Inflation Risk Premiums and Inflation Targeting: An Empirical Measure of Credibility

*Ivan Medovikov and Ksenia Bushmeneva**

Abstract

In this paper we attempt to empirically establish credibility of inflation targets set by the Bank of Canada, using inflation risk premiums on Government of Canada nominal marketable bonds. Explanatory power of the distance of observed inflation from target over inflation risk premiums is interpreted as degree of credibility. We use diagrammatic framework, and develop simple analytical model to demonstrate these ideas. We find that the distance from target is statistically significant, suggesting high degree of credibility over the past decade, and that inflation close to upper or lower bounds of the inflation target range is associated with lower inflation risk premiums than inflation on target.

JEL Classifications: E58, E52, E43, E44.

Keywords: Inflation Targeting, Credibility, Monetary Policy, Real Return Bonds.

1. Introduction

Conventional macroeconomic theory suggests that anticipated and unanticipated inflation causes agents to economize on real money balances and brings uncertainty and risk to financial markets. Empirical studies of long-run welfare costs of inflation are divided in their findings. Lucas (2000), Barro (1996), Tryon (1993), Altig and Bryan (1993) and Fisher (1991) find negative correlation between rate of inflation and growth rate of real output. On the other hand, by analyzing data for 110 countries over 30 years, McCandless and Weber (1995) find that in the long run rates of inflation and growth of real output are essentially uncorrelated. The latter finding puts under question the long-term merit of monetary policy as such. Whether inflation is costly in terms of output or not, the general consensus in the literature is that lower rates of inflation are preferred over high rates, and surveys such as Tella et al. (2001) show strong preference over low inflation among the general public.

*We are grateful to the Course Committee: Professors Sicular, Livshits and Professor Brzozowski for their help and guidance. We also wish to thank to Prof. Nathan Sussman of Hebrew University of Jerusalem for his enduring advisory.

The disinflation seen in some developed countries, including Canada, over the past decade and a half is often attributed to explicit inflation targeting adopted by the central banks and their spelled-out commitment to price stability. The adoption of the two percent inflation target with one to three percent target range by the Bank of Canada in the mid-1990s is largely seen as effective. Canadian core CPI, the Bank of Canada's operational target, averaged to about two percent over the past decade and remained within the target bound most of the time.[1] However, success of inflation targeting can be challenged by comparing the performance of inflation-targeting central banks with non-targeters. Neumann and von Hagen (2001) investigate performance of six inflation-targeting central banks before and after adoption of inflation targets. Inflation targeting is found useful in reducing the level and volatility of inflation, but none of the inflation-targeting banks significantly outperform non-targeters. Kuttner and Posen (1999) and Johnson (1998) also present mixed evidence on the effectiveness of inflation targeting.

Whether they are effective, inflation targets serve as an important nominal anchor, which decreases the costs of forming expectations and reduces uncertainty. Mishkin (2000) emphasizes the role of inflation targeting as a source of transparency, accountability and as a safeguarding measure that helps to ensure that the Central Bank's policy is time-consistent. In return, these benefits can lead to a more efficient financial market and more favorable conditions for foreign investment. We believe that these merits of explicit inflation targeting are important and should be emphasized in monetary policy discussions.

In order for inflation targets to fulfill this role, credibility of the policy is required. A non-credible nominal anchor does not provide any significant information to the agents and its benefits are diminished. It is, therefore, important for the central bank to build and maintain credibility, and be able to establish some measure of credibility which can be monitored over time.

Several measures of credibility have been developed and assessed in the literature. Most studies interpret the spread between target value and expected inflation, which is commonly obtained from forecasts or derived empirically, as a proxy for credibility. This difference between inflation expectations and the single value of the policy target can be an incomplete and biased measure. Central banks choose a range rather than the single value of acceptable inflation as their operational target, and inflation above or below the target but within the target range can still be consistent with the Bank's policy. Agents can view the policy as highly credible, and at the same time expect inflation to be different from the target but within the bound, which would falsely imply lack of credibility. Many authors recognize these limitations and point out that other variables such as inflation risk premium on financial assets could be a better source of information (Remolona et al. (1998)).

Financial markets are highly efficient, and in most cases, correctly interpret information and signals available to them. Beliefs of the market participants about Bank of Canada's ability to keep inflation within the bound and their inflation expectations are conveyed through asset prices, and this motivates our choice of inflation risk premiums as a variable of interest. By definition, inflation risk premium indicates the level of perceived inflation uncertainty. This suggests that

[1] For discussion of recent Canadian monetary policy see Laidler and Robson, "The two percent target: Canadian monetary policy since 1991", 2004.

under the assumption of perfect credibility, markets should behave as if inflation cannot lie outside the target bound set by the bank. The degree, to which the markets exhibit this behavior, in other words the likelihood with which they believe inflation will remain within the target bound, can be interpreted as credibility. In the present study we will express these ideas in a simple model and attempt to empirically establish the level and evolution of credibility over time using inflation risk premiums seen in secondary market for Government of Canada marketable bonds. Empirical approach to establishing credibility and a new quantifiable measure is the main contribution of the present study.

The rest of this paper is organized as follows. Section II provides an overview of credibility studies to date. Section III reviews theoretical foundations for our measure of credibility and presents a simple model. Section IV presents our empirical model and findings. Section V concludes.

2. Margin of Research

Few studies address credibility of inflation targets directly. Most works, however, fall into three categories based on definition of credibility. First group views difference between polled anticipated and target inflation as a primary measure. Second group focuses on distance between anticipated targets and actual inflation targets. Third group encompasses data extracted from financial markets into their analysis. The latter approach will be especially helpful to our work.

Johnson (1998) interprets the spread between the forecasted inflation and inflation target as a measure of credibility. Using data for Canada, Australia, New Zealand, Finland and Sweden from 1985 to 1995 he finds that disinflation of the early 1990s was not anticipated, and therefore inflation targeting was not immediately credible. Author believes that inflation targeting policy made a significant contribution to the disinflation at the time.

