cited

Amano, R., S. Ambler, and P. Ireland. 2008. "Price-Level Targeting, Indexation, and Welfare." Bank of Canada Working Paper. Forthcoming.

Amano, R., D. Coletti, and S. Murchison. 2000. "Empirical Estimation and the Quarterly Projection Model: An Example Focusing on the External Sector." Sveriges Riksbank Working Paper No. 104.

Amano, R. and S. Murchison. 2005. "Factor-Market Structure, Shifting Inflation Targets, and the New Keynesian Phillips Curve." In *Issues in Inflation Targeting*, 89–109. Proceedings of a conference held by the Bank of Canada, April 2005. Ottawa: Bank of Canada.

Ambler, S. 2007. "Price-Level Targeting and Stabilization Policy: A Review." Bank of Canada Discussion Paper No. 2007–11.

Bank of Canada. 2006. *Renewal of the Inflation-Control Target: Background Information*. Ottawa: Bank of Canada. Available at http://www.bankofcanada.ca/en/press/background_nov06.pdf.

Coletti, D., R. Lalonde, and D. Muir. 2008a. "Inflation Targeting and Price-Level Path Targeting in the GEM: Some Open Economy Considerations." IMF Staff Paper. Forthcoming.

———. 2008b. "Inflation Targeting and Price-Level Path Targeting in the GEM: Some Open Economy Considerations." Bank of Canada Working Paper. Forthcoming.

Côté, A. 2007. "Price-Level Targeting." Bank of Canada Discussion Paper No. 2007–8.

Duguay, P. 2006. "Productivity, Terms of Trade, and Economic Adjustmen.t." Remarks to the Canadian Association for Business Economics, Kingston, Ontario, 28 August.

Erceg, C. J., D. W. Henderson, and A. T. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

Literature Cited (cont'd)

Fay, B. and S. Lavoie. 2002. "How Certain Are We About the Role of Uncertainty in the Labour Contract Duration Decision?: Evidence for Canada and Implications." In *Price Adjustment and Monetary Policy*, 155–98. Proceedings of a conference held by the Bank of Canada, November 2002. Ottawa: Bank of Canada.

Lalonde, R. 2005. "Endogenous Central Bank Credibility in a Small Forward-Looking Model of the U.S. Economy." Bank of Canada Working Paper No. 2005–16.

Lalonde, R. and D. Muir. 2007. "The Bank of Canada's Version of the Global Economy Model (BoC-GEM)." Bank of Canada Technical Report No. 98.

Lavoie, C. and S. Murchison. 2008. "The Zero Bound on Nominal Interest Rates: Implications for Monetary Policy." *Bank of Canada Review,* this issue, pp. 27–34.

Levin, A. T., F. M. Natalucci, and J. M. Piger. 2004. "The Macroeconomic Effects of Inflation Targeting." *Federal Reserve Bank of St. Louis Review* 86 (4): 51–80.

Macdonald, R. 2007. "Not Dutch Disease, It's China Syndrome." *Canadian Economic Observer* 20: 3.1–3.11. Statistics Canada Catalogue No. 11–010.

Pesenti, P. 2008. "The Global Economy Model (GEM): Theoretical Framework." IMF Staff Papers. Forthcoming.

Selgin, G. A. 1997. "Less Than Zero: The Case for a Falling Price Level in a Growing Economy." Institute of Economic Affairs Hobart Paper No. 132.

Svensson, L. E. O. 2008. "Inflation Targeting." In *The New Palgrave Dictionary of Economics*, 2nd edition, edited by L. Blum and S. Durlauf. Forthcoming (May).

Taylor, J. B. 1993. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195–14.

Woodford, M. 1999. "Optimal Monetary Policy Inertia." National Bureau of Economic Research (NBER) Working Paper No. 7261.

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