Predictability of Average Inflation over Long Time Horizons

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- *Uncertainty about the level of future inflation adversely affects the economy because it distorts savings and investment decisions.*
- *The costs of inflation uncertainty can be reduced by adopting a policy framework that makes future inflation more predictable. Thus, when the inflation-control target was renewed in May 2001, the agreement included several refinements to increase the predictability of inflation over the longer term.*
- *This article describes how the policy commitment to move inflation to the 2 per cent midpoint of the inflation-control target range makes it easier to predict average inflation rates over long time horizons.*

Since 1991, Canada's monetary policy framework has included formal targets for the 12-month change in the consumer price index. Inflation targeting has proven to be a successful strategy for achieving low and predictable rates of inflation from year to year. It is also important that the targeting framework be designed to make inflation more predictable over longer time periods, since many of the adverse effects of inflation uncertainty result from uncertainty about the size of price changes over periods longer than one year. Thus, when the Government of Canada and the Bank of Canada renewed their inflation-target agreement in May 2001, the joint statement and the Bank's background paper included a number of refinements to strengthen the implementation of the targets and to increase the long-run predictability of inflation. These refinements include[1]

- a longer term for the agreement (five years, to the end of 2006, versus the three-year term of the two previous agreements)
- affirmation that monetary policy will be directed to moving inflation to the 2 per cent midpoint of the target range over a six-to-eight-quarter horizon
- a commitment to explain the reasons for any persistent deviations of inflation from the 2 per cent target midpoint in the Bank of Canada's *Monetary Policy Reports* and *Updates*, and
- the adoption of a superior measure of core inflation, formerly called CPIX, as the short-term operational guide for policy.

1. In addition to these refinements, the new agreement extended the existing targets for CPI inflation (1 to 3 per cent with a target midpoint of 2 per cent). See Bank of Canada (2001a, 2001b) for further discussion of the agreement.

This article examines how the commitment to moving inflation to the target midpoint improves the predictability of inflation over the longer term.

Predictability of Inflation in the Short Run and the Longer Run

Uncertainty about future levels of inflation adversely affects the economy because it creates uncertainty about the purchasing power of future payments and receipts. For example, inflation uncertainty can make businesses less willing to invest in long-term capital goods because it makes the real returns from investment projects less certain.[2] Since these projects involve planning horizons of many years, increased certainty about long-run inflation will facilitate better investment decisions by firms. Similarly, inflation uncertainty may cause savers to be less likely to hold longer-term financial assets, since it makes the real return from these assets less certain. Thus, greater predictability of inflation will increase the willingness of households to allocate part of their savings to longer-term financial assets, thereby improving the operation of long-term financial markets. These examples indicate that designing the inflation-targeting framework in ways that improve the long-run predictability of inflation will promote better economic outcomes.

Greater predictability of inflation will increase the willingness of households to allocate part of their savings to longer-term financial assets, thereby improving the operation of long-term financial markets.

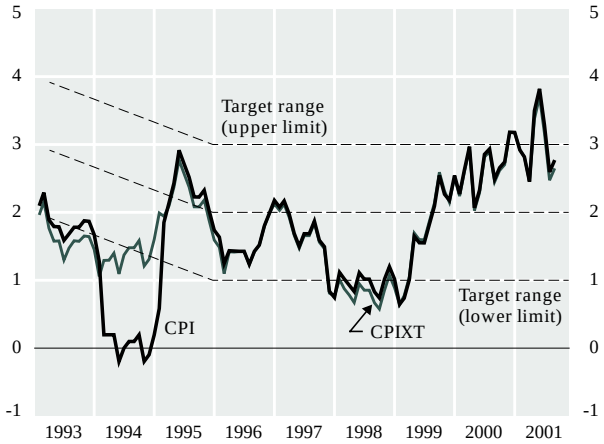
A systematic commitment to move inflation to the 2 per cent midpoint means that inflation would be expected to average 2 per cent over extended periods. However, monetary policy cannot maintain inflation exactly at 2 per cent each year. Unpredictable disturbances to aggregate demand and supply may cause unexpected movements in inflation that cannot be offset by monetary policy in the short run, given the lags between changes in policy and the effect of these changes on inflation. Large disturbances to the prices of volatile components, such as energy, may also cause unexpected short-run fluctuations in inflation. Yet another reason for imperfect short-run control over inflation is that monetary authorities do not have exact knowledge of the structure of the economy. In recognition of these practical limitations, the target for the 12-month change in the consumer price index (CPI) is defined as a 2 per cent midpoint with a range of +/- 1 per cent around this midpoint.