Similarly to Johnson (1998), Reid, Dion and Christensen (2004) contrast the movements in expected inflation with changes in the policy instrument to make inferences about credibility. Long-term inflation expectations are approximated using break-even inflation rate, or BEIR, which is the spread between yields on Government of Canada nominal and real return bonds (RRBs). Assuming that BEIR captures inflation expectations correctly, the difference between the BEIR and the Bank of Canada target value of inflation can be interpreted as a measure of credibility. Values of BEIR from 1994 to 1999 converge to two percent, possibly indicating credibility gains, but diverge for 2000 and subsequent years[2].

BEIR systematically differs from inflation expectations obtained from the polls of forecasters. The spread between nominal and real bond yields includes other variables such as inflation risk and liquidity premiums together with expected inflation and accounts for market segmentation, which makes BEIR a noisy and imprecise measure. This significantly diminishes the usefulness

[2] Figure 1 in the Appendix shows the break-even inflation rate obtained from yields on Government of Canada nominal and real return bonds from 1991 to 2006.

of surveying the BEIR in order to establish credibility, which is widely recognized in Reid et al. (2004).

Unlike inflation forecasts, inflation risk premium is not reported but can be derived from market data. Fung, Mitnick and Remolona (1999) empirically extract information about inflation expectations and risk premiums using comovements of interest rates across the yield curve for Canada and the United States. By contrasting inflation expectations with the inflation target they find that targeting slowly gained credibility since 1993. Inflation expectations obtained in Fung et al. (1999) systematically differ from polled expectations, which is recognized by the author.

Remolona, Wickers and Gong (1998) and Shen (1998) use data for UK nominal and inflation-indexed government bonds and polled inflation expectations to factor out and study the time path of inflation risk premiums in the UK bonds market. The premiums are found to be responsive to major policy chances. In particular, IRPs declined by 70 basis points after the UK left the European Exchange Rate Mechanism in 1992.

Statistical relationship between inflation risk premiums and various monetary policy initiatives such as inflation targeting has not been previously addressed in the literature. In the present study, inflation risk premium is modeled as a dependent variable, and features of the targeting policy regime are shown to have significant explanatory power over IRP. This is interpreted as evidence of credibility.

3. Theoretical Model

3.1 General Specification

The model consists of agents who participate in secondary markets for nominal and real return (inflation-index) government bonds, and the central bank. Agents are holding portfolio of assets which consists of nominal and real return bonds. Composition of portfolio changes in response to changes in expected inflation, inflation risk and relative liquidity between the two assets. Inflation risk, a prime variable of interest in our study, represents the likelihood that actual inflation will be different from expected in the future. This interpretation is consistent with earlier studies of inflation risk. Prices of bonds in the bond markets are determined by demand and supply, and market prices inversely determine bond yields. In accordance with standard theory of asset price determination[3], the spread between equilibrium yields in the market for inflation-indexed bonds and nominal marketable bonds is a sum of expected inflation, liquidity premium which is required by the agents to compensate for differences in liquidity between the two assets, and inflation risk premium. Changes in any of the three variables shift demand and supply curves in the two markets, which determine equilibrium bond prices, bond yields and in return risk and liquidity premiums.

[3] For example, see Mishkin, F., and A. Sterletis. "The Economics of Money, Banking, and Financial Markets", 2004.

3.2 Bond Markets

For simplicity, both bonds are assumed to be issued for the period of one year with no coupon payments, with identical face values and are redeemable at par. Yields on nominal and real return bonds are:

$$y_r = \frac{V - P_r}{P_r} \quad (1)$$

$$y_n = \frac{V - P_n}{P_n} \quad (2)$$

Where y_r is the yield on real return bond, y_n – yield on nominal return bond, P_r, P_n are the respective prices for inflation-indexed and nominal bonds, and V is the redemption value of both bonds. Initial equilibrium in the two bonds markets is shown in Figure 1. The initial equilibrium assumes some positive yield differential between the nominal and inflation-indexed government bonds.

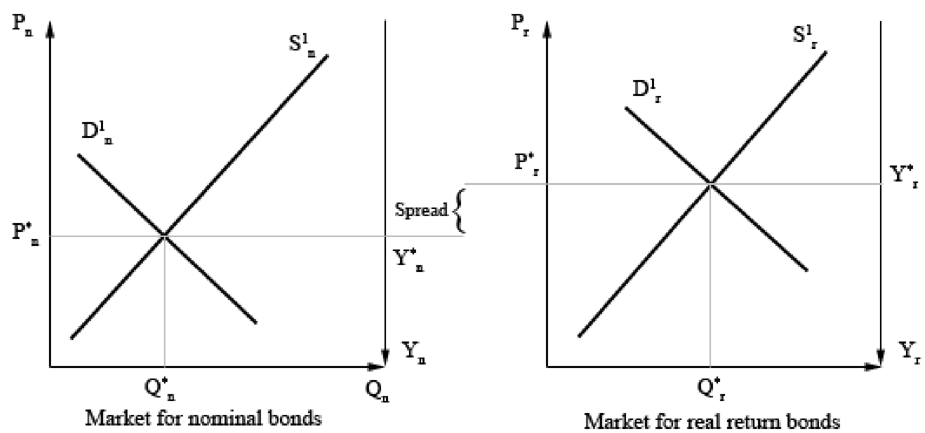

Figure 1. Initial equilibrium in the market for nominal and inflation-indexed bonds.

P^*_n, P^*_r are prices, and Q^*_n, Q^*_r are equilibrium quantities of nominal and real bonds. Y^*_n and Y^*_r are equilibrium yields.

Inflation-indexed and nominal marketable bonds are assumed to be substitutes. Due to their inflation-indexed nature, real-return bonds do not expose bond holder to inflation risks. Both bonds have zero risk of default, and real return bonds are assumed to be less liquid. The bonds are otherwise identical to the potential investor. The spread between the yields on nominal and real return bonds is therefore a sum of expected inflation, inflation risk and liquidity premiums. The following proposition is expressed in equation (3) below.

$$y_n - y_r = \pi_e + IRP + LP \quad (3)$$

Where π_e is expected rate of inflation, *IRP* is inflation risk premium and *LP* is liquidity premium. Both premiums are measured as percent of the yield on nominal bond. Inflation risk premium compensates nominal bond holder for inflation-related uncertainty over future value of her investment income, and liquidity premium accounts for relative differences in costs of searching for a buyer or seller of the two securities.

