Lags of Monetary Policy: Evidence from Canada and its Provinces

by

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Abstract

This paper provides evidence on the lags of monetary policy actions on inflation and output. The evidence is based on Canadian data from 1994-2023 on inflation, nominal and real interest rates as well as GDP, employment and unemployment rate. The methodology used is dynamic correlation analysis to determine the peak lead effect of monetary policy on inflation and output. The main monetary policy instruments are the overnight money market rate and a constructed real interest rate. Additionally, money supply is introduced as a supplemental monetary policy instrument. The results suggest that the lagging effects of monetary policy are above 20 months measured through the inflation target variables, and close to a year for the output target variables. Similar findings are seen for the provinces individually. The results show stability even through COVID-19 times.

Key words: monetary policy; lags; inflation lags; output effects; dynamic correlation; inflation persistence

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1 Introduction

Monetary policy plays a key role in stabilizing and steering the macroeconomy mostly through influence on the inflation rate. Many central banks in the developed as well as in the developing countries have implemented inflation targeting frameworks which are forward-looking. For example, in Canada this framework was introduced in the early 1990's (Beaudry & Ruge-Murcia, 2017). The target is now set at 2% annually, for the total consumer price index based inflation, with a range of 1% to 3% (Dodge, 2005). The forward-looking framework requires an understanding of the lags of monetary policy for optimally setting the inflation targeting horizon. This is because the effects of monetary policy are not immediate and it usually takes a long time to see their effects in the economy, hence the existing of the lags.

This research measures the lags of monetary policy for Canada, across number of dimensions: monetary policy instruments, inflation and output target variables and regions in Canada. The following monetary policy instruments are considered: overnight rate, constructed overnight real rate and money supply. CPI inflation, core inflation, GDP, employment and unemployment rate are used as target variables. These are not targets in terms of the Bank of Canada's framework per se, but rather serve as variables of interest for the transmission of monetary policy. Regarding the regions, the estimation is done for Canada as a whole, as well as the ten provinces individually.

The lags of monetary policy are most commonly associated with Friedman. His views were particularly influential for his time. His findings suggest long and variable lags, limiting the usefulness of discretionary monetary policy (M. Friedman, 1961). He advocated that a rules-based approach in guiding the monetary policy can lower the impact on the economic activity and the business cycle fluctuations (M. Friedman & Schwartz, 2008). More recently, the focus is on the operation of forward-looking monetary policy in inflation-targeting frameworks. Batini and Nelson (2001) provide empirical evidence for the existence of these lags, building their findings based on previous Friedman's work. Estimating the monetary policy lags can provide guidance for setting the inflation targeting horizons.

An important focus of this research are the lags of systematic monetary policy in contrast to the lags specific to exogenous monetary policy. This means that this research looks at the systematic or aggregation of all shocks in the economy, rather than individual instances. This is consistent with Friedman's original focus as well as Batini and Nelson's methodology. Looking at the systematic monetary policy allows for estimating the typical lags which can guide the direction of policy or framework adjustments.

The regional scope of this paper covers Canada and its provinces. It is natural to consider Canada as a whole for estimating the lags of monetary policy. This is because the monetary policy conducted by the central bank is one for the whole country. However, Canada is a collection of diverse provincial economies operating within a common monetary policy environment. Each province manages its own fiscal policy, supported by the federal fiscal policy, which may result in different economic activity levels. The objective of this paper will be to estimate whether there is uniformity in the lags of monetary policy across the provinces and whether any discrepancy occurs among them.

The main results are expected to show approximately 2 year lags for inflation and significantly shorter lags for the economic activity variables. Additionally, the results are expected to hold during different time periods. This paper will contribute in providing supporting empirical evidence for Friedman's and Batini and Nelson's studies, but for the case of Canada. Additionally, it will show whether the previously estimated lags hold even in turbulent times such as the global pandemic.

This paper proceeds as follows. In section 2, a literature review is introduced to initiate the topic and review papers that discuss similar topics or have similar methodologies. In section 3, the methodology used for the empirical analysis will be explained, including the data overview and the modeling of the real interest rate. In section 4, the empirical evidence can be found. There, the analysis is split in two parts: National and Provincial evidence. In section 5, the conclusions and future directions are discussed.

2 Literature Review

Friedman has made a few important contributions to the literature when it comes to monetary policy. He has been advocating against discretionary monetary policy, and supporting predetermined rules-based policy. That requires analyzing the lags in order to determine the rules by which the monetary policy will be guided. Therefore, he has focused his research on recognizing and examining the lags of monetary policy. M. Friedman (1972) has analyzed the lead and the peak of $M1$ and $M2$ money aggregates to industrial production as a measure of economic activity. He has identified the peaks and the troughs and found that the money aggregates lead with 3 to 4 quarters. With these results, Friedman has provided evidence on the monetary policy legitimacy which have been criticized in that period, mostly due to economists making exaggerated claims leading to social discontent. His main conclusions were that monetary policy changes take much longer to affect the prices than the output (M. Friedman, 1972). Furthermore, M. Friedman and Schwartz (2008) advocated that predictable monetary policy can be an important factor in stabilizing the economy. Moreover, M. Friedman (1961) suggests that the lags of monetary policy are present under different monetary arrangements and periods, meaning that the lagging is structural. Besides, he has been advocating about money neutrality and his work has had a big role and implications in policy making as well. The key concept associated with him is that changes in the money supply can have an effect on nominal variables such as prices but not on real economic variables (M. Friedman, 1961). M. Friedman (1980) suggests that a successful monetary policy to reduce inflation will lead to slowdown in the economic activity coupled with the inevitable lags in wages and price adjustments. His findings have been seconded by B. M. Friedman and Kuttner (1992) saying that the role of money as a monetary policy framework or an intermediate target might be weak, and they found no evidence that suggest a strong relationship between the money base level and prices levels, supporting money neutrality.

The monetary policy lags are important element in the inflation targeting framework that Bank of Canada has implemented. They are part of the policy horizons, that represent the period that a monetary policy is expected to return to target (Mu & Voss, 2022). One of the main reasons for specifying the policy horizons is to provide transparency about the central bank intentions for returning the inflation within target (Mu & Voss, 2022). This can be essential for setting up expectations for inflation by the agents in the economy. The consensus has been that the lags are around the 2 year mark, which has been supported by empirical evidence by Batini and Nelson (2001). Identifying the lags and choosing a optimal inflation horizon is important due to the adverse effect of misspecification. Coletti et al. (2006) suggest that too short horizon may be destabilizing for the real economy due to the high volatility by changes in the monetary policy, whereas too long horizon may result in persistent deviations of the inflation from the target. This highlights the importance of exploring the lags of monetary policy especially for the context of inflation targeting.

There are different approaches in the literature to examine the lags of monetary policy. One approach is timing with respect to business cycle dates. This approach used by Friedman uses correlations of money supply and the turning points of the business cycle. This type of estimation requires identification of the peaks and the troughs of the business cycles. Romer and Romer (1989) established and used the business cycle dates to estimate the lags of monetary policy as well. Their estimation had the same methodology as M. Friedman (1961). In this paper they found that the highest effect of the monetary policy to the unemployment rate is at 11 periods (months). Therefore, in the post-war era they found significant and persistent lagging effects of monetary policy on output measured through the unemployment rate and industrial production.

Another approach is estimating the lags of monetary policy by using the inflation persistence. There are different types of inflation persistence, including positive serial correlation in inflation, lags between systematic policy changes and their peak effect on inflation and lagged responses to non-systematic policy shocks (Batini & Nelson, 2001). For the first type of inflation persistence Batini and Nelson (2001) provide evidence on high serial correlation using autoregressive models. This approach has been used to motivate the use of the Phillips curve that imposes inertia in inflation (Fuhrer & Moore, 1995). Batini and Nelson (2001), using dynamic correlation methodology which utilizes the second type of inflation persistence and model-free estimation, showed that the delay in the effect of monetary policy are consistent regardless of the inflation regime, comparing the lags for the USA and the UK. Their results are robust to different regimes such as the non-inflationary regimes in the USA and the UK and different settings. The third type uses the policy shocks to estimate the lagged responses to inflation and/or output. Rotemberg and Woodford (1997) used this approach and set up structural economic model to estimate the effects of monetary policy on the economy. Nevertheless, Batini and Nelson (2001) argue that both Lucas as well as the New Keynesian economists do not claim that the policy shocks are the most important source of output variability or that the monetary policy shocks dominate the business cycles.

In addition, a dynamic stochastic general equilibrium models have been used to explore the inflation dynamics. This type of modeling usually requires modeling of the economy behaviour, monetary policy, market clearing conditions as well as shocks, and typically utilizing the New Keynesian Phillips Curve framework. For example, Macklem (2001) examines the response of inflation on the short run using a model affected by supply shocks. There, he is using the premise that not all prices are perfectly flexible in the short run. Similarly, Nishiyama (2009) uses aggregate demand and aggregate supply shocks in a structural model to estimate the lags of monetary policy as well. Their estimates suggest 9 quarters of lags for CPI inflation.

3 Empirical Analysis

3.1 Methodology

There are two main streams in the literature to approach the estimation of the lags of monetary policy. One approach is to estimate the lags by examining the effects of exogenous monetary policy shocks on macroeconomic aggregates, and the other approach is to use dynamic correlations estimation between the monetary policy instruments and the inflation and economic activity measures. The first approach uses the exogenous monetary policy shocks or shocks that are non-monetary and are coming from the private sector or are fiscal. With this method, one can utilize these shocks to undertake an impulse response function analysis and analyze the inflation dynamics. This approach requires setting up a dynamic general equilibrium model and can be vulnerable to missspecification of the shocks (Christiano et al., 2005). Additionally, this methodology utilizes the New Keynesian Phillips Curve and does not imply persistence in inflation. Gali and Gertler (1999) use this methodology to estimate the inflation dynamics.

Alternatively, the dynamic correlation methodology focuses on the general pattern between the monetary policy and inflation. One can estimate the peak of the correlation coefficient using both the maximum or minimum value depending of the context, between the measures of systematic monetary policy and inflation or output. For example, Batini and Nelson

(2001) use model-free estimation of inflation persistence using dynamic correlation analysis. This approach overcomes the main issue of model misspecification (Batini & Nelson, 2001).

3.1.1 Dynamic correlations analysis

The methodology used in this paper will be the dynamic correlation methodology. Therefore, the focus will be on analyzing the dynamic correlations of inflation and economic activity on one side and the monetary policy instruments on the other.

Dynamic correlation analysis allows for exploring how the relationship between different economic variables changes over time. They are based on unconditional bivariate relationship between the examined variables. Main advantage of using this approach is that it is not vulnerable to model misspecification, as the model using exogenous monetary shocks (Batini & Nelson, 2001). Instead of looking at individual shocks in isolation, this method allows for the use of the fact that a combination of individual shocks can generate a particular pattern of correlations (Batini & Nelson, 2001). The systemic monetary policy actions can result in dynamic cross-correlations in the data, that can be seen as empirical regularities and serve as evidence of the lagging effects. Additionally, compared to the New Keynesian Phillips Curve modeling (hereafter, simply NKPC), this methodology is not subject to omitted variable bias (Hall et al., 2009). Furthermore, the variables in NKPC can be vulnerable to measurement error (Hall et al., 2009). Other advantages to the dynamic correlation analysis are: the ability to adapt to changing economic conditions and capture nuanced relationships, and reveal more time-variant insights that the static analysis cannot.

Looking at the dynamic correlations only has some limitations. The dynamic correlations do not capture a causation, meaning that the findings from this analysis is suggestive. Another concern of using this methodology is that there should not be an observed relationship between the monetary policy measures and inflation if the monetary policy adjusts to off-set exogenous shocks (Batini & Nelson, 2001). However, in practice those relationships exists, especially in the forward-looking inflation targeting frameworks. For instance, M. Friedman (1961) found that the the relationship between the lags of monetary policy and other variables such as inflation measures or output measures are present under different monetary arrangements and different time periods. This suggests that the lagging relationship is structural. His findings suggest that the dynamic relationship prevail over long time span and therefore lags are not determined by different policy rule. Furthermore, according to Batini and Nelson (2001) the systematic component of policy is essential in inflation behaviour, and they suggest that there is no theory that asserts that only the exogenous shocks matter.