The preceding discussion indicates that deviations from the 2 per cent target midpoint cannot be eliminated in the presence of random disturbances. Nevertheless, if monetary policy acts systematically to move inflation towards the midpoint, the target range should contain the actual outcomes a high percentage of the time. To illustrate this relationship, Chart 1 shows the 12-month rates of change for the CPI and for the CPI excluding the effect of changes in indirect taxes (CPIXT). The latter measure is the focus in this article, since the Bank's policy actions do not attempt to offset the first-round effects of changes in indirect taxes.[3] CPIXT inflation has been within the target

Chart 1

CPI and CPI Excluding the Effect of Changes in Indirect Taxes

12-month percentage change



2. Stuber (2001) reviews the theoretical and empirical literature on the relationship between inflation uncertainty and real economic activity.

3. This treatment reflects the fact that changes in indirect taxes are largely unpredictable or are one-time events. In recent years, the two measures of inflation have been quite similar, although the difference between them in 1994 (owing to a large decrease in tobacco taxes) shows that changes in indirect tax rates can significantly affect CPI inflation.

Table 1

CPI Excluding the Effect of Changes in Indirect Taxes

12-month inflation

	Percentage of time within a range around the target midpoint		
	Range		
	+/-1%	+/-1.2%	+/-1.5%
December 1995 to July 2001	72	82	98
December 1992 to July 2001	63	81	98

range over 70 per cent of the time since the target midpoint reached 2 per cent in December 1995 (Table 1).[4,5] Increases in energy prices temporarily pushed inflation above the upper end of the range in mid-2001.

For later discussion, it is useful to highlight how transitory price movements in the volatile components of the CPI have contributed to the volatility of inflation in the short run. This effect is illustrated using the Bank's measure of core inflation, which excludes the eight most volatile components of the CPI and the effect of changes in indirect taxes on the remaining components.[6] Comparisons between this core measure and the change in the CPI excluding the effects of indirect taxes (CPIXT) provide information on the impact of transitory shocks on current inflation. As shown in Table 2, core inflation has been within 1 per cent of the target midpoint a much higher proportion of the time (approximately 95 per cent) since December 1995. Thus, transitory shocks have increased the volatility of CPIXT inflation and have contributed to the movements of the 12-month inflation rate outside the target range of +/- 1 per cent.

4. Table 1 also reports the frequency with which inflation has been within the target range since December 1992. Under the original agreement in 1991, the target midpoint declined gradually from 3 per cent in December 1992 to 2 per cent in December 1995.

5. Although economists typically use confidence intervals of 95 per cent or 99 per cent, the target range was never described as a range that would contain actual inflation with such a high level of confidence. Indeed, empirical work done by Bank staff in 1990–91 suggested that inflation would be inside the range only about two-thirds of the time.

6. The components excluded from core inflation are fruit, vegetables, gasoline, fuel oil, natural gas, intercity transportation, tobacco, and mortgage-interest costs. These components represent approximately 16 per cent of the CPI basket. See Macklem (2001) for further discussion of this measure of core inflation.

Table 2

12-Month Rate of Core Inflation (CPIX)

	Percentage of time within a range around the target midpoint		
	Range		
	+/-0.7%	+/-0.8%	+/-1.0%
December 1995 to July 2001	69	84	97
December 1992 to July 2001	70	84	96

The impact of temporary shocks is illustrated further in Charts 2 and 3. Each bar in these charts shows the percentage of time that 12-month inflation has fallen within particular intervals. Relative to the distribution for CPIXT inflation (Chart 2), the observations for core inflation are more tightly clustered around the mean. This observation confirms that random fluctuations in the most volatile components of the CPI have significantly increased the short-run volatility of overall inflation.