When bond markets are in equilibrium, equation (3) will hold with equality. If it was otherwise, for example, if $y_n > y_r + \pi_e + IRP + LP$, the net real return on nominal bonds would be greater than return on real bonds. Investors would want to substitute out of real into higher-yielding nominal bonds, since they can be compensated for higher inflation risk, for expected depreciation of the nominal value of their future income, for different level of liquidity, and still earn additional profits. This will drive the prices of nominal bonds up and yields down. Therefore, $y_n > y_r + \pi_e + IRP + LP$ can not be sustained in equilibrium. Similarly, if $y_n < y_r + \pi_e + IRP + LP$, net returns from investing in the real bonds market are higher than net returns on nominal bonds. Investors will substitute into real bonds, driving the real yields down. This means $y_n < y_r + \pi_e + IRP + LP$ also cannot be sustained. Therefore, it must be that in equilibrium, equation (3) holds with equality. This can be thought of as a no-arbitrage condition in the bonds markets, which ensures that in equilibrium there are no positive risk-free economic profits to be made.

Demand and supply functions of both nominal and real return bonds respond to changes in the level of expected inflation, changes in relative liquidity, which is defined as the extent to which nominal bonds are more liquid than real bonds, and to the changes in inflation risk, which are exogenous to both secondary markets. Increase in the level of expected inflation, level of inflation risk, and decrease in the level of relative liquidity makes nominal bonds less attractive and real return bonds more attractive to the risk-averse investors, on the margin causing them to substitute out of nominal bonds into real bonds. As a result, demand for nominal bonds drops, supply of nominal bonds increases, demand for real return bonds increases and supply of real return bonds drops. Similarly, a decrease in the level of expected inflation, decrease in the level of inflation risk and increase in the relative liquidity makes nominal bonds more attractive. Inverse demand and supply functions for nominal and real bonds are captured in equations (4) to (7).

$$P_r = a + bQ_r^S + \alpha\pi_e - \gamma L + \beta R_\Pi \quad (4)$$

$$P_r = c - dQ_r^D + \delta\pi_e - \varepsilon L + \phi R_\Pi \quad (5)$$

$$P_n = e + fQ_n^S - \eta\pi_e + \kappa L - \lambda R_\Pi \quad (6)$$

$$P_n = g - hQ_n^D - \mu\pi_e + \varpi L - \nu R_\Pi \quad (7)$$

Where Pr, Pn are the prices of real return and nominal bonds, QSr, QSn QDr, QDn are respective quantities supplied and quantities demanded of real and nominal bonds, πe is the level of expected inflation, RΠ is the level of inflation risk and L is the level of relative liquidity. α,β,γ,δ,ε,φ,κ,λ,μ,ν,ϖη are the parameters which determine how responsive are demand and supply in both markets to RΠ,L and πe. For example, a unit increase in the measure of inflation risk RΠ will shift the demand curve (7) for nominal bonds to the left by ν. These effects are summarized in Table 1.

Change in demand and supply	**Change in exogenous variable**		
	R_Π increase (decrease)	L increase (decrease)	π_e increase (decrease)
Real Return Bonds			
Demand	↑(↓)	↓(↑)	↑(↓)
Supply	↓(↑)	↑(↓)	↓(↑)
Nominal Return Bonds			
Demand	↓(↑)	↑(↓)	↓(↑)
Supply	↑(↓)	↓(↑)	↑(↓)

Table 1. Effects of change in the levels of inflation risk, relative liquidity and expected inflation on demand and supply in the markets for nominal and inflation-indexed (real return) government bonds.

Figure 2 shows the effects of the increase in the level of inflation risk on both markets for a given level of relative liquidity and expected inflation. Since agents are assumed risk-averse, there is a substitution out of now riskier nominal bonds into inflation-indexed "real" bonds. Supply and demand in both markets adjust accordingly, setting new market prices and yields.

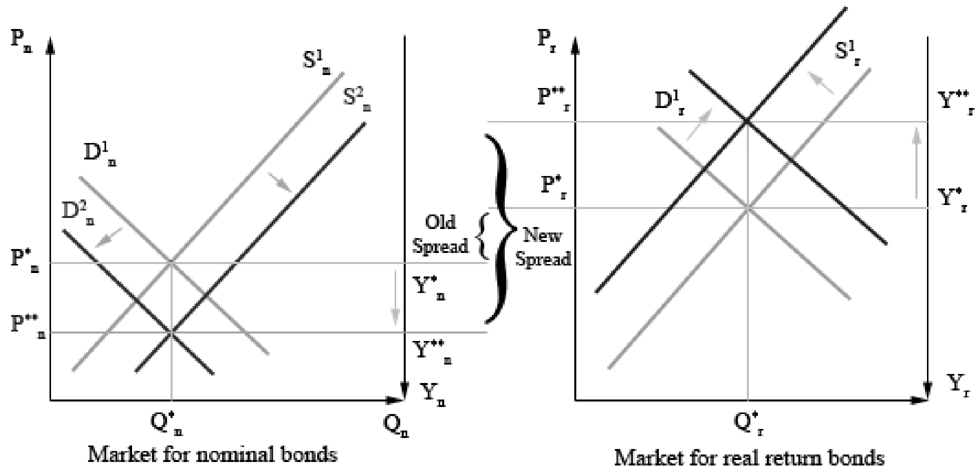

Figure 2. Effects of increase in the level of inflation risk on the markets for nominal and inflation-indexed bonds. Grey lines represent initial equilibrium from Figure 1. Y^{**}_n, Y^{**}_r are the new equilibrium yields.

The yield differential widens, which accounts for an increase in inflation risk premium.