The general methodology will the the following: calculating the dynamic correlations between any monetary policy instrument x_t, and any target measure (inflation or economic activity) Δy_t:

$$\rho_k(x_t, \Delta y_{t+k}), \qquad\qquad k = 0, \ldots, 36$$

where k is set to 36 months throughout the analysis.

A summary measure of the lags of monetary policy for any instrument and target variable is the k^p. It gives the peak correlation, minimum or maximum depending upon the context. For example, a negative peak correlation is expected between the inflation and the interest rate monetary policy instruments. The central banks utilize this relationship to influence lowering of the inflation by increasing the overnight interest rates. Similarly, a negative peak correlation is expected between the interest rates and the GDP growth and employment, whereas a peak positive correlation is expected for the unemployment rate. This is because when interest rates are high, the economic activity typically slows down making the GDP and employment lower, and the unemployment rate higher. When it comes to the money aggregates as monetary policy measures, a peak positive correlation is expected between them and the inflation. The reasoning here is that when there is influx of money supply on the market that is usually associated with higher inflation rates. The peak correlations will be reported in tables, whereas the full sets of the dynamic correlations will be reported as figures to allow for more comprehensive summary of the relationship between the monetary policy instruments and the target variables.

3.1.2 Consideration of monetary policy instruments and target variables

In this paper, three monetary policy instruments will be considered:

1. Overnight rate
2. Real overnight rate
3. Money aggregates

The overnight rate is chosen as the main monetary policy instrument since the Bank uses it to channel its policy and announces its target at eight fixed dates each year ("Policy Interest Rate", 2023). The Bank of Canada indirectly uses it to influence the interest rates on the market and therefore through them have an effect on the inflation rate. The historic changes of the overnight money market rate as well as the yields of the Treasury Bills (1 month), and two long-term Canadian benchmark bond yields (5 and 10 year) are shown in Figure 7 in the Appendix. Secondly, the real overnight rate has the advantage of measuring the real change in monetary policy and may provide a cleaner measure of policy changes. Finally, money supply aggregates will be used as well. Money aggregates are traditional measures of monetary policy and may provide further insights to the question of monetary policy lags; as well, allow for comparison with other studies.

Target variables will be used to capture the lags of monetary policy. Here, target variables refer to inflation and economic activity variables and by no means it implies that these are all targets of the central bank's monetary policy framework. The following target variables will be used in this estimation:

- inflation and core inflation
- GDP, employment, and unemployment rate

The lags of the monetary policy will be observed firstly on inflation. For this purpose, I will use two inflation measures. The first one is the All-items CPI (hereafter, simply CPI). The second one is an inflation measure which will serve as an approximation measure for the core inflation. Bank of Canada uses different measures for core inflation. For instance, CPI-trim excludes the prices that are in the tail of the distribution of price changes, CPI-median bases the core inflation measure around the 50th percentile of the distribution, and CPI-common tracks the common price changes across different categories of the basket. However, these are not available on the provincial level. The series used in this paper is the All-items excluding food and energy (hereafter, simply CPIX). By using it, I will try to exclude the variation in the price indices due to changes of gasoline and food prices, and capture only the core price changes. This could be particularly relevant when it comes to the recent variations in gasoline and food prices driven by the Russo-Ukrainian War, and COVID-19. Additionally, CPIX core inflation measure was used by the Bank from 2001 to 2016 as a core inflation measure, which covers most of the examined period, therefore it is a suitable measure for core inflation ("Bank of Canada's Preferred Measures of Core Inflation General Information Document", 2020). The core inflation measure measured through CPIX is not a preferred measure of core inflation, but it is quite closely related to the measure of core inflation, therefore it will be a used in this estimation (Mu & Voss, 2022).

The inflation and core inflation will be used for both the Canadian and the provincial estimates. In regard to the economic activity variables, the GDP and employment will be used for the national estimation, whereas the unemployment rate will be used for the provinces.

This is due to the unavailability of monthly GDP series on provincial level, but also because the unemployment rate is very responsive to changes in the economic environment and represents a good output measure.

3.2 Data

3.2.1 Variable definitions

All series used will be discussed in this section. Table 1 summarizes how the data series are used in the estimation, including their transformations. The raw data series and their sources are represented in Table 8 in the Appendix.

The sample period for this estimation is 1994M1-2023M6, except for the GDP series which is only available from 1997M1. The start date is chosen because that is when the two percent mid-point target for the inflation was specified, even though the first inflation targeting framework was introduced 1991 (Beaudry & Ruge-Murcia, 2017). The examination period for this paper is set to end on June 2023. Therefore, the full sample includes some of the effects of the recent changes in the overnight rate due to the inflation being above target.

The CPI and CPIX data is in monthly frequency setting the frequency and period of interest of this analysis as a month. The interest rate raw data is in daily frequency, and it has been transformed to monthly frequency using the mean value per month.

Table 1: Series and transformations for estimation

Instrument Measures		
Variable	Transformations	Description
i_t	Levels	Overnight money market interest rate
r_t	Levels	Real overnight monetary market interest rate (see text for details)
m_1	$\Delta_{12} \ln M_t^{1+}$	M1+ (gross) Seasonally adjusted
m_2	$\Delta_{12} \ln M_t^{2++}$	M2++ (gross) Seasonally adjusted
Target Measures (National and Provincial)		
Variable	Transformations	Description
π_t	$\pi_t,\ \Delta_6\pi_t$	CPI All-items (P_t): $\pi_t = \Delta_{12} \ln P_t$
π_t^c	$\pi_t^c,\ \Delta_6\pi_t^c$	CPIX All-items excluding Food and Energy (P_t^c): $\pi_t^c = \Delta_{12} \ln P_t^c$
g_t	g_t	GDP All Industries growth: $g_t = \Delta_{12} \ln Y_t$
e_t	e_t	Employment : $e_t = \Delta_{12} \ln E_t$
$\Delta_{12}u_t$	$\Delta_{12}u_t$	Unemployment rate 15-years and above: u_t

Note: Data sources are provided in the Appendix A.

The historic yearly growth of both money aggregates is visualized in Figure 8 in the Appendix.

As indicated in Table 1, some variables will be used in a 6-month or 12-month changes. Batini and Nelson (2001) use year-on-year change for inflation and the money growth variables. In this paper 6-month change in inflation variables will be used, as well as year-on-year GDP growth and employment, and unemployment rate. Using changes in variables helps to deal with the unit root tests and non-stationary time series. When taking the first difference of a non-stationary series, the series is being mathematically transformed into a series of changes which helps make the series stationary (Kotu & Deshpande, 2019). Moreover, using change in the variables rather than the level makes the variables not be dominated by long-term swings in the mean of the variable driven by non-policy factors (Batini & Nelson, 2001). Finally, variety of measures were tried and these transformations were chosen since they were giving the cleanest results.

3.2.2 Constructing the real interest rate

One of the most famous hypothesis representing the simple equilibrium models was discussed by Irving Fisher (Dimand, 1999). The hypothesis suggests that there is a relationship between the nominal interest rate, the real interest rate and the expectation of inflation (Fisher, 1965). This means that a measure of the real interest rate can be constructed by subtracting the expected inflation rate from the nominal interest rate. Therefore, in order to estimate the real interest rate for this estimation, first an estimation of the expected inflation must be conducted.

There are many forecasting models used to estimate the expected inflation nowadays, including different autoregressive models where the lags are determined by the Akaike Information Criterion (AIC), different ARIMA models, models based on Treasury Bills spreads and others. The model used to estimate the expected inflation in this paper is based on a Philips Curve forecast. It is a modification of Gordon's "triangle model" (Gordon, 1981). The triangle model includes: lagged inflation, unemployment and supply shock variables. For simplification, yet solid estimation, the model used in this paper used to estimate the expected inflation includes core inflation lag lengths of 24 months, as well as unemployment rate lags of 12 months:

$$\pi_{t+1} = \alpha_0 + \sum_{i=1}^{24} \beta_i \pi^c_{t+1-i} + \sum_{i=1}^{12} \gamma_i u_{t+1-i} + \epsilon_{t+1}$$

The determination of the lags of inflation and unemployment rate was based on Akaike Information Criteria because this estimation together with the Final Prediction Error (FPE) allows for minimizing the underestimation and maximizing the probability of recovering the true lag length (Liew, 2004). AIC uses maximum likelihood method as a measure of fit, and the lower the coefficient of AIC the better is the fit of the model. From a Vector Auto-Regression estimation, it has been determined that the lags for inflation should be 24. This lag was suggested by both AIC and FPE. In regard to the unemployment rate, the optimal lags have been determined to be 12 according to both criteria.

Since this is a forecasting regression, the R^2 coefficient is relevant and it is 0.9379. This suggest that around 94% of the variance in the dependent variables is explained by the independent variables included in the model. The adjusted R^2 , which penalizes for including many independent variables, is 0.9309. The F-statistic is 133.02, which suggests that the independent variables are jointly highly statistically significant.

The equation used to estimate the real interest rate for the purposes of this paper is the following:

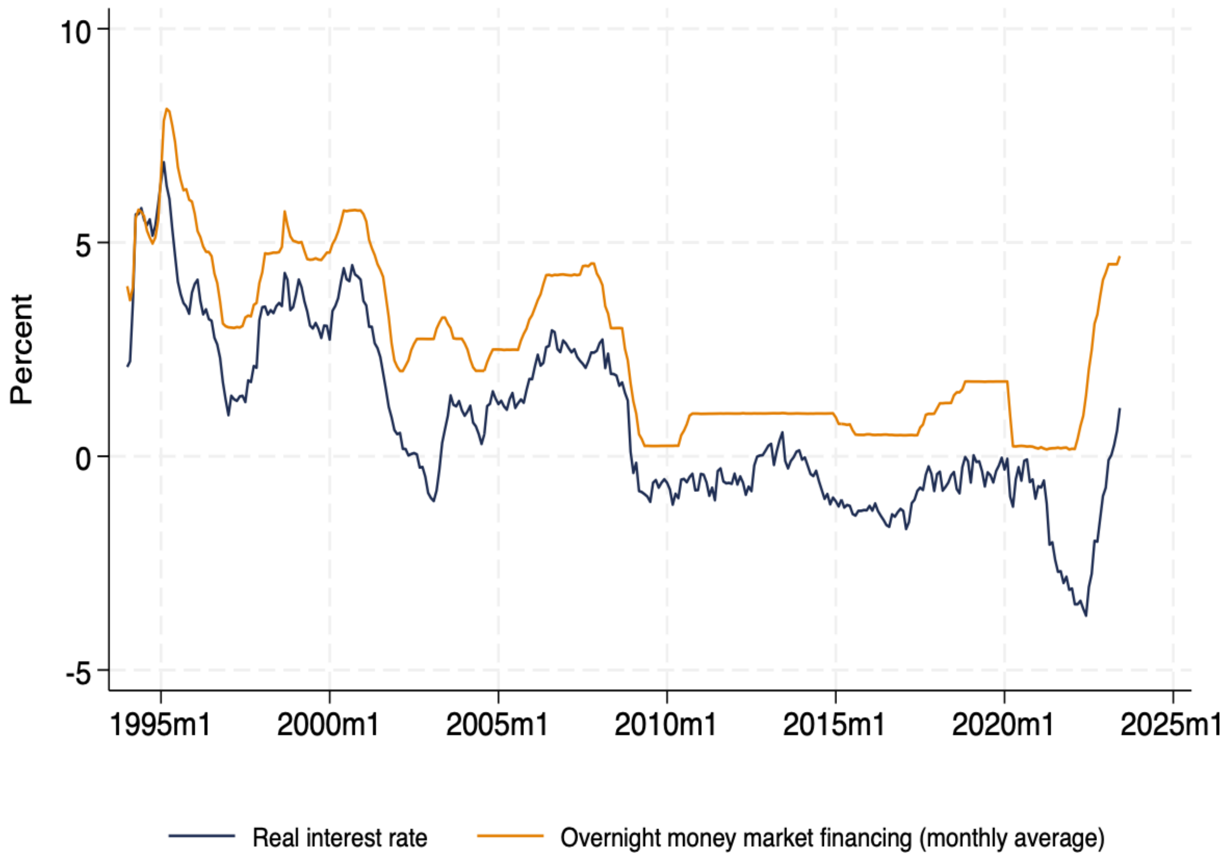
$$r_t = i_t - E_t \pi_{t+1}$$

where the expected inflation is estimated by using the fitted values from the regression above:

$$E_t \pi_{t+1} = \hat{\pi}_{t+1} = \hat{\alpha_0} + \sum_{i=1}^{24} \hat{\beta}_i \pi^c_{t+1-i} + \sum_{i=1}^{12} \hat{\gamma}_i u_{t+1-i}$$

To illustrate the constructed real interest rate against the overnight market rate, a graphical representation follows :

Figure 1: Overnight money market rate and real interest rate



3.2.3 Summary statistics

To better illustrate the data, summary statistics are calculated for the sample. Table 2 shows the details for Canada, whereas Table 3 shows the summary statistics for the provincial data.