Inflation will be more predictable over horizons longer than one year when monetary policy aims at moving inflation towards the 2 per cent midpoint of the target range. With this systematic commitment,

Chart 2

Distribution of 12-Month Inflation of CPI Excluding Taxes

December 1995 to July 2001

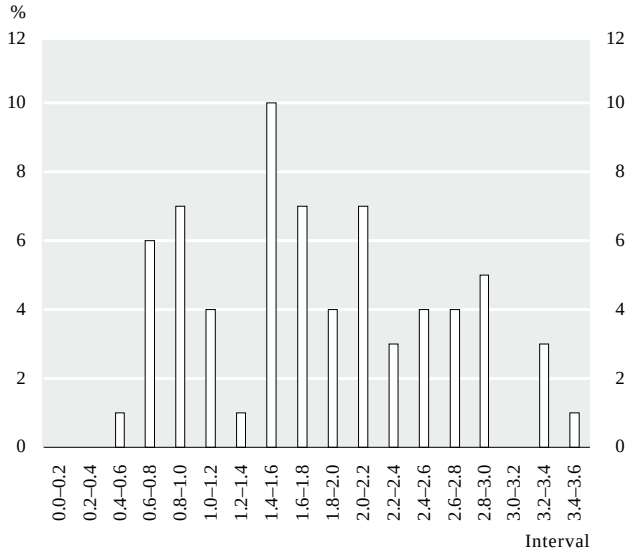
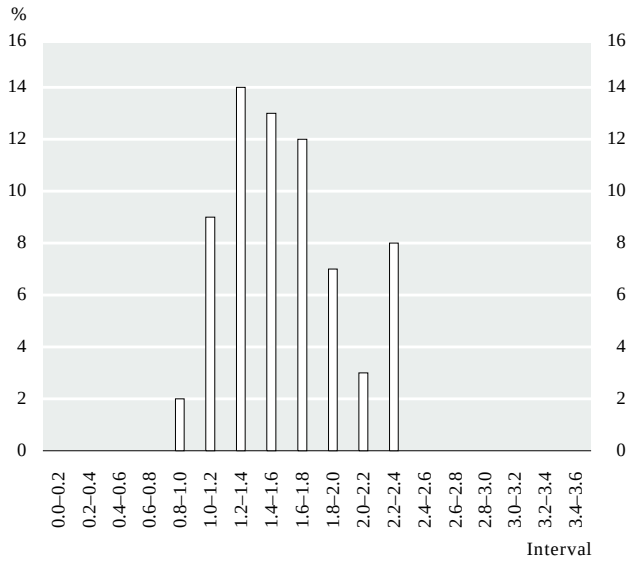


Chart 3

Distribution of 12-Month Core Inflation

December 1995 to July 2001



the probability of achieving an average inflation rate close to 2 per cent will increase with the length of the averaging period, because there is a greater probability that the temporary random shocks will average close to zero.[7] As an informal illustration of this effect, note that the annualized rate of CPIXT inflation over periods of two years is within 1 per cent of the target midpoint approximately 90 per cent of the time (Table 3), compared with only 72 per cent for the 12-month inflation rate (Table 1).

Inflation will be more predictable over horizons longer than one year when monetary policy aims at moving inflation towards the 2 per cent midpoint of the target range.

7. Intuitively, the statement that random shocks will average closer to zero as the averaging period lengthens is analogous to the expectation that the average value from tossing a die will move closer to 3.5 as the number of tosses increases. One type of shock that would not average zero over time would be repeated changes in the same direction in indirect tax rates.