3.3 The Central Bank

The central bank adopts explicit inflation targeting, and announces inflation target and target range, which are known to the agents. To model the behavior of the Bank of Canada, we let inflation target to be 2%, with a target range of 1% to 3%.

3.4 Credibility

Market participants view inflation as exogenous. Every time period new value of year-over-year inflation becomes known to participants. Since inflation may or may not be on target, we let d_t be the distance of inflation from the central bank's target in period t.

$$d_t = |\pi_t - 2| \quad (8)$$

Credible targets

If inflation targets are credible, agents believe that inflation will remain within bounds, and d_t will lie between 0 and 1. If π_t is on target, increase or decrease in π_{t+1} up to 1% in either direction will be consistent with the central bank's policy. Agents are therefore presented with considerable uncertainty about future inflation, as inflation can go up or down in the next period. If π_t is above target, central bank will attempt to bring inflation down in the next period. From the agents' perspective, it is now more likely that inflation will decrease in the next period, rather than increase, which means there is less uncertainty about the level of inflation than there was when inflation was on target. Similarly, when π_t is below target, it is more likely that inflation will increase, meaning there is less inflation risk than when π_t=2%.

The relative likelihoods with which inflation will go up or down, and therefore the level of inflation risk, depend on values of d_t. For example, if π_t is severely off target at 3%, d_t =1, under perfect credibility, agents believe that inflation in the next period is almost certain to decrease, and if π_t is at 1% (d_t=1), that it is almost certain to increase. This entails very little inflation risk, making nominal bonds more attractive than before. Under the assumption of perfect credibility, the level of inflation risk and inflation risk premium are inversely related to d_t.

Non-credible policy

In the absence of credibility, values of d_t convey no information about the relative likelihoods of an increase or decrease in future inflation to the agents. If inflation today is at 3%, inflation tomorrow is as likely to increase, as it is to decrease, unlike in perfectly credible case, where agents believe it can only decline.

Measure of credibility

If inflation targets are perfectly credible, distance of inflation from target has high explanatory power over inflation risk premiums seen in the markets, and it has no power in explaining IRP's when credibility is completely absent. If inflation targeting is only partially credible, d_t explains some variation in IRP, depending on the degree of credibility. Inflation risk, and as result, inflation risk premium, is therefore a sum of two components: a function F of "regime uncertainty" and some decreasing function G of the values of d_t. This is a modification of formulation of sources of inflation uncertainty seen in Evans and Wachtel (1993), where uncertainty is decomposed in the two categories: "regime uncertainty" and "certainty equivalence".

In our model, regime uncertainty entirely determines IRP under no credibility, and a function of d_t determines IRP under perfect credibility. This idea is captured in equations (9) and (10), where $0 \leq \rho \leq 1$ is a credibility parameter and R is the level of inflation risk.

$$R = (1-\rho)F(\cdot) + \rho G(d_t) \quad (9)$$

$$IRP = Z[R] = Z[(1-\rho)F(\cdot) + \rho G(d_t)] \quad (10)$$

Inflation risk premium is some increasing function Z(·) of R. Z[R] takes a unit of the measure of inflation risk, and converts it into a unit of measure of inflation risk premium, which is percent yield on nominal bond. Substituting for R in equation (10) gives IRP in terms of regime uncertainty, distance of inflation from target and credibility parameter.

Inflation targets are perfectly credible when ρ=1, and are completely not credible when ρ=0. Regime uncertainty F(·) can be a function of such variables as some political conditions index or level and volatility of inflation in countries which are major trading partners. The level of inflation risk R represents the likelihood that actual inflation will be different from what is expected. For example, for a given level of expected inflation, high chance of war in the oil-producing regions of the Middle East will represent a higher level of inflation risk, as it is likely to result in a shock to fuel prices, driving down the real value of future investment income from nominal bonds. It should be noted that knowing $G(d_t)$ is sufficient to determine credibility parameter ρ. We therefore do not need information about variables in F(·) for empirical analysis, since variations in inflation risk premium that are not explained by $G(d_t)$ can automatically be attributed to the effects of F(·).

The theoretical model is not sensitive to most simplifying assumptions. For example, if we assume that bonds are no longer substitutes, changes in inflation risk will generate similar changes in inflation risk premiums, but smaller in magnitude.

Simplified analytical model

By adopting several simplifying assumptions, we can solve analytically for equilibrium in the markets for real and nominal bonds, and demonstrate the effects of change in the level of inflation risk on inflation risk premium when the policy is credible, and when it is not. Assuming that relative liquidity and inflation expectations are constant when the change in inflation risk occurs, and that demand and supply curves in both markets respond to changes in level of inflation risk symmetrically, equations (4)-(7) can be re-written as follows:

$$P_r = \alpha - \beta Q_r^D + \gamma R \quad (10)$$

$$P_r = \delta + \beta Q_r^S + \gamma R \quad (11)$$

$$P_n = \varepsilon - \beta Q_n^D - \gamma R \quad (12)$$

$$P_n = \theta + \beta Q_n^S - \gamma R \quad (13)$$

Where (10) and (11) are respective demand and supply functions in the market for real bonds, (12) and (13) – in the market for nominal bonds. R is a measure of the level of inflation risk. The Greek-letter parameters in equations (10)-(13) are different from parameters in equations (4)-(7). Measures of liquidity and inflation expectations are captured in intercept terms α, δ, ε, θ since they no longer vary. Market-clearing in the two markets imposes: $Q_r^D = Q_r^S = Q_r^*$, $Q_n^D = Q_n^S = Q_r^*$, and $\{P_r^*, P_n^*, Q_r^*, Q_n^*\}$ are the quantities and prices that solve (10)-(13).

$$P_n^* = \frac{1}{2}\theta + \frac{1}{2}\varepsilon - \gamma R \quad (14)$$

$$P_r^* = \frac{1}{2}\alpha + \frac{1}{2}\delta + \gamma R \quad (15)$$

The price of nominal bond is decreasing, and price of real bond is increasing in the level of inflation risk. Positive price requires that $\gamma R < \frac{1}{2}\theta + \frac{1}{2}\varepsilon$. Substituting (14) and (15) into yield equations (1) and (2) gives:

$$y_n^* = \frac{V}{\frac{1}{2}\theta + \frac{1}{2}\varepsilon - \gamma R} - 1 \quad (16)$$

$$y_r^* = \frac{V}{\frac{1}{2}\alpha + \frac{1}{2}\delta + \gamma R} - 1 \quad (17)$$