Here, the measure of inflation persistence is represented by ρ. It is calculated as a simple AR(1) specification:

$$y_{t+1} = \alpha + \beta y_t + \upsilon_{t+1}$$

where:

y_{t+1} represents π/π^c in the current period

y_t represents π/π^c in the previous period

Table 2: Summary statistics - Canada

Variable	N	Mean	Median	σ	ρ
Inflation (π)	354	2.002	1.882	1.312	0.945
Core inflation (π^c)	354	1.736	1.586	0.935	0.960
Overnight money market rate (i)	354	2.561	2.253	1.906	
Real overnight interest rate (r)	354	0.825	0.114	2.088	
Money aggregate (m_1)	354	8.112	7.959	4.755	
Money aggregate (m_2)	354	6.484	6.355	1.876	
Unemployment rate ($\Delta_{12}u$)	354	-0.212	-0.300	1.361	
Employment (e)	354	1.502	1.710	2.304	
GDP growth (g)	306	2.238	2.615	2.791	

Note: σ is the standard deviation; ρ is the inflation persistence coefficient

The core inflation shows lower average and lower variability compared to the CPI inflation. Regarding the money supply, $M1$ shows significantly more variation than $M2$. When it comes to the economic activity variables, the GDP growth rate is the most variable.

The mean inflation in Canada and the provinces for the examined period is in the range of 1.79% to 2.32% with British Columbia and Quebec being the only provinces averaging below the 2% mark. The province with the highest standard deviation in inflation is Prince

Table 3: Summary statistics - Provinces

Provinces	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC
(π)										
N	354	354	354	354	354	354	354	354	354	354
Mean	2.004	2.092	2.113	2.027	1.828	2.071	2.140	2.163	2.324	1.789
Median	1.905	1.928	1.863	1.808	1.651	1.955	2.018	1.937	2.028	1.761
σ	1.482	2.084	1.696	1.655	1.451	1.343	1.456	1.257	1.644	1.370
ρ	0.902	0.936	0.928	0.928	0.947	0.932	0.932	0.908	0.872	0.945
(π^c)										
N	354	354	354	354	354	354	354	354	354	354
Mean	1.632	1.688	1.737	1.609	1.515	1.850	1.918	1.910	2.078	1.484
Median	1.410	1.496	1.545	1.394	1.319	1.713	1.786	1.796	1.776	1.345
σ	0.944	1.172	1.026	1.200	1.200	0.941	1.038	0.899	1.244	1.191
ρ	0.878	0.936	0.922	0.941	0.956	0.942	0.932	0.920	0.960	0.959
($\Delta_{12}u$)										
N	354	354	354	354	354	354	354	354	354	354
Mean	-0.334	-0.339	-0.278	-0.200	-0.307	-0.188	-0.161	-0.130	-0.134	-0.170
Median	-0.350	-0.300	-0.300	-0.300	-0.400	-0.200	-0.100	-0.200	-0.300	-0.400
σ	1.709	1.619	1.291	1.356	1.560	1.468	1.147	1.220	1.709	1.562

Note: σ is the standard deviation; ρ is the inflation persistence coefficient

Edward Island (2.08), and the province with the lowest variability measured through the standard deviation (1.26) is Saskatchewan. The inflation persistence coefficient moves in the range of 0.872 to 0.945 as expected. The mean core inflation rate ranges from 1.48% for British Columbia to 2.08% for Alberta. The range of the core inflation persistence coefficient is: 0.878 to 0.96. That means that the inflation persistence shows a higher coefficient for the core inflation compared to the CPI inflation.

4 Empirical Evidence

4.1 National evidence

The key focus of the monetary policy is inflation. In regard to inflation, the results presented in Table 4 suggest that the lags of monetary policy are estimated to be 17 to 24 months. The overnight interest rate and the real interest rate show similar findings, whereas the lagging effects are quite shorter as examined through the money aggregates. Additionally, the lags are estimated to be slightly longer for the core inflation measure.

Table 4: Monetary policy lags for Canada

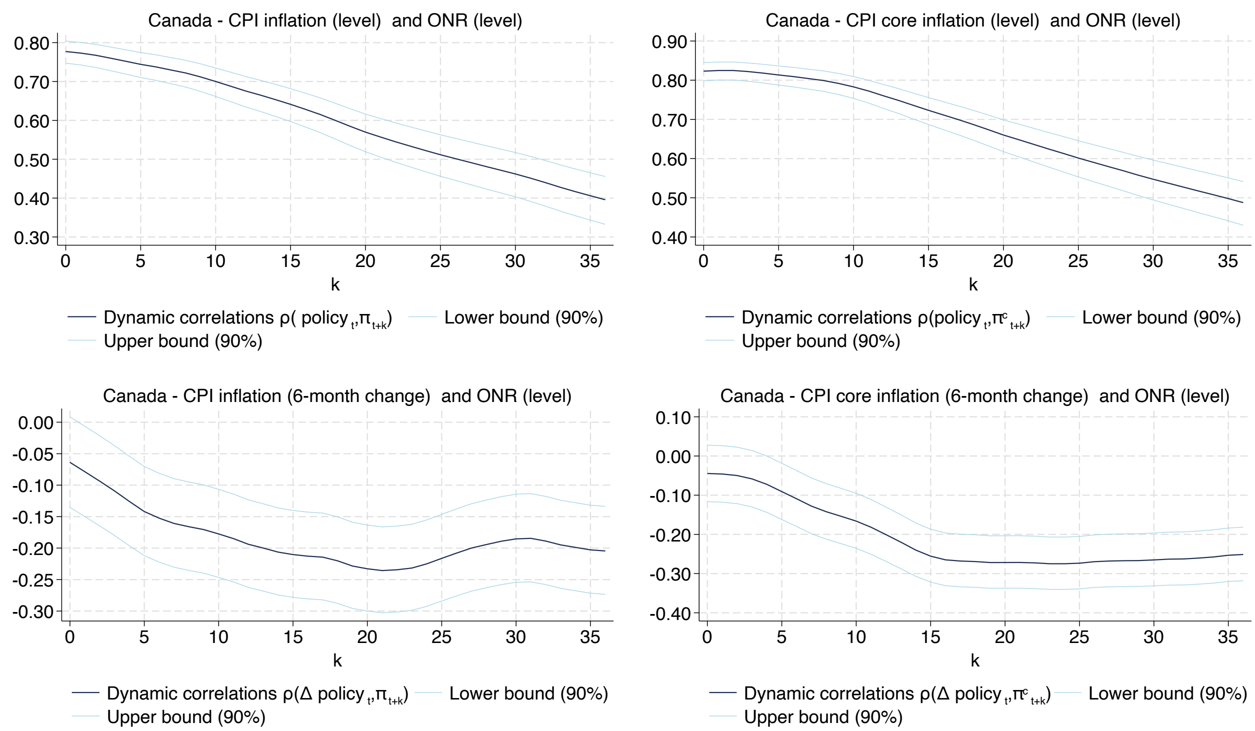
	Target variables		
	Inflation effects / (k^p)		
Monetary policy measures		CPI ($\Delta_6\pi$)	CPIX ($\Delta_6\pi^c$)
i		21*	24*
r		17*	17*
m_1		12*	12*
m_2		6*	7*
	Output effects / (k^p)		
	GDP (g)	Employment (e)	Unemployment rate ($\Delta_{12}u$)
i	12	13*	12*
r	32	12*	9*

Note: * Significantly different from zero using conventional two-sided t-test at 90% level

Overall, the results indicate that there are long lags of monetary policy on inflation, and those are estimated to be around the 2-year mark. Using two different inflation variables, and different monetary policy measures support the robustness of the main findings. Additionally, the results suggest that the core inflation lags are slightly longer. This might be due to the food and energy prices adjusting quicker to the changes in the interest rates. These findings are robust since the core inflation lags are equal or longer as estimated through all four monetary policy measures.

When it comes to the main monetary instrument (i), a full set of the dynamic correlation coefficients are shown in Figure 2 for up to 36 lags.

Figure 2: Dynamic correlations (CPI/CPIX & Overnight money market rate)



Note: Sample Period: 1994M1-2023M6

The first two graphs show the dynamic correlations of the levels of inflation and the overnight rate. The first month lags have a high positive correlation coefficient of approximately 0.8, that starts to decrease as the lags are increasing. This is reasonable since there is a high coefficient of inflation persistence. The third and the forth graph in this figure are the main part of the analysis. From here we can clearly see that the minimum correlation coefficient is between 20 to 25-month mark. A full set of the dynamic correlation coefficients for the real overnight rate is presented in Figure 9 in the Appendix, and Figure 12 and 13 for the money aggregates.

Secondly, the lagging effects of monetary policy on the output target variables are estimated to be quite shorter than on inflation. For the unemployment rate the lags are estimated to be 9-12 months. The employment has similar estimated lags of 12-13 months. Finally, the effects on GDP growth are estimated to be 12-32 months, but the results are statistically insignificant. Overall, the output lagging effects are estimated to be around 9-13 months. The findings are consistent across different output measures especially for the main monetary policy instrument, adding an additional layer of robustness to the results.

Figure 10 and Figure 11 in the Appendix represent the full sets of dynamic correlations between the monetary policy measures and the output measures. For the overnight rate, the extremes for all of the three output measures are between the 10 and 15-month mark. Similar picture can be seen for the real interest rate, resulting in the extremes being close to the 10-month mark for unemployment rate and the employment growth. The GDP growth minimum correlation coefficient is between the 30th and the 35th month, however it is statistically insignificant.

The main findings that there are long monetary policy lags on inflation estimated to be around the 2-year mark are in line with previous research. Batini and Nelson (2001) found that for the post-war data for the USA, the lags of monetary policy on inflation are estimated to be 2 years. Here, there are estimated to be 21-24 months. Additionally, M. Friedman (1972) has found that $M1$ lead peaks at 4 quarters, where as $M2$ lead peaks at 3 quarters for the post-war period. This is close to the findings measured through the money aggregates. The second main conclusion in this paper is that the lags on the economic activity are estimated to be shorter and ranging around 12 months. This is consistent with Friedman's findings and conclusions. M. Friedman (1972) found that monetary policy changes take longer to affect prices than output.