Table 3

CPI Excluding the Effect of Changes in Indirect Taxes

Annualized inflation over two-year horizons

	Percentage of time within a range around the target midpoint		
	Range		
	+/-0.7%	+/-0.8%	+/-1.0%
December 1996 to July 2001	59	79	88

Ranges for Average Inflation over Periods Longer than One Year

The last section used historical evidence since the mid-1990s to show that the likelihood of achieving inflation within 1 per cent of the target midpoint increases when inflation is averaged over longer periods. An important implication of this result is that a narrower range of inflation rates would capture a given frequency of outcomes as the length of the averaging period is increased. For example, if we use recent history to estimate the interval that would include actual inflation 75 per cent of the time, a range of about +/- 1 per cent would be necessary for the 12-month inflation rate (Table 1), whereas a range of less than +/- 0.8 per cent would contain the average annual inflation rate over a two-year period (Table 3). Although this example uses evidence from only a limited number of years, it suggests that average inflation rates are more predictable under inflation targeting as longer periods are considered.

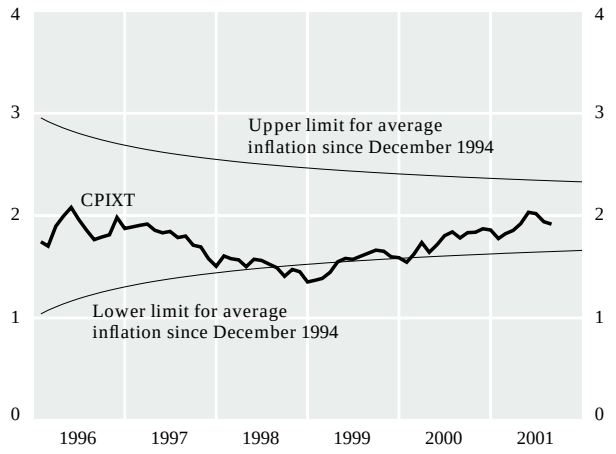
The remainder of this section presents a more formal analysis of the relationship between the width of these ranges and the length of the averaging period (relative to December 1994).[8] If monetary policy is directed at moving inflation to the 2 per cent target midpoint, the distribution of 12-month inflation rates (using data over a sufficient period of time) is expected to have a mean value of 2 per cent, and most outcomes for 12-month inflation will be contained within a range of +/- 1 per cent around this midpoint. Thus, in Chart 4, the range shown for December 1995 is +/- 1 per cent

8. December 1994 is the base period for calculating the average annualized rate of inflation because December 1995 was the first month with a target midpoint of 2 per cent for the 12-month inflation rate.

Chart 4

CPI Excluding the Effect of Changes in Indirect Taxes

Average percentage change since December 1994 at annual rates



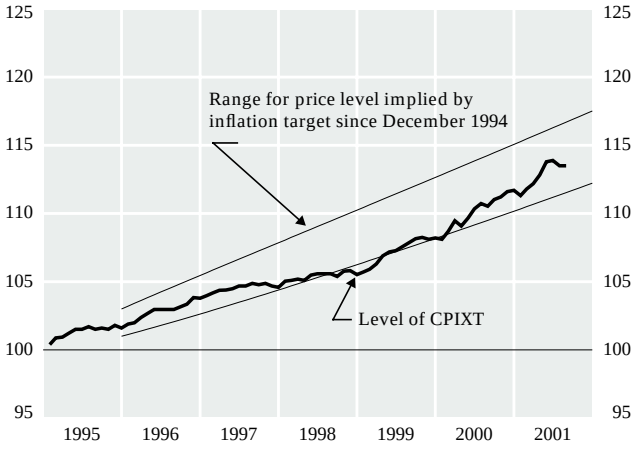
around 2 per cent. The width of the range containing the same frequency of outcomes (say, 75 per cent) declines when the average inflation rate is calculated over a longer period and when there is no correlation between non-overlapping 12-month inflation rates. Specifically, as shown in the appendix, the range is inversely proportional to the square root of the length of the averaging period. Therefore, relative to the +/- 1 per cent target range for 12-month inflation, the corresponding interval falls to approximately +/- 0.7 per cent for the average annualized inflation rate over two years (i.e., December 1996 in Chart 4) and to approximately +/- 0.45 per cent for average inflation over five years.[9] The actual outcomes will move outside these implied target ranges if there is a series of unexpected shocks of sufficient magnitude in the same direction. The narrowing of the range over longer horizons reflects the idea that average inflation rates become more predictable over time under inflation targeting.