Nominal yield is increasing, and real yield is decreasing in the level of inflation risk, for non-negative ranges of the yields. Subtracting equation (17) from equation (16) gives yield differential from equation (3) as function of the level of inflation risk and demand/supply functions parameters.

$$y_n^* - y_r^* = \frac{V}{\frac{1}{2}\theta + \frac{1}{2}\varepsilon - \gamma R} - \frac{V}{\frac{1}{2}\alpha + \frac{1}{2}\delta + \gamma R} \quad (18)$$

Assuming yields are non-negative and that due to expected inflation, (18) is positive, yield differential is an increasing function of inflation risk. This behavior is consistent with what is shown in Figure 1 and Figure 2. When the level of inflation risk R is zero, equation (18) represents the yield spread less inflation risk component and gives the value of expected inflation and relative liquidity premium as a function of demand and supply curve parameters. By evaluating (18) at R=0 and subtracting this value from yield differential singles out the expression for inflation risk premium.

$$irp^* = \frac{V}{\frac{1}{2}\theta + \frac{1}{2}\varepsilon - \gamma R} - \frac{V}{\frac{1}{2}\alpha + \frac{1}{2}\delta + \gamma R} + \frac{V}{\frac{1}{2}\alpha + \frac{1}{2}\delta} - \frac{V}{\frac{1}{2}\theta + \frac{1}{2}\varepsilon} \quad (19)$$

Inflation risk premium is an increasing function of inflation risk for values of R which give positive yields. Substituting equation (9) gives functional form for inflation risk premium expressed in terms of credibility parameter ρ and distance of inflation from target d_t. Full expression is presented in the appendix as equation (24). In the perfect credibility scenario, ρ=1, and derivative of *irp** with respect to d_t is:

$$\frac{d(irp^*)}{d(d_t)} = \frac{V\gamma\left(\frac{dG(d_t)}{d(d_t)}\right)}{\left(\frac{1}{2}\theta + \frac{1}{2}\varepsilon - \gamma G(d_t)\right)^2} + \frac{V\gamma\left(\frac{dG(d_t)}{d(d_t)}\right)}{\left(\frac{1}{2}\alpha + \frac{1}{2}\delta + \gamma G(d_t)\right)^2} < 0 \quad \text{for } \rho = 1 \quad (20)$$

Since G(d_t) is a decreasing function of d_t, $\frac{dG(d_t)}{d(d_t)}$ is negative, which makes equation (20) negative. Inflation risk premium is therefore a decreasing function of the distance of inflation from target when ρ is different from zero. When ρ=0, that is when credibility is absent, distance of inflation from target does not enter equation for inflation risk premium, and changes in d_t have no effect on *irp**.

$$\frac{d(irp^*)}{d(d_t)} = 0 \quad \text{for } \rho=0 \quad (21)$$

Additional properties of the theoretical model are discussed in the Appendix.

4. Empirical Model

The Government of Canada issues inflation-indexed "real return" bonds since 1991. Together with yields on nominal bonds, RRB yields are reported on a regular basis by the Statistics Canada. Using inflation forecasts from the Economist Poll of Forecasters and the Canadian Outlook as a proxy for inflation expectations, we can single out a combination of inflation and liquidity risk premiums from yields on nominal bonds:

$$y_n - y_r - \pi_e = IRP + LP \quad (22)$$

A combination of inflation risk and liquidity premiums will be a dependent variable in our initial empirical analysis.

Bond yields

For nominal and real yields, we use monthly data from Statistics Canada CANSIM database. Yields on real return bonds are first reported in November 1991, and at the time of this writing, series end on July 2006, which gives us a total of 179 observations.

Inflation expectations

Inflation forecasts are commonly used in the literature to approximate expected inflation. Forecasts made by a reputed organization present an inexpensive way for the market participants to form expectations, and it is reasonable to assume that fund managers or private investors who are looking to buy or sell nominal bonds would turn to forecasts to make inferences about future inflation, rather than go through costly estimations on their own.

We use two sources to obtain inflation forecasts. The first is a quarterly "Canadian Outlook" published by the Conference Board of Canada. The report provides highlights on economic performance and trends in Canada and the US, and includes forecasts of GDP, interest rates, employment and other macroeconomic variables together with consumer price index. Quarterly CPI values are forecasted for up to two years ahead from the publication date. Each publication therefore represents one observation of inflation expectations on the date when the report was released.

The quarterly frequency of Conference Board of Canada reports restricts dataset to only 46 observations. In addition, since the Board is a non-profit organization, it may lack incentives to refine forecasts beyond the level of accuracy which ensures that its operational costs are covered. We therefore use Canadian Outlook data as a reference case to test how sensitive are our findings to different sources of data.

Our primary source of inflation forecasts is monthly Economist Poll of Forecasters published by the Economist Business Unit. The poll presents consensus forecast for inflation, GDP and other macro-level variables for a small sample of countries, including Canada. Respondents to the poll include international financial and research bodies[4], many of which are directly involved in the markets for Canada Government bonds. Forecasts are made for the year of publication and for the subsequent year, which presents a problem since the horizon of the forecasts changes as publications progress through the year. For example, inflation forecast for 2006 made in January entails considerably more uncertainty than November forecast, since more information about the economy and consumer prices in 2006 is known in the end than in the beginning of the year.