4.2 Provincial evidence

For simplicity and due to data availability, in the provincial empirical analysis, the lagging effects are examined thorough three target variables including: CPI inflation, core inflation and unemployment rate. The monetary policy instruments of interest will be the overnight rate and the real overnight rate as they serve as the main monetary policy instruments. The results are shown in the table below:

Table 5: Monetary policy lags for the Provinces (Monetary policy instrument: Overnight rate)

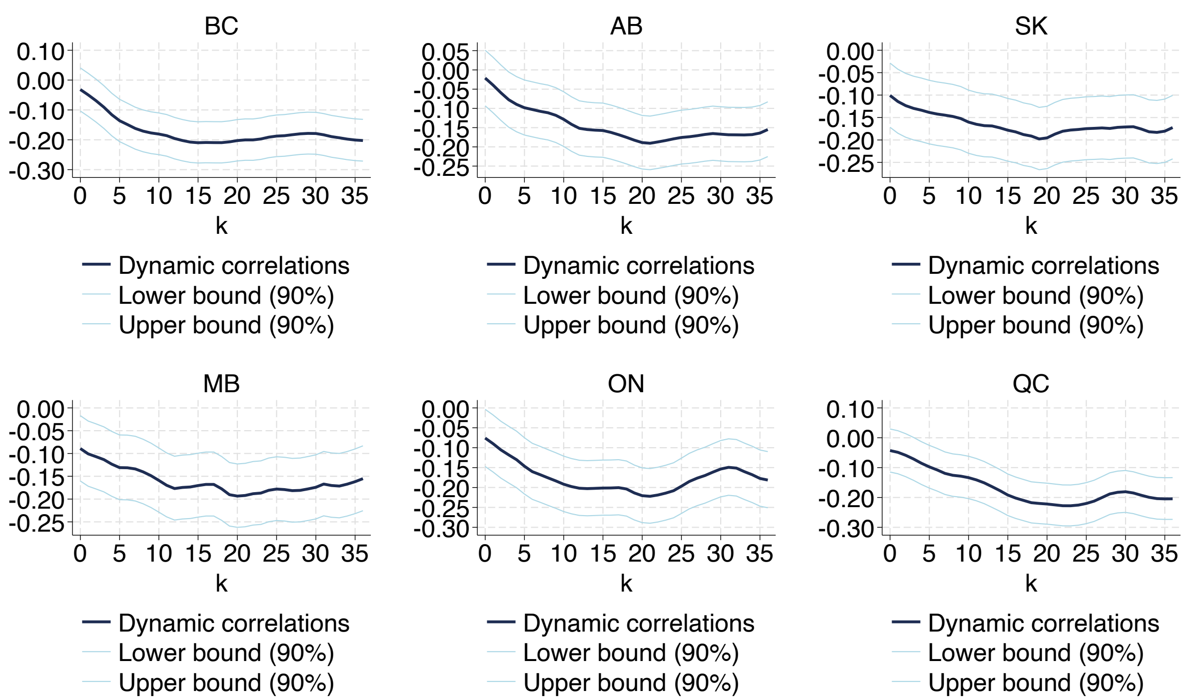
Monetary policy instrument: i

Provinces	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC
Target variables / (k^p)										
$\Delta_6\pi$	29*	35*	23*	34*	23*	21*	20*	19*	21*	15*
$\Delta_6\pi^c$	31*	25*	26*	34*	24*	19*	25*	31*	21*	34*
$\Delta_{12}u$	23*	10*	13*	9*	11*	12*	14*	16*	17*	12*
Consistency										
$k^p(\pi)/k^p(u)$	1.26	3.50	1.77	3.78	2.09	1.75	1.42	1.19	1.24	1.25
$k^p(\pi^c)/k^p(u)$	1.35	2.50	2.00	2.78	2.18	1.58	1.79	1.94	1.24	2.83

Note: * Significantly different from zero using conventional two-sided t-test at 90% level

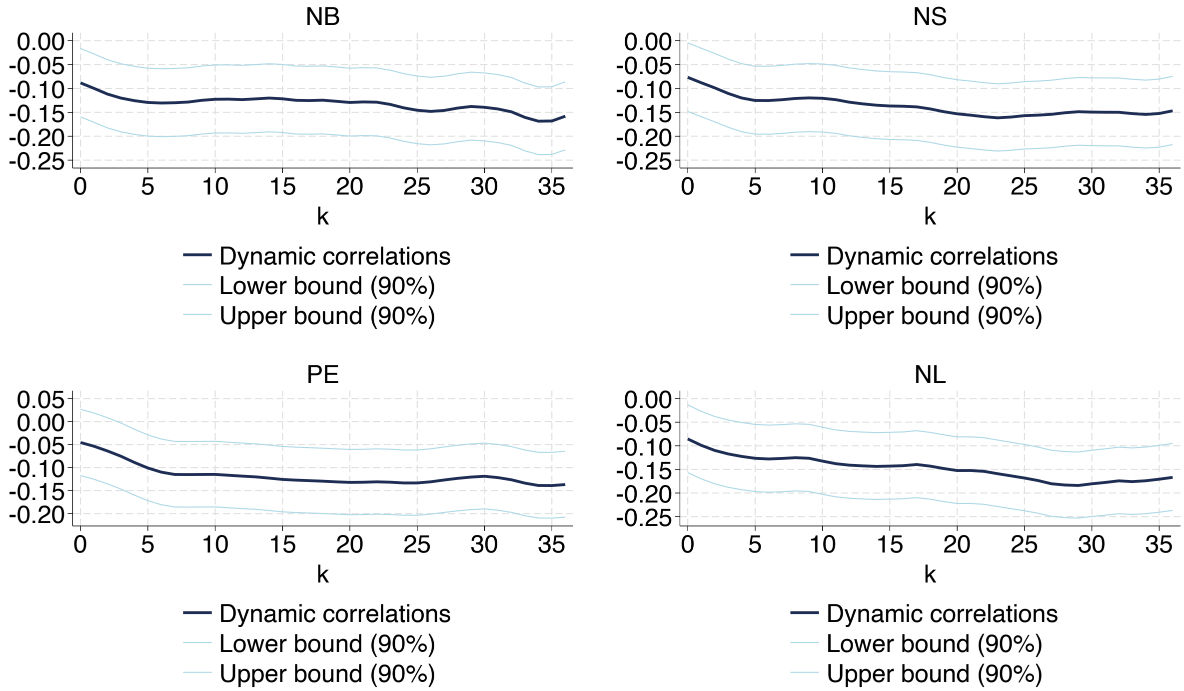
The CPI inflation lags for the provinces individually as measured through the overnight rate are estimated to be between 15-35 months, with majority of the lags being around 20 months. The maritime provinces have relatively longer monetary policy lags compared to the rest of the provinces. The only two provinces with lags over 30 months are attributed to these provinces. These results are consistent with the national estimate of 21 months. When it comes to the core inflation measure, the monetary policy lags are ranging between 19-34 months. The lowest number of lags is 19 and is observed for Ontario. These results are confirming the findings from the national estimates where longer lags are estimated for the core inflation. Full dynamic correlation coefficient sets are shown in Figure 3 and 4 for the CPI below and Figure 14 and 15 for the CPIX available in the Appendix.

Figure 3: Dynamic correlations for the Provinces Part.1 (CPI (6-month change) & Overnight money market rate)



Note: Sample Period: 1994M1-2023M6

Figure 4: Dynamic correlations for the Provinces Part. 2 (CPI (6-month change) & Overnight money market rate)



Note: Sample Period: 1994M1-2023M6

The other aspect of the lagging effect of monetary policy for the provinces is observed through the output effects. Here, the results also suggest that the monetary policy lags are shorter for the economic activity compared to inflation as it was the case for Canada as a whole. The lags are estimated to be in the range of 9-23 months, with majority of provinces having approximately 13-month lag.

To check for consistency of the results, a ratio of the inflation variables lags and the output lags is calculated. The ratio is uniformly above 1 across all provinces, for both measures of inflation. This provides additional support to the claim that the economic activity responds more quickly to monetary policy changes. The ratio ranges from 1.19 to 3.78, meaning that in some instances the economic activity responds almost 4 times faster. This is mostly due to the maritime provinces having especially long inflation lags, whereas the economic activity lags are more uniform across provinces.

Another perspective can be seen in Table 6 where the results of having real rate as monetary policy measure are represented. The monetary policy lags observed there show that for the CPI inflation they are in the range of 0 to 32 months, whereas for the core inflation they are in the range of 0 to 31 lags. The output lags are estimated to be between 6 and 13 months.

Table 6: Monetary policy lags for the Provinces (Monetary policy instrument: Real rate)

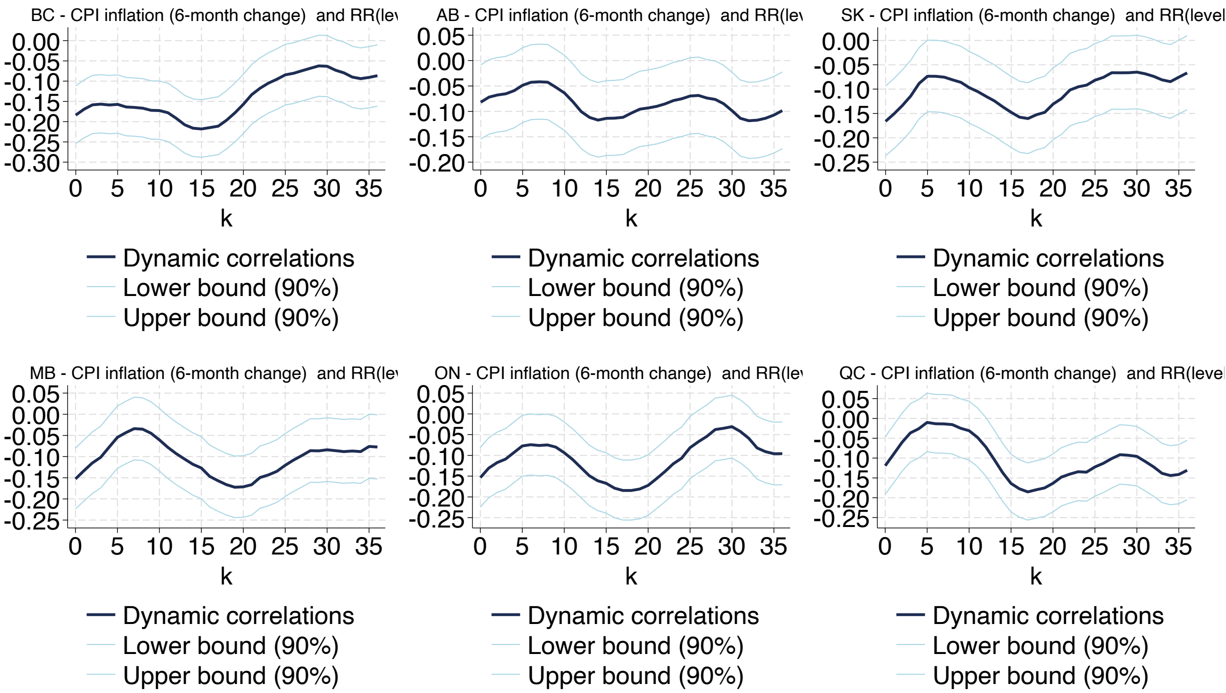
Monetary policy instrument: r

Provinces	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC
Target variables / (k^p)										
$\Delta_6\pi$	0*	0*	0*	0*	17*	18*	19*	0*	32*	15*
$\Delta_6\pi^c$	0*	21*	19*	0*	17*	17*	0*	0*	31*	0*
$\Delta_{12}u$	7*	8*	13*	6*	6*	9*	9*	7*	13*	9*
Consistency										
$k^p(\pi)/k^p(u)$	0.00	0.00	0.00	0.00	2.83	2.00	2.11	0.00	2.46	1.67
$k^p(\pi^c)/k^p(u)$	0.00	2.63	1.46	0.00	2.83	1.89	0.00	0.00	2.38	0.00

Note: * Significantly different from zero using conventional two-sided t-test at 90% level

However, this table does not show the whole picture. Better representation of the lags as measured through the real interest rate can be observed in Figure 5 and 6 below and Figure 16 and 17 for the core inflation available in the Appendix.