Chart 4 also plots the observed outcomes for the average annual rates of change (relative to December 1994) for the CPI excluding the effect of changes in indirect tax rates. That is, the observation for December 1996 is the annualized inflation rate for the 24-month period beginning in December 1994, and the observation for December 1997 is the annualized inflation rate for the 36-month period. The average inflation rate dropped below the lower end of the range in 1998, following a series of 12-month inflation rates below 1 per cent during the Asian economic crisis. Average inflation moved back inside the range in 1999 and was close to 2 per cent in mid-2001. Overall, the average inflation rate has been within the range 87 per cent of the time since December 1995.

Chart 5

CPI Excluding the Effect of Changes in Indirect Taxes

December 1994 = 100



The ranges for average inflation have direct counterparts for the most likely outcomes for the price level (Chart 5). As described in the appendix, the width of the confidence interval for the price level increases with time at a rate that is proportional to the square root of the length of the averaging period.[10] Since the average annualized inflation rate (relative to

9. The appendix shows that the range is wider than illustrated in Chart 4 if the non-overlapping 12-month inflation rates are positively correlated. The appendix also reports evidence that the zero-correlation assumption underlying Chart 4 is appropriate for the period of inflation targeting in the 1990s.

10. The width of the range containing the most likely outcomes for the price level after five years is less than half of what would be obtained by simply extrapolating the target range of +/- 1 per cent for the 12-month inflation rate. This occurs because the implied target range for average inflation decreases with the length of the averaging period. Thus, with the +/- 0.45 per cent range for the five-year average rate of 12-month inflation (noted previously), the corresponding range for the price level is approximately +/- 2.25 per cent (5 multiplied by +/- 0.45 per cent).

December 1994) was close to 2 per cent in mid-2001, the actual price level at that time was near the middle of the range for the price level.

Conclusion

Monetary policy can increase the long-run predictability of inflation if it consistently strives to move inflation to the 2 per cent target midpoint over a six-to-eight-quarter horizon. When policy is conducted in this manner, the likelihood increases that average inflation will move closer to the midpoint as the averaging period is lengthened. Although the 12-month inflation rate has moved outside the target range from time to time in recent years, the average annualized inflation rate since December 1994 reached a level quite close to 2 per cent by mid-2001.

One measure of the Bank's success in meeting the target objectives is whether the longer-run averages of inflation are contained within the types of ranges discussed in this article. Accordingly, these ranges can be used as an accountability mechanism for the conduct of monetary policy.

Literature Cited

Bank of Canada. 2001a. "Bank Releases Background Information on Renewal of the Inflation-Control Target." *Bank of Canada Review* (Summer): 58.

———. 2001b. "Renewal of the Inflation-Control Target: Background Information." *Bank of Canada Review* (Summer): 59–67.

Macklem, T. 2001. "A New Measure of Core Inflation." *Bank of Canada Review* (Autumn): 3–12.

Stuber, G. 2001. "Implications of Uncertainty about Long-Run Inflation and the Price Level." Bank of Canada Working Paper (forthcoming).

Appendix

Ranges for Average Inflation and the Price Level

A *confidence interval* for inflation represents the range of inflation rates that will include the actual outcome a given percentage of the time. If the frequencies from the 1995–2001 period shown in Table 1 of the text are representative, the target range of 1 to 3 per cent can be interpreted as roughly the 75 per cent confidence interval for the 12-month inflation rate of the CPI excluding the effect of changes in indirect taxes. This appendix describes the formula for calculating the corresponding confidence intervals for the average rates of inflation over longer time horizons.

If π_i is the inflation rate for an individual year (year *i*), the average inflation rate over *n* years is

$$\bar{\pi}_{(n)} = \sum_{i=1}^{n} \pi_i / n \ .$$

If the non-overlapping annual inflation rates are not correlated, it can be shown that the standard deviation of the average annual rate of inflation over *n* years is[1]

$$\sigma_{\bar{\pi}_{(n)}} = \sigma / \sqrt{n} \ , \qquad \text{(A1)}$$

where σ is the standard deviation of the 12-month inflation rate.