To account for this, we let inflation expectations at the date of publication be a weighted average of the forecasts for the publication year and the subsequent year. The weight depends on how far in the year the forecast was made.

$$\pi_{e_t} = \left(1 - \frac{n}{12}\right)\pi_{f_t} + \left(\frac{n}{12}\right)\pi_{f_{t+1}} \quad (23)$$

Equation (11) expresses inflation expectations at time t as a weighted average of two forecasts, where π_{ft} is forecast for publication year, π_{ft+1} – for subsequent year and n – is the calendar number of the month when the forecast was published. Expectations for inflation over the next

[4] Respondents to the Economist Poll of Forecasters are: ABN Amro, Deutsche Bank, Economist Intelligence Unit, Goldman Sachs, HSBC Securities, KBC Bank, J.P. Morgan Chase, Morgan Stanley, Decision Economics, BNP Paribas, Royal Bank of Canada, Citigroup Scotiabank and UBS.

twelve months are formed almost entirely from π_{ft} in the beginning of the year, and from π_{ft+1} in the end.

Summary statistics and descriptions of the variables in our dataset are presented in Table 2 and Table 3.

Variable	Obs.	St. Error	Mean	Min.	Max.
ccpi	179	.4914797	2.017318	1.1	3.9
cpie1	178	.9470319	2.073596	0.3	5.9
cpie2	178	.3854348	2.172472	1.2	3.6
weight	178	.2904049	.5416854	0.08	1
cpi	179	1.127576	2.163687	-0.2	5.5
ynb	179	1.533521	6.488492	4.04	9.97
yrb	179	.9228449	3.708466	1.44	5.03
tdebti	178	30.39466	171.5662	100	205.76
wexp	178	.5908242	2.121708	0.444	5.468

Table 2. Summary statistics.

Variable	Description
ccpi	Core CPI, Bank of Canada operational target definition
cpie1	The Economist Poll of Forecasters CPI forecast for publication year
cpie2	The Economist Poll of Forecasters CPI forecast for subsequent year
weight	Weight placed on cpie1
cpi	Total consumer price index
ynb	One year yield on Government of Canada nominal marketable bonds
yrb	One year yield on Government of Canada inflation-indexed bonds
tdebti	Index for total government debt outstanding (1991/08=100)
wexp	Weighted inflation expectations

Table 3. Variable descriptions

Initial model

Inflation risk premium is the variable of interest. As per equation (10), we find combination of inflation risk and liquidity premiums as a difference between nominal and real yields less expected inflation, which serves as dependent variable in our model. Let IRP = ynb – yrb – wexp. Distance of observed inflation from operational target is constructed as D=|cpi-2|, and is one of the explanatory variables. Index of total government debt outstanding (TDEBTI) will serve as proxy for level of liquidity of government debt in order to capture variations in level of liquidity in inflation risk plus liquidity premiums residual. All variables are reported with monthly frequency. Since in practice inflation figures are released and are known to agents with approximately one quarter (three month) lag, we use L3.D - values of D lagged by three periods, instead of D. R is a dummy for deflation. Initially estimated model is written in equation (I).

$$IRP = \alpha + \beta_1 L3.D + \beta_2 TDEBTI + \beta_3 R + \varepsilon \quad \text{(I)}$$

Since inflation target of two percent was somewhat firmly established only in 1994, we estimate initial model on a subset of data (1994-2006) to avoid dealing with non-stationary process, where target changes over time. OLS regression results are shown in Table 4.

Initial Regression Results (1994-2006), Model I, OLS	
	Number of observations = 148 R-squared = 0.71 Adjusted R-squared = 0.71
	IRP
Three-month lag of distance of core CPI from target (L3.D)***	-0.37 (0.12)
Dummy for deflation (R)***	0.84 (0.28)
Index for total government debt outstanding (TDEBTI)***	-0.034 (0.0024)
Constant***	5.96 (0.54)

Table 4. Initial regression of inflation risk and liquidity premiums residual on distance of inflation from target, deflation dummy and index for government debt outstanding. 1994-2006. Standard errors are indicated in parenthesis.

All coefficients are significant at 1% level. Magnitudes of coefficients are also intuitive: distance of core CPI from the target is inversely related to level of inflation risk and therefore to risk premium on bonds, presenting strong evidence in support of credibility, deflation is associated with high inflation risk, and index of total government debt is found to be inversely related to the dependent variable, suggesting that liquidity premium declines when more debt is outstanding.

Looking deeper into the data reveals several flaws. Variable TDEBTI has unit root and cannot be used in our model, however all other variables are stationary. Since dependent variable is a combination of two premiums and is stationary, this suggests liquidity premium remained constant, and all variations in dependent variable can be attributed to changes in inflation risk premium.

Refined model

Data are not heteroscedastic, but are heavily auto-correlated (positively). We reformulate the model as AR(1), leave TDEBTI out, and use iterated estimates to obtain unbiased coefficients. We also replace R, dummy for deflation, with D_1994, a dummy for 1994. Canada experienced unusually low inflation rates (close to zero) throughout 1994, but only in four months prices actually declined. We believe that a dummy for a whole year better captures increased uncertainty in this whole period. Refined model is presented in equation (II).

$$IRP_t = \alpha + \beta_1 L3.D_{t-3} + \beta_2 D\_1994_t + \beta_3 IRP_{t-1} + \varepsilon_t \quad \text{(II)}$$

Table 5 contains estimation results for Model (II).

Refined Regression Results (1994-2006), Model II, AR(1), Iterated	
	Number of observations = 148 R-squared = 0.89 Adjusted R-squared = 0.89
	IRP
Three-month lag of distance of core CPI from target (L3.D)***	-0.20 (0.07)
Dummy for 1994 (D_1994)***	0.47 (0.11)
Lag of explanatory variable (IRP_{t-1})***	0.80 (0.038)
Constant***	0.14 (0.046)

Table 5. Refined model results of regressing inflation risk premium on three-month lag of distance of core CPI from target, dummy for 1994 and AR(1) for 1994-2006. Standard errors are indicated in parenthesis.

All variables are significant at 1%, and there is no evidence of heteroscedasticity or serial correlation. High statistical significance of D_{t-3} suggests good evidence for credibility of inflation target. Distance of core CPI from the target is inversely related to inflation risk premium and therefore to the level of inflation risk, which is consistent with implications of the theoretical model. Unusually low inflation in 1994 is correlated with high inflation risk.