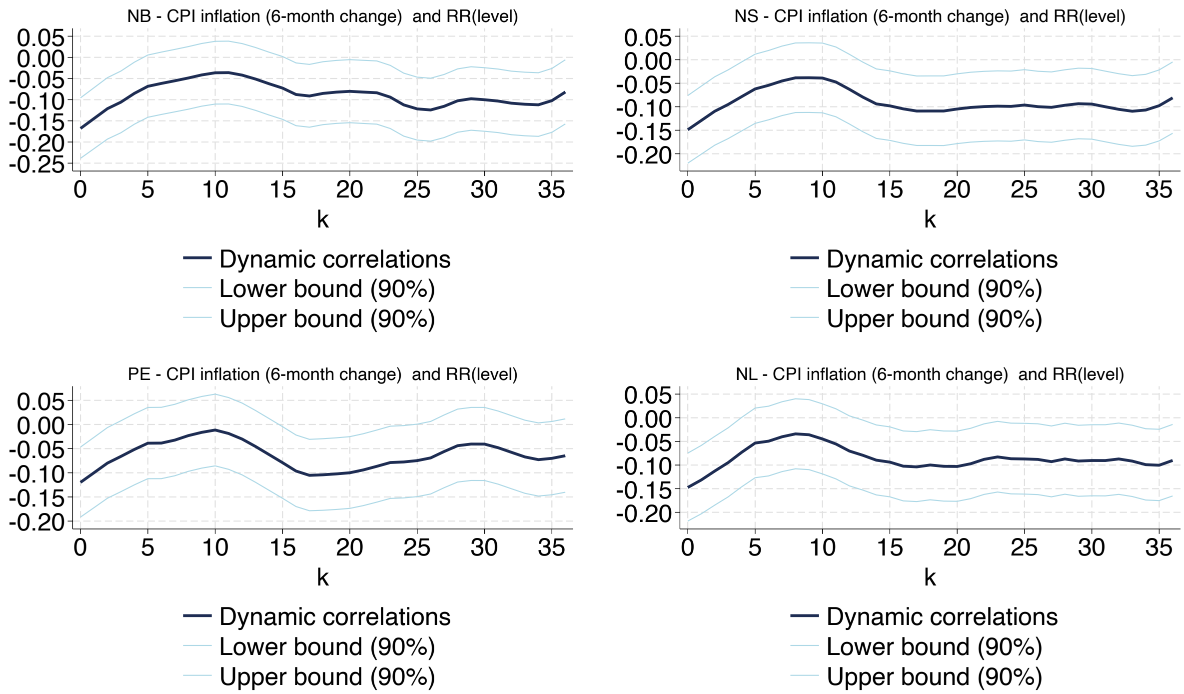
Figure 5: Dynamic correlations for the Provinces Part.1 (CPI (6-month change) & Real interest rate)



Note: Sample Period: 1994M1-2023M6

From here we can see that the real interest rate does not have a more immediate adjustment to the monetary policy changes as the overnight rate since it depends on inflation expectations and it is not as closely related to the monetary policy changes as the overnight rate. Therefore, from these visuals we can observe the local minimums rather than the global minimums for the real lagging effect of the monetary policy. For the CPI inflation, majority of the provinces have their local minimum at 15 to 20 months, except for New Brunswick where the lagging effect is estimated to be after the 25th month. Similar picture can be seen for the CPIX inflation, where the majority of the provinces have their lagging effect of monetary policy to be estimated between 15 to 20 months with a couple more provinces seeing lagging effects longer than 20 months. This interpretation of the results is more in line with the findings from the main monetary policy instrument (i), and is confirming the notion from the national results that the lags are shorter as measured through the real overnight

Figure 6: Dynamic correlations for the Provinces Part.2 (CPI (6-month change) & Real interest rate)



Note: Sample Period: 1994M1-2023M6

rate. The full set of dynamic correlation coefficients for unemployment rate can be seen in Figure 18 and 19 for the overnight rate and Figure 20 and 21 for the real overnight rate in the Appendix.

4.3 Stability

The national estimates indicated that the lags of monetary policy on inflation are over 20 months for the main monetary policy measure (i). The lags as measured by the real interest rate measure were estimated to be around 17 months, which is a bit shorter. When it comes to the lags on economic activity, the lags were shorter for all three target variables and were estimated to be approximately 12 months.

To explore whether the results will alter because of the COVID-19 pandemic, an estimation has been done by dropping the data after 2019M12. This means that with this sample, the influence of the pandemic will be stripped out of the estimation. The results are presented in Table 7.

Table 7: Monetary policy lags for Canada excluding COVID-19

	Target variables		
	Inflation effects / (k^p)		
Monetary policy measure		CPI $(\Delta_6\pi)$	CPIX $(\Delta_6\pi^c)$
i		21*	24*
r		17*	17*
m_1		12*	12*
m_2		6*	7*
	Output effects /(k^p)		
	GDP (g)	Employment (e)	Unemployment rate $(\Delta_{12}u)$
i	12	13*	12*
r	32	12*	9*

Note: * Significantly different from zero using conventional two-sided t-test at 90% level; Sample period until 2019M12

The findings after dropping the time period of the pandemic are identical as including it. This gives the results another layer of robustness.

This robustness check has been conducted on the provincial level as well. That estimation also showed identical estimated lags as including the pandemic data. The results are shown in Table 10 in the Appendix.

5 Conclusions

The purpose of this paper was to provide empirical evidence on the lagging effects of monetary policy for Canada and its provinces. The results for Canada indicate that the lagging effects are above 20 months for the inflation measures. This is in line with the findings for the USA done by Batini and Nelson (2001), where their results for CPI inflation suggest lags between 12 to 29 months. This paper also includes the COVID-19 period with high inflation rates, followed by frequent increases and changes in the overnight rates. The results suggest that even in unstable periods, the lags on inflation are around 2 years. When it comes to the economic activity effects, the results indicate that the lagging effects of monetary policy on output are shorter than the lags on inflation. They lagging periods are estimated to be around 12 months as measured through the overnight rate. The results are around the 12-month mark for all the output target variables: the unemployment rate, employment and GDP growth. This provides another layer of robustness of the results. This is also in line with the findings done in the USA by Romer and Romer (1989) where they found that the lagging effect of monetary policy on unemployment rate is around 11 months. Finally, the lags on inflation measured through $M1$ suggest that there is a 12-month lag, whereas for $M2$ the lags are estimated to be shorter.

Similar findings are seen on the provincial level as well. Overall, the output lagging effects are quite shorter than the inflation lagging effects. This is in line with the findings for Canada as a whole, and the previous research. For majority of the provinces, the monetary policy lags for inflation are estimated to be above 20 months. The findings also indicate that the lags are shorter for the CPI inflation compared to the core inflation. Additionally, the maritime provinces have longer lagging effects on average compared to the rest of Canada. The results also imply that the output lagging effects are shorter than the effects we see for inflation. They are in the range of 9-23 months with majority of the provinces having lags of around 1 year.

The cleanest and most robust results are seen through the main monetary policy instrument - the overnight money market rate. This is expected since Bank of Canada conducts its monetary policy by directly influencing the overnight money market rate, hence it shows the most robust results. When it comes to stability, the output target variables showed more stable results across the different monetary policy instruments. The reason for this phenomenon could be influenced by various factors, such as transmission mechanisms. If it takes time for the money supply to respond to the interest rate changes, than this may underlie the lagging effects of money aggregates on inflation.

The methodology in this paper was dynamic correlation examination to identify the extreme (minimum or maximum) correlation coefficient for the different monetary policy measures and the different outcome variables. I would expect other methods to deliver similar conclusions in terms of the lags of monetary policy and support the previous findings. Future directions and considerations could be enriching the robustness of the results by examining the lags of monetary policy through different periods of time such as exploring the lags of monetary policy prior to the inflation targeting framework and comparing the lags of monetary policy across different monetary policy frameworks.

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Appendices

A. Data sources

Table 8: Data Sources

Series Defintions	Series
Price Indices (π)	
(1) All-items CPI (2002=100)	see below
(2) CPI XFE: CPI All Items excluding Food and Energy (2002=100)	see below
Interest Rates (i)	
Overnight money market financing	V39049
Government of Canada benchmark bond yields, 5 year	V39053
Government of Canada benchmark bond yields, 10 year	V39055
Treasury Bills, 1-year	V39067
Employment Rate(u)	
(3) Unemployment Rate (Percentage); Both sexes; 15 years and over	see below
Employment(e)	
Employment; Persons; Both sexes; 15 years and over; Seasonally adjusted	V2062811
GDP (g)	
Canada ; Seasonally adjusted at annual rates; Chained (2012) dollars; All industries (Dollars)	V65201210
Money supply (M)	
Canada ; M1+ Gross (dollars)	V371510
Canada ; M2++ Gross (dollars); Canada Savings Bonds, non-money market mutual funds)	V41552801

Table 9: Data Sources Extension

National and Provincial Series Codes

	CA	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC
(1)	v41690973	v41691244	v41691379	v41691513	v41691648	v41691783	v41691919	v41692055	v41692191	v41692327	v41692462
(2)	v41691233	v41691369	v41691503	v41691638	v41691773	v41691909	v41692045	v41692181	v41692317	v41692452	v41692588
(3)	v2091177	v2091807	v2092446	v2093076	v2093706	v2094336	v2094966	v2095596	v2096226	v2096856	v2097536

Notes: All series are from CANSIM Database; Country and province codes are: CA: Canada; NL: Newfoundland; PE: Prince Edward Island; NS: Nova Scotia; NB: New Brunswick; QC: Quebec; ON: Ontario; MB: Manitoba; SK: Saskatchewan; AB: Alberta; BC: British Columbia. Wages are spliced from the two reported series.

B. Additional Tables and Figures

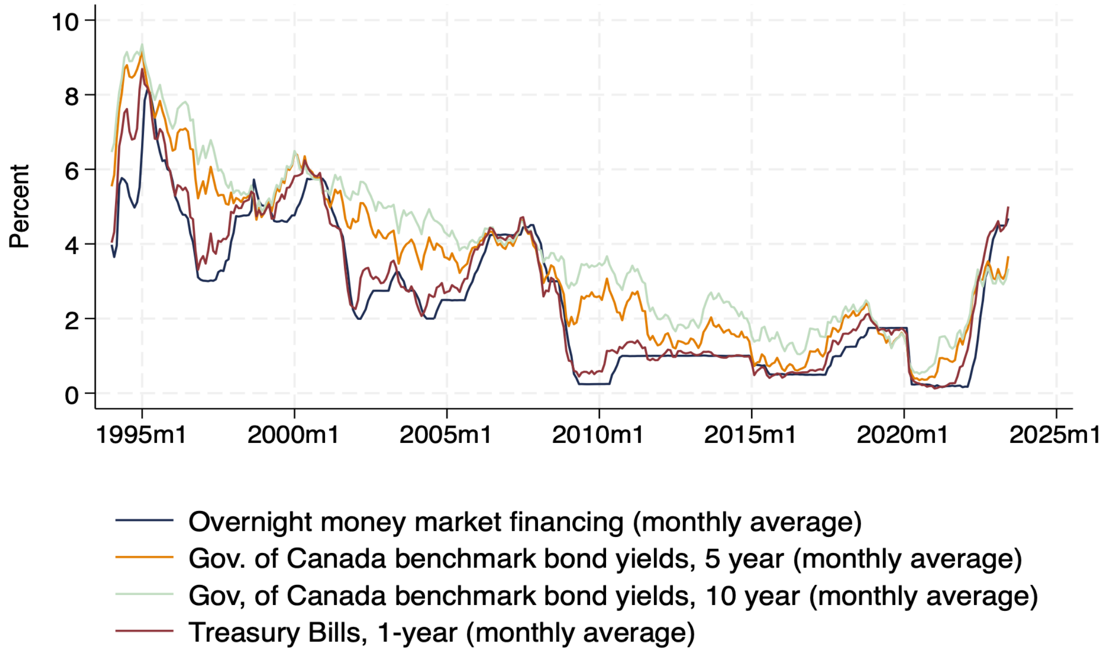
Table 10: Monetary policy lags for the Provinces (Monetary policy instrument: Overnight rate)