Equation (A1) shows that the standard deviation of the average inflation rate is inversely proportional to the square root of the number of years used to calculate the average. The confidence interval for a given horizon is proportional to the standard deviation of average inflation over that period. Thus, equation (A1) implies that the width of the confidence interval is inversely proportional to the square root of the length of time over which the average is calculated. Chart 4 in the text illustrates how the confidence interval for average inflation narrows with the duration of the averaging period when it is assumed that non-overlapping 12-month inflation rates are not correlated.

If the annual inflation rates are autocorrelated, the standard deviation of the average inflation rate over *n* years is an extended version of the previous formula:

$$\sigma_{\bar{\pi}_{(n)}} = \frac{\sigma\sqrt{1 + \rho_1 + \rho_2 + \ldots + \rho_{n-1}}}{\sqrt{n}} \ , \qquad \text{(A2)}$$

where ρ_i is the correlation between the current 12-month inflation rate and the 12-month inflation rate lagged *i* years.

Equation (A2) indicates that the multi-year confidence interval is wider when annual inflation rates are positively correlated ($\rho > 0$). One situation in which positive correlations (particularly beyond one year)[2] could occur would be if the policy authorities were not committed to maintaining inflation at a targeted rate. Relative to this case, a commitment to achieving the target midpoint should narrow the multi-year confidence intervals and make inflation more predictable.

Empirical evidence regarding the effect of autocorrelation on the width of the confidence intervals was obtained by estimating the relationship between the current 12-month inflation rate (π_t) and previous non-overlapping 12-month rates:

$$\pi_t = \alpha_0 + \phi_1 \cdot \pi_{t-12} + \phi_2 \cdot \pi_{t-24} + u_t \ ,$$

where π is the change in the CPI excluding the effect of changes in indirect taxes, u_t is a random error term, and the parameters to be estimated are α_0, ϕ_1, and ϕ_2.

When the estimation is restricted to the period since the first explicit target (December 1992), the parameter estimates for the lagged inflation variables π_{t-12} and π_{t-24} are small and are not statistically different

1. If there is no autocorrelation from year to year, the variance of average inflation is equal to

$$\sigma^2_{\bar{\pi}_{(n)}} = \sum_{i=1}^{n} \sigma^2 / n^2 = n\sigma^2 / n^2 = \sigma^2 / n \ ,$$

and the standard deviation of average inflation is defined by equation (A1).

2. The first autocorrelation coefficient could be positive if there is a policy of moving inflation back to the target over a two-year period.

from zero (Table A1). Thus, the zero-correlation scenario underlying Charts 4 and 5 in the main text is consistent with empirical evidence from the 1990s.[3]

Confidence intervals can also be constructed for the price level. The price level *n* years ahead depends on the annual inflation rates over that period:

$$P_n = P_0(1 + \pi_1)(1 + \pi_2)\ldots(1 + \pi_n) \ ,$$

where P_n is the price level after *n* years and P_0 is the initial price level.

The proportional standard deviation of the price level *n* years ahead is equal to $\sigma\sqrt{n}$ if the non-overlapping annual inflation rates are not correlated. Therefore, the width of the confidence interval for the price level increases with the square root of time. Chart 5 shows the ranges of the most likely outcomes for the price level over alternative time horizons.

3. The parameter estimates for the lagged inflation variables are positive when the estimation period starts in the mid-1980s. These positive coefficients reflect the effects of the transition from the moderate-inflation years of the mid-to-late 1980s to the low-inflation period of the 1990s. When describing the confidence intervals in an inflation-targeting regime, the relevant evidence is that obtained from the estimation restricted to the 1990s.

Table A1

Regression Results

December 1992 to July 2001[a]

Model	α_0	ϕ_1	ϕ_2
1 lag	1.56	0.15	
	(5.19)	(0.72)	
2 lags	1.80	0.09	-0.08
	(3.66)	(0.36)	(0.78)

[a] *t*-statistics in parentheses