To test for effects of changes in the management of the Bank of Canada, we created dummy variables for different governors of the bank who took position from 1993 to 2006. To account for major events which affected bond markets throughout the period, we created a dummy to capture effects of the collapse of Long Term Capital Management fund in 1998. LTCM encountered major liquidity problems after loosing $4.8 billion in developing countries' bond markets. Together with the default of Russian government on its debt in 1998, this triggered "flight to liquidity" – a large-scale sell-off of Japanese and European bonds, and a surge in demand for US and Canadian government securities. The crisis was not exactly a threat to inflation, but can affect Model II through the constant term, if demand shocks in nominal and real bond markets were asymmetric. Including dummy variables and re-estimating Model II, however, indicates that changes in the Bank of Canada management and LTCM collapse are highly insignificant.

Evolution over time

While Model II provides some empirical evidence of credibility, it carries no information about the time path. In this section we use rolling window approach to investigate how explanatory power of D_t over IRP changed from 1994 to 2006. We use a window span of three years beginning rolling in November 1991 until June 2006. Window shifts by one month, and for each shift model (III) which is shown below is estimated.

$$IRP_t = \alpha + \beta_1 D_{t-3} + \varepsilon_t \quad \text{(III)}$$

Data allow us to run 115 rolling-window regressions. R-squared together with the variance of CPI in each window are plotted in Figure 3. Variance of CPI helps to ensure that drops in R-squared are not due to lack of variation in inflation figures. Dates on horizontal axis show when each window begins. Values of R-squared, the explanatory power of D_t over *IRP,* can be interpreted as the degree of credibility.

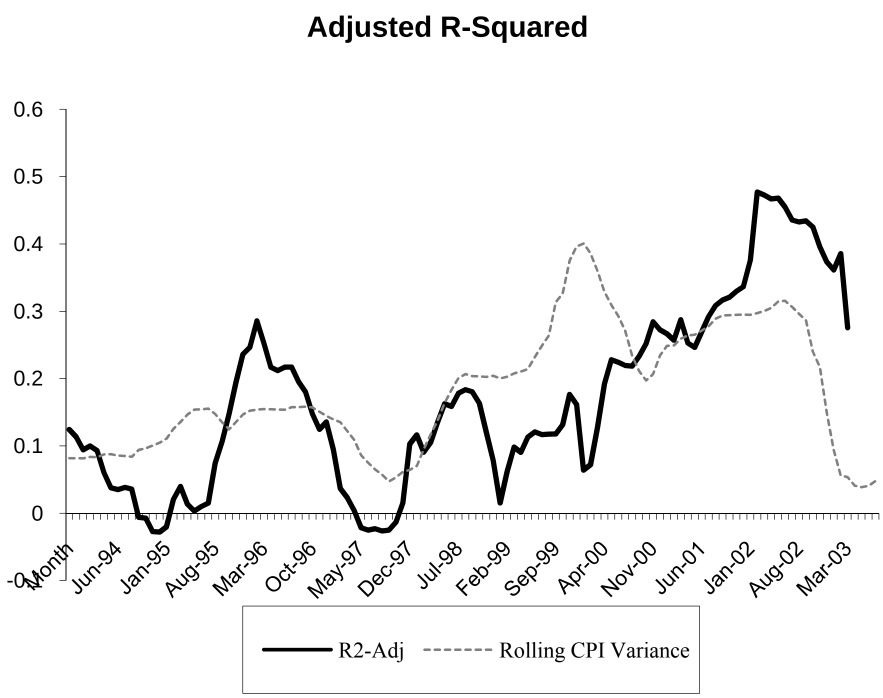

Figure 3. Regression parameters from rolling window estimations.

D_{t-3} explains up to 50% of variation in IRP at the peak and reaches the low of zero, and is significant below 10% most of the time. Figure 3 can be interpreted to show that inflation targeting quickly gained credibility after Bank of Canada announced its policy. Credibility declines sharply in windows starting in 1997-1998, but then increases to reach its high in windows starting in approximately 2002. Loss of credibility in 1997-1998 may be due to financial crisis in Asia and Russia at the time, when investors may have believed that the Bank of Canada is incapable of resisting inflationary pressures from abroad. Credibility seems to decline again in windows beginning in early January 2003, which may be due to sharp appreciation of Canadian dollar, or to a change in political climate.

5. Conclusion

In the present study we attempt to empirically establish credibility of inflation targets set by the Bank of Canada using inflation risk premiums, derived from yields on Government of Canada nominal marketable bonds. We present diagrammatic framework and a simple analytical model of the credibility of inflation target. Key feature of the model is the treatment of inflation risk, and as result, inflation risk premium, as a combination of two effects: "regime uncertainty" and some decreasing function G(·) of the distance of actual inflation from target d_t. Under perfect credibility, inflation risk premium is entirely determined by $G(d_t)$, and when credibility is lacking, inflation risk premium is determined by regime uncertainty. The degree to which targets are credible is represented by the credibility parameter ρ.

We use inflation forecasts from the Economist Poll of Forecasters and Canadian Outlook reports by the Conference Board of Canada as proxy for inflation expectations, and yields on the Government of Canada inflation-indexed bonds to factor out inflation risk premium from nominal yields. Explanatory power of distance of observed inflation from the operational target of 2% over inflation risk premium is interpreted as the degree credibility.

We find inflation close to upper or lower ends of the target bound of 1%-3% to be strongly associated with low inflation risk premiums, and inflation on target - with higher inflation risk. This suggests a function G(·) of distance of inflation from target to large extent determines the level of inflation risk perceived by the markets, which is interpreted as evidence of credibility. The plot of risk premiums versus distance of inflation from target can be seen in the Appendix. Distance of inflation from target is significant at 1% in our empirical model, where inflation risk premium serves as dependent variable. Using rolling-window approach, we find evidence that targeting gained credibility after it was announced, but credibility declined in the late 1990s and in rolling windows beginning in 2002.

For inflation above 2%, our findings contradict that of Crawford and Kasumovich (1996), who find that level of inflation is positively correlated with inflation risk. Present study finds that low inflation risk is associated with inflation below *and* above target, close to either end of the target bound.