Monetary policy instrument: i

Provinces	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC
Target variables / (k^p)										
$\Delta_6 \pi$	29*	35*	23*	34*	23*	21*	20*	19*	21*	15*
$\Delta_6 \pi^c$	31*	25*	26*	34*	24*	19*	25*	31*	21*	34*
$\Delta_{12} u$	23*	10*	13*	9*	11*	12*	14*	16*	17*	12*
Consistency										
$k^p(\pi)/k^p(u)$	1.26	3.50	1.77	3.78	2.09	1.75	1.42	1.19	1.24	1.25
$k^p(\pi^c)/k^p(u)$	1.35	2.50	2.00	2.78	2.18	1.58	1.79	1.94	1.24	2.83

Note: * Significantly different from zero using conventional two-sided t-test at 90% level

Figure 7: Overnight money market rate, long-term bond yields, and T-bill yield

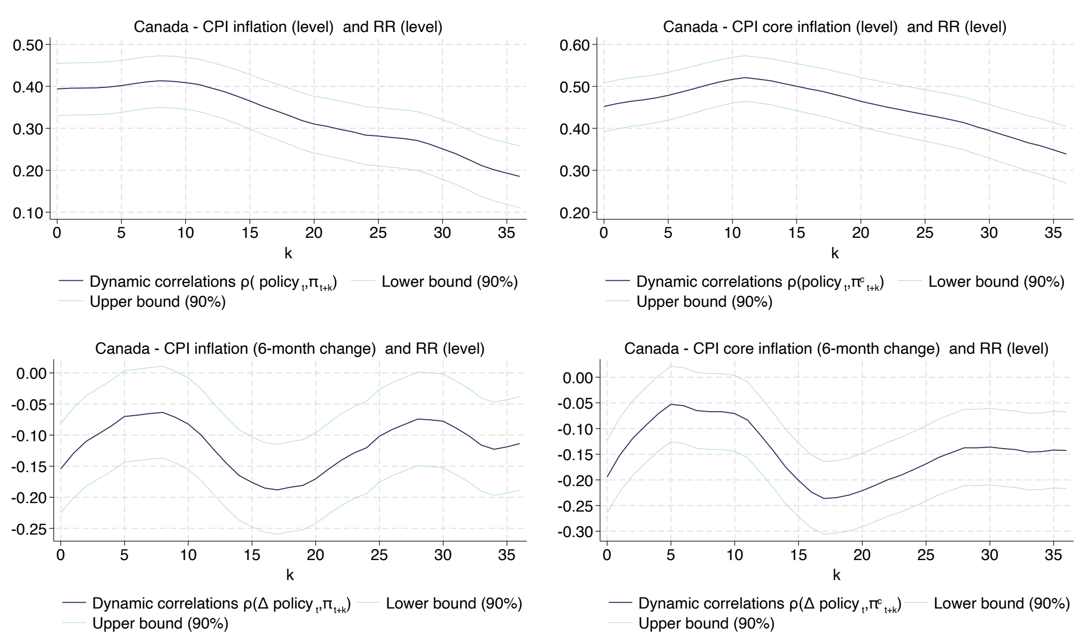


Note: Sample Period: 1994M1-2023M6

Figure 8: Money aggregates growth

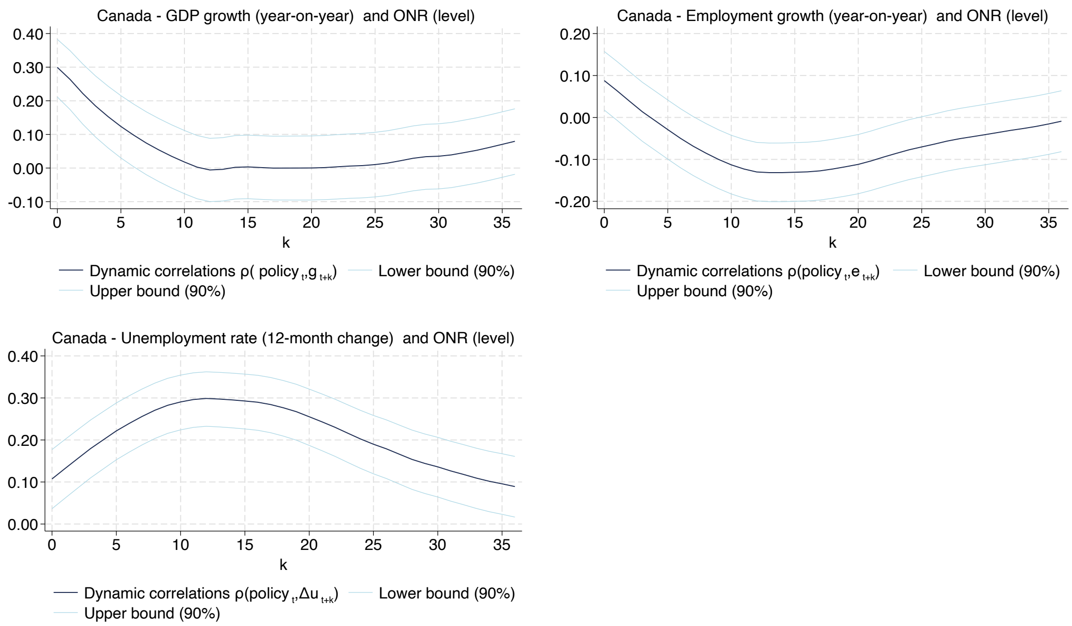
Note: Sample Period: 1994M1-2023M6

Figure 9: Dynamic correlations (CPI & CPIX & Real interest rate)



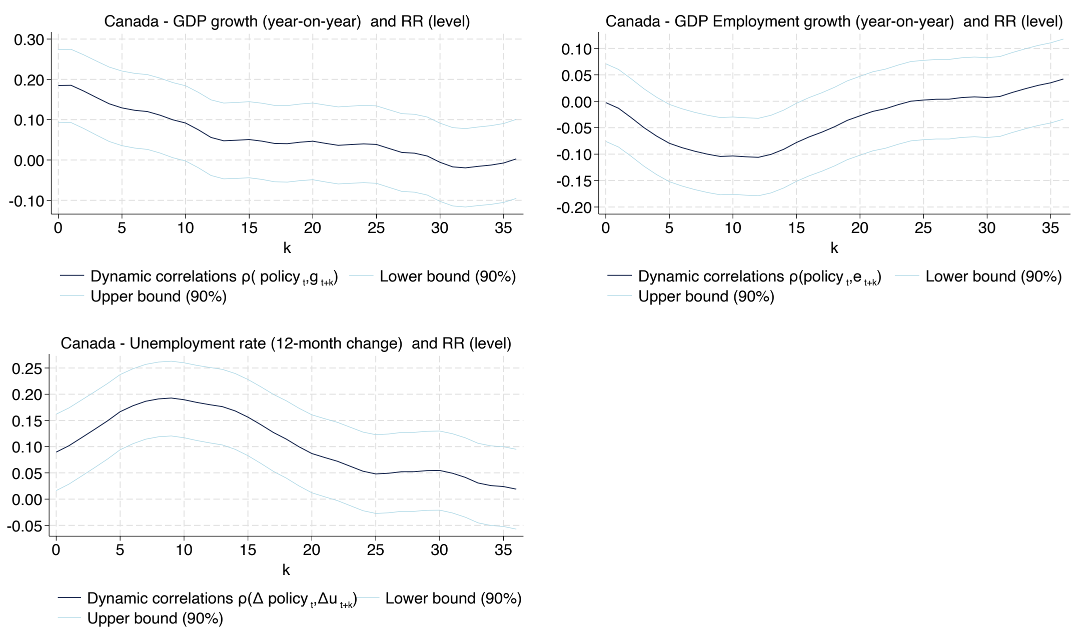
Note: Sample Period: 1994M1-2023M6

Figure 10: Dynamic correlations (Output & Overnight money market rate)



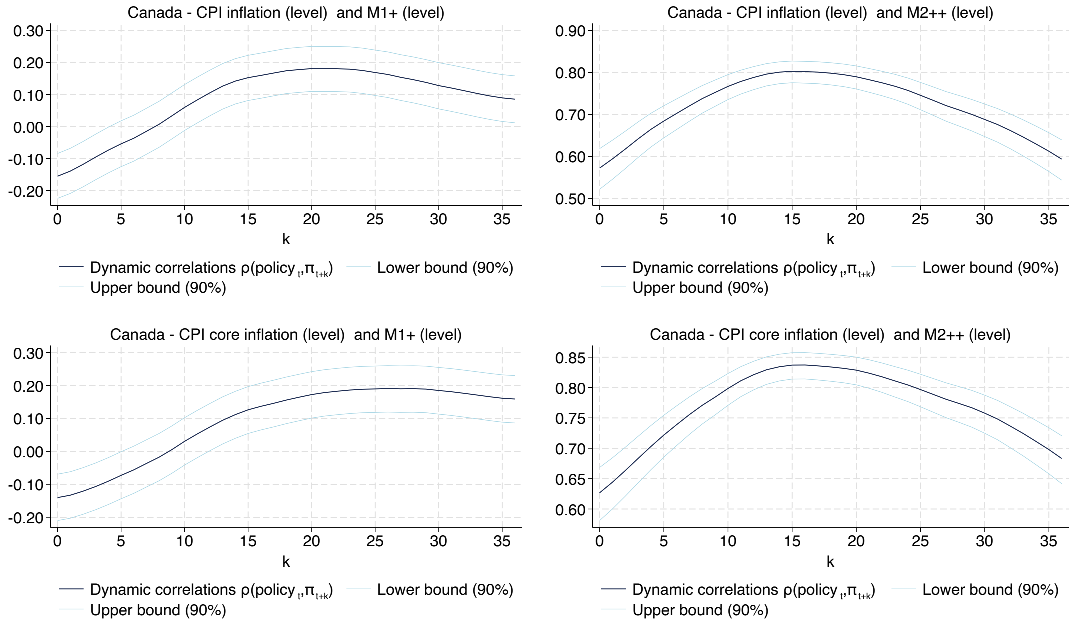
Note: Sample Period for Employment and Unemployment Rate: 1994M1-2023M6 ; Sample Period for GDP: 1997M1-2023M6

Figure 11: Dynamic correlations (Output & Real interest rate)



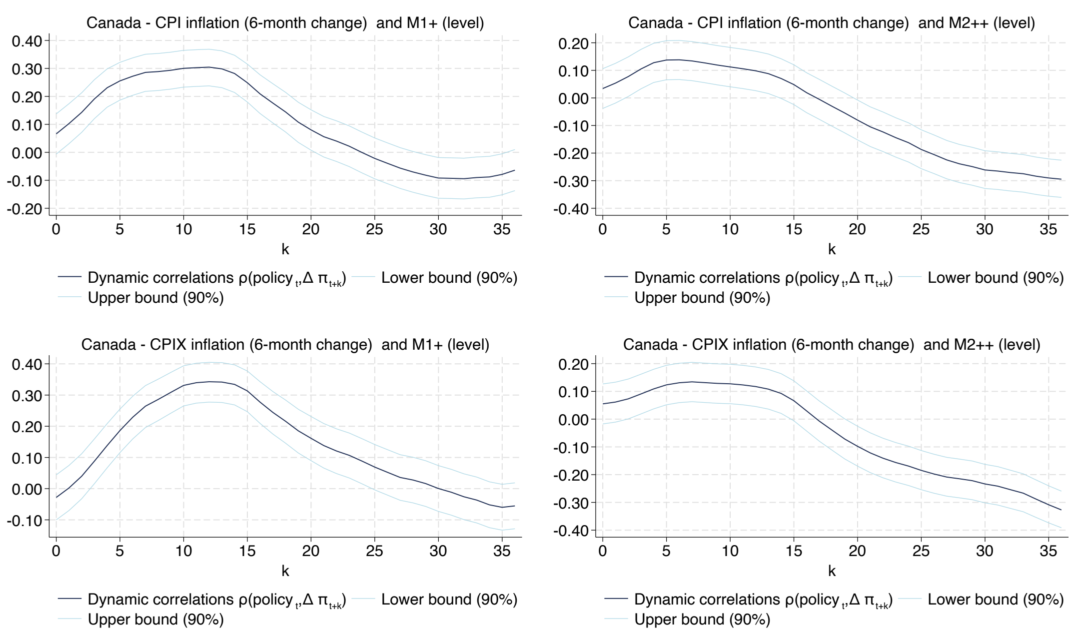
Note: Sample Period for Employment and Unemployment Rate: 1994M1-2023M6 ; Sample Period for GDP: 1997M1-2023M6

Figure 12: Dynamic correlations (CPI/CPIX & Money aggregates



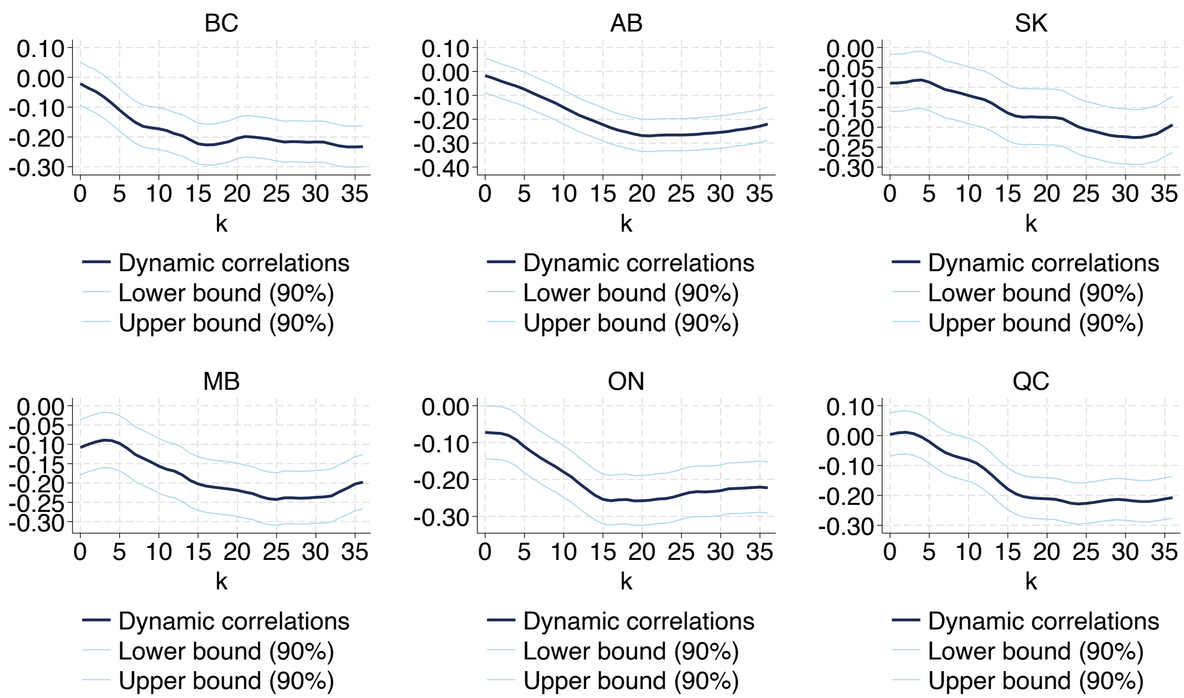
Note: Sample Period: 1994M1-2023M6

Figure 13: Dynamic correlations (6-month change in CPI/CPIX & Money aggregates



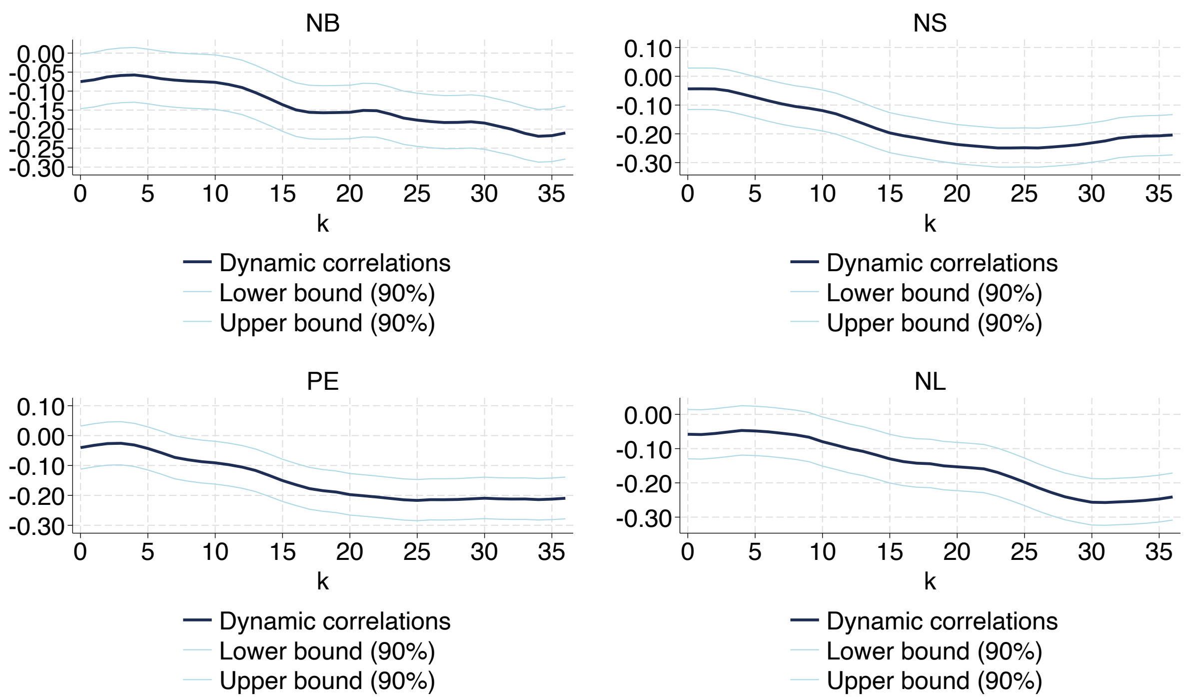
Note: Sample Period: 1994M1-2023M6

Figure 14: Dynamic correlations for the Provinces Part. 1 (CPIX (6-month change) & Overnight money market rate)



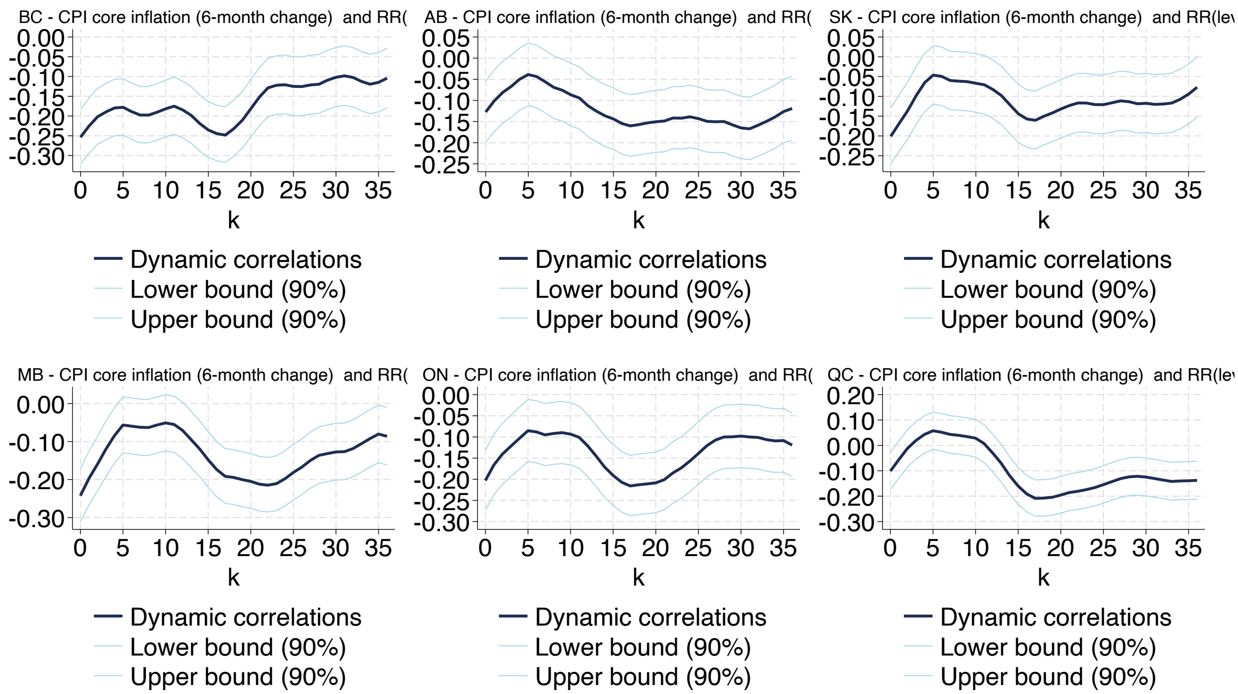
Note: Sample Period: 1994M1-2023M6

Figure 15: Dynamic correlations for the Provinces Part.2 (CPIX (6-month change) & Overnight money market rate)



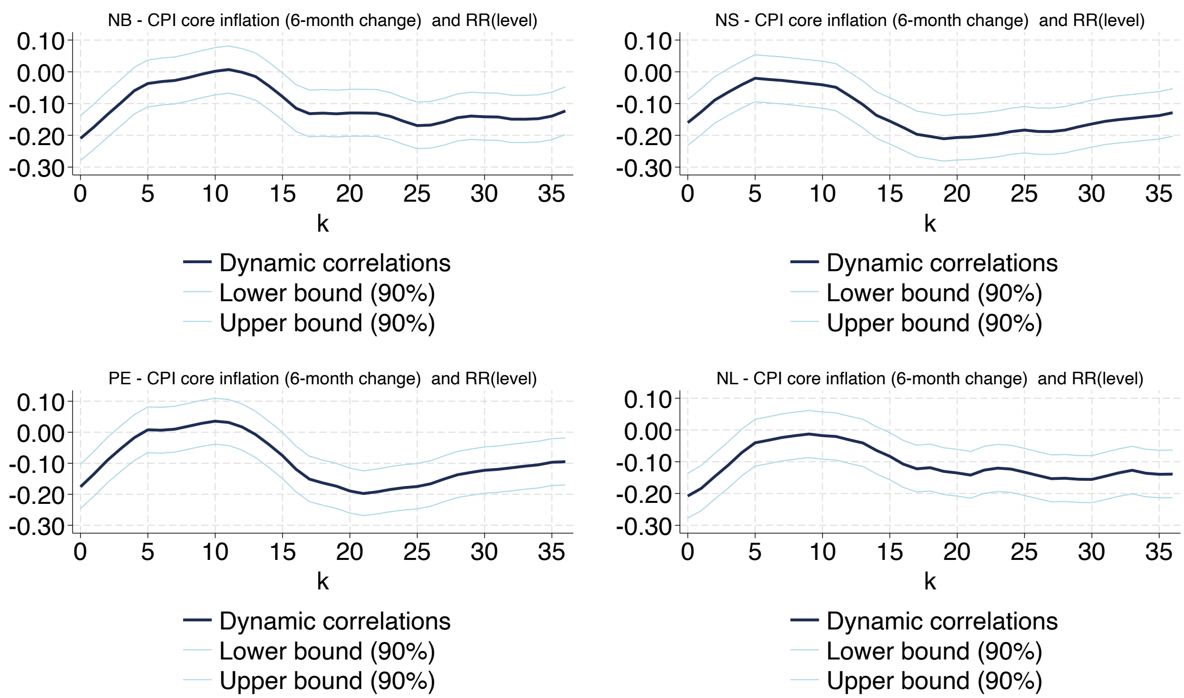
Note: Sample Period: 1994M1-2023M6

Figure 16: Dynamic correlations for the Provinces Part.1 (CPIX (6-month change) & Real interest rate)