One limitation of our study is the exclusion of liquidity from the analysis. Both real and nominal Canadian Government bonds are readily accessible, but it may be that there is a positive liquidity premium on inflation-indexed debt due to a lower outstanding stock than nominal debt. Assuming there is no spurious correlation between liquidity premium and d_t, this does not diminish the findings, since independent variables used in regressions have no reason to be correlated with liquidity. This attributes explanatory power of the distance of inflation from target over dependent variable to correlation between d_t and inflation risk premium alone. In the future, liquidity can be factored out using measures such as relative quantities of outstanding nominal and inflation-indexed debt, turnover ratios, defined as the volume of bonds traded divided by the total quantity of outstanding debt, and ideally, the bid/ask spreads in the secondary market. Liquidity index developed in Amihud (2002) can also be used[5].

Our study may have several implications for the policy-makers. Since inflation risk premium is closely linked to the level of perceived uncertainty about future inflation, tracking credibility helps determine how well is the policy faring, as seen by financial community. Public speeches and general enhancements to the central bank's transparency can be used to improve credibility when it is lacking, and as result, overall climate in financial markets. If "regime uncertainty" is assumed to be more risky for investors than inflation on target under perfect credibility, the government may save on interest payments on nominal bonds when the central bank is credible, since lower compensation for inflation risk is required by investors in the latter case. This is in line with arguments made in Shen (1998), where a case for a switch to government borrowing using mostly real return bonds is put forward, and interest savings from switching are found to be in the range of £10-£16 millions of British Pounds per year.

Our work differs from earlier studies of credibility in that it proposes a measure to empirically establish credibility, which allows seeing how it evolved over time. The findings should be kept in perspective, as they are a first attempt to use this measure.

One useful future extension is to use inflation risk data from other financial markets such as stock and forward currency markets. Cross-country study could also yield interesting results.

[5] Amihuds (2002 measures stock illiquidity as "the average ratio of the daily absolute return to the (dollar) trading volume on that day". The index is defined as $ILLIQ_{iy} = \frac{1}{D_{iy}} \sum_{t=1}^{D_{iy}} \frac{|R_{iyd}|}{VOLD_{ivyd}}$, where D_{iy} is the number of days for which data are available for stock *i* in year *y*, R is the return and VOLD is the daily volume.

References

Altig, D. E., And B. Michael F. (1993). "Policy and long-run output: A sensitivity analysis." *Federal Reserve Bank of Cleveland*.

Amihud, Y. (2002). "Illiquidity and Stock Returns: Cross-Section and Time-Series Effects". *Journal of Financial Markets* 5: 31- 56.

Barro, R. J. (1995). "Inflation and Economic Growth." *NBER Working Paper Series*, Issue 5326.

Blinder, A. S. (2000). "Central-Bank Credibility: Why Do We Care? How Do We Build It?" *American Economic Review* 90, Part 5: 1421-1431.

Côté, A., Jacob, J., Nelmes, J., and M. Whittingham (1996). "Inflation expectations and Real Return Bonds." *Bank of Canada Review* 2: 41-53.

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

Evans, M., and P. Wachtel. (1993). "Inflation Regimes and the Sources of Inflation

Uncertainty." *Journal of Money, Credit and Banking* 25: 475-511.

Fischer, S. (1991). "Growth, Macroeconomics, and Development." In *NBER Macroeconomics Annual 1991,* Vol. 6, edited by O. Blanchard and S. Fischer, 329–64. Cambridge, MA: MIT Press/National Bureau of Economic Research.

Fung, B., Mitnick, S., And E. M. Remolona. (1999). "Uncovering Inflation Expectations and Risk Premiums From Internationally Integrated Financial Markets." *Bank of Canada Working Paper* No. 99-6.

Johnson, D. (1997). "The Credibility of Monetary Policy: International Evidence Based on Surveys of Expected Inflation." *Bank of Canada Conference Proceedings*.

Kuttner, K. N. And A. S. Posen. (1999). "Does Talk Matter After All?: Inflation Targeting and Central Bank Behavior." *CFS* Working Paper No. 1999-04.

Lucas Jr., L. E. (2000). "Inflation and Welfare." *Econometrica* 68, No. 2: 247- 274.

McCandless, G. T. Jr. And W. E. Weber. (1995). "Some Monetary Facts." *Federal Reserve Bank of Minneapolis Quarterly Review* 19, No. 3: 2-11.

Mishkin, F. S. (2000) "Inflation Targeting in Emerging-Market Countries." *The American Economic Review* 90, No. 2: 105-109

Neumann, M. And J. von Hagen. (2001). "Does Inflation Targeting Matter?" *Centre for European Integration Studies*. Working Paper No. B 01 2002.

Ragan, C. (1998). "On the Believable Benefits of Low Inflation." *Bank of Canada Working Paper* No. 98-15.

Reid, C., Dion, F., And I. Christensen. (2004). "Real Return Bonds: Monetary Policy Credibility and Short-Term Inflation Forecasting." *Bank of Canada Review* 3: 15-26.

Remolona, E. M., Wickens, M. R., and F. F. Gong. (1998). "What Was the Market's View of UK Monetary Policy? Estimating Inflation Risk and Expected Inflation With Indexed Bonds." *Centre for Economic Policy Research London. Discussion Paper Series*, Issue 2022.

Shen, P. (1998). "How Important Is the Inflation Risk Premium?" *Economic Review – Federal Reserve of Kansas City* 83, No. 4: 35-48.

Svensson, L. E. O. (1993). "The Simplest Test of Inflation Target Credibility." *NBER Working Paper Series*, Issue 4604.

Tella, R., MacCulloch R. J., and A. J. Oswald. (2001). "Preferences over Inflation and Unemployment: Evidence from Surveys of Happiness." *The American Economic Review* 91 No. 1: 335 - 341.

Yetman, J. (2001). "Gaining Credibility for Inflation Targets". *Bank of Canada Working Paper* No. 2001-11.