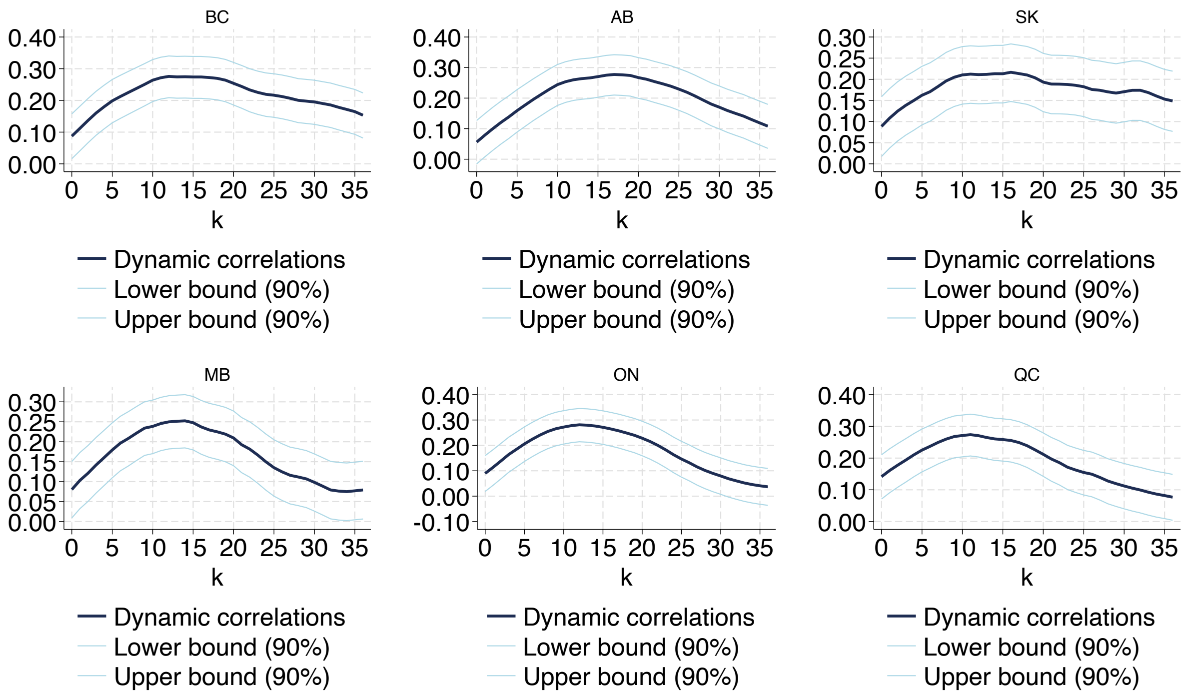
Note: Sample Period: 1994M1-2023M6

Figure 17: Dynamic correlations for the Provinces Part.2 (CPIX (6-month change) & Real interest rate)



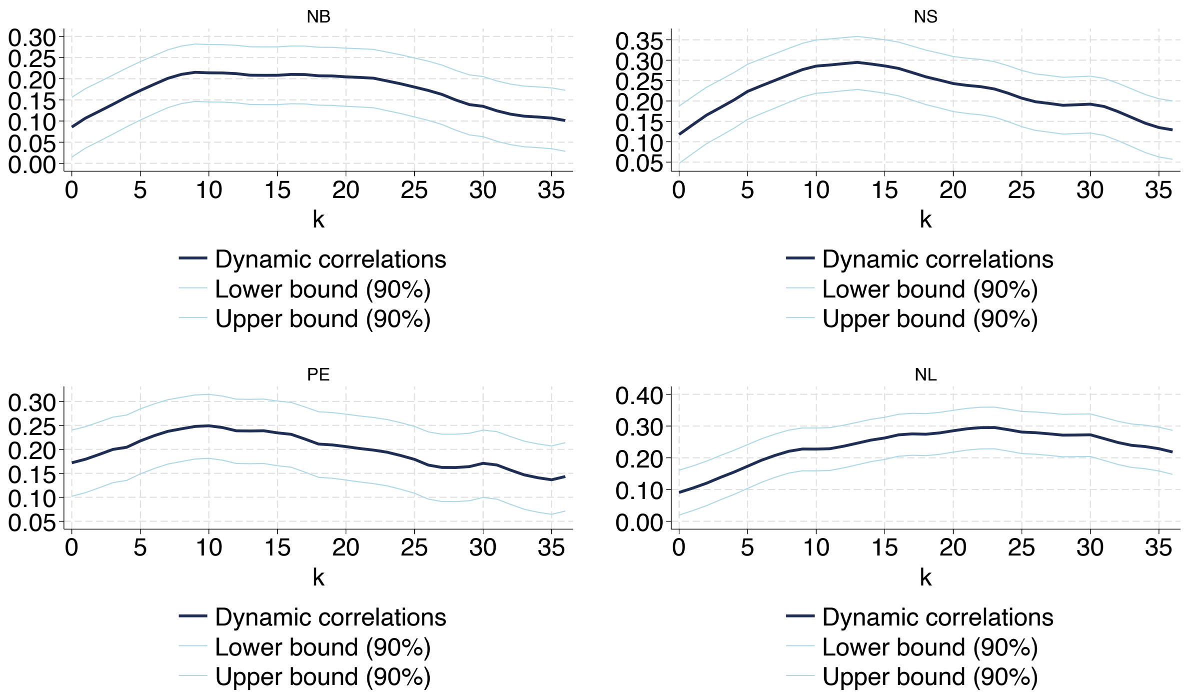
Note: Sample Period: 1994M1-2023M6

Figure 18: Dynamic correlations for the Provinces Part.1 (Unemployment Rate (12-month change) & Overnight money market rate)



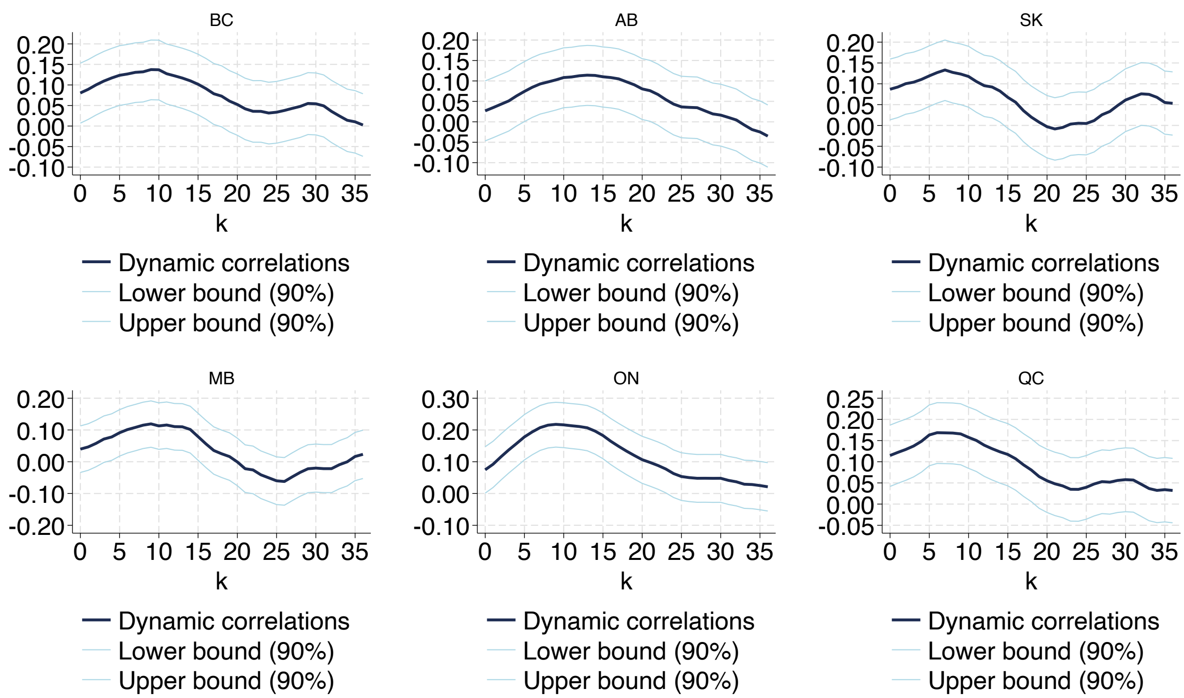
Note: Sample Period: 1994M1-2023M6

Figure 19: Dynamic correlations for the Provinces Part.2 (Unemployment Rate (12-month change) & Overnight money market rate)



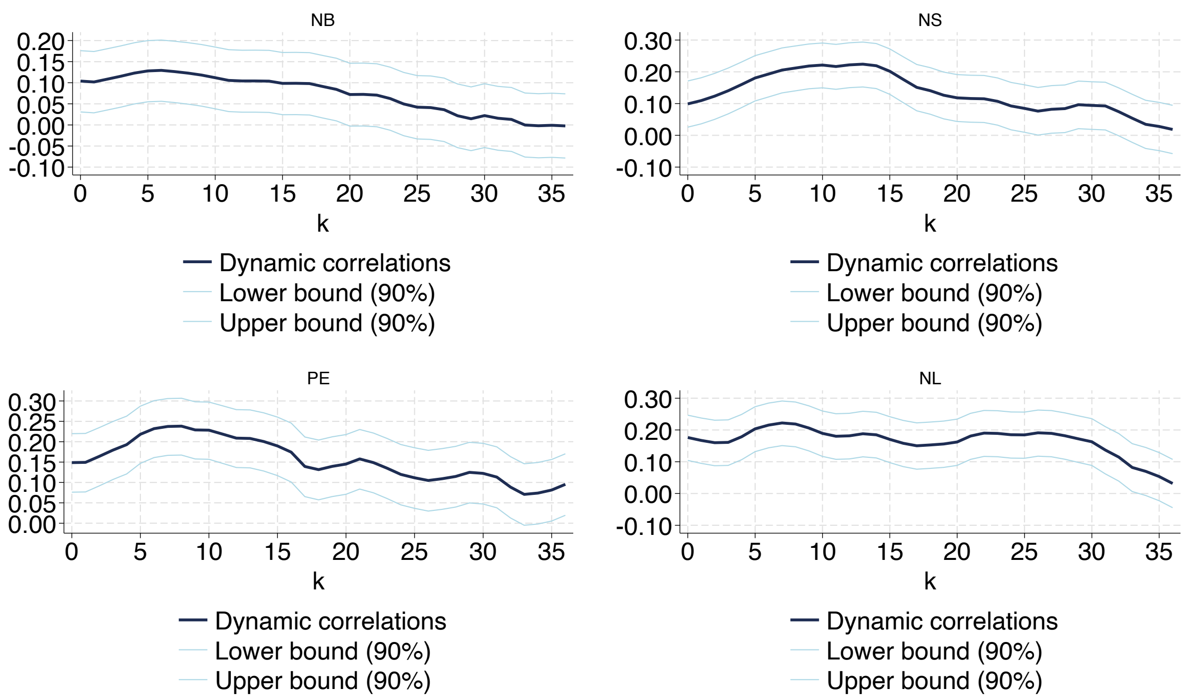
Note: Sample Period: 1994M1-2023M6

Figure 20: Dynamic correlations for the Provinces Part.1 (Unemployment Rate (12-month change) & Real interest rate)



Note: Sample Period: 1994M1-2023M6

Figure 21: Dynamic correlations for the Provinces Part.2 (Unemployment Rate (12-month change) & Real interest rate)



Note: Sample Period: 1994M1-2023M6

C. List of Figures

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D. List of Tables

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