Monetary Policy Shocks in the Canadian Economy

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Introduction and Motivations

Monetary policy and its transmission channels have always been of great importance, especially given the role monetary policy played in driving Canada's post pandemic recovery. Moreover, the pandemic forced global economies to emerge from a decade of ultra-loose monetary policy and, as such, marked a shift in structural regimes. Thus, it is only natural to investigate how the relationship between monetary variables and macroeconomic measures has changed as a result of the pandemic. Moreover, the findings from such a study can also inform future policymaking by understanding how monetary policy shocks propagate through the Canadian economy post pandemic.

Our paper aims to analyse such issues by understanding how monetary policy shocks impact Canadian macroeconomic variables and whether this relationship has materially changed post pandemic. We implement a traditional VAR model to capture the interdependencies between our chosen macroeconomic and policy variables. VAR regression models have been pivotal in time series modelling given their ability to capture bidirectional relationships without imposing too restrictive structural assumptions. A key advantage of a VAR regression is the model's flexibility for analyzing the development of economic shocks through an interconnected economy such as Canada's. This is the primary focus of our paper. The aim of our study is to understand how shocks in the chosen monetary policy variables impact Canadian macroeconomic measures, both in terms of magnitude and time delays.

Our paper aims to follow an approach similar to the papers discussed below in the Literature Review section. Choosing the correct model specification and variables are crucial for accurately capturing the underlying relationships in the Canadian economy. A large portion of VAR regression literature already addresses appropriate model specifications. However, current literature on applying VAR regression frameworks to the Canadian economy are both dated and limited. As such, we derive a suitable matrix of variables from Fung and Yuan (1999) and augment it slightly to incorporate more recent and relevant variables.

After a summary of the relevant literature, our paper discusses the underlying methodology and model, the data used, and the interpretation of the results, before providing a conclusion.

Literature Review

The following discusses three primary papers that our research follows. Bernanke and Mihov (1998) provide the model specification of the underlying VAR regression. Fung and Yuan (1999) apply Bernanke and Mihov's approach to the Canadian economy. Sims (1980) helps understand the importance of impulse response functions and their role in enhancing the interpretability of VAR models.

Bernanke and Mihov (1998) developed a VAR-based methodology for measuring monetary policy innovations and their macroeconomic effects. The authors created a new measure of policy innovations based on the estimates of the central bank's operating procedures. As such, their methodology provided a more accurate representation of monetary policy actions and their real economic impacts, thereby piloting VAR models in policy analysis.

Fung and Yuan (1999) presented an exact monetary policy stand within the Canadian economy, using the VAR framework to understand the interlinkages of policy and non-policy variables. Their study applies VAR modelling to explain the transmission mechanism of monetary policy. This paper is vital for identifying appropriate Canadian macroeconomic variables and other measures to accurately capture relationships within the Canadian economy.

Lastly, Sims (1980) introduced the VAR framework as a flexible tool to study the dynamic interactions between the included variables. The paper discussed the use of IRF functions to demonstrate how economic shocks propagate through an economy. This approach helped interpret the economic significance of various shocks and provided a more intuitive interpretation of VAR models. The pivotal findings in this paper laid the groundwork for using VAR regressions and IRF functions for policy analysis.

Our paper contributes to the existing literature by applying a VAR framework that incorporates all three above discussed papers. Most of the available research studies do not place great importance on the post-pandemic analysis of macroeconomic linkages for the Canadian economy. Our research aims to provide more insights into how such relationships may have developed pre-and-post-pandemic in the Canadian economy. This regional focus recognizes the deep economic integration for Canada and underscores the importance of considering spillover effects from exogenous disturbances.

Methodology and Model

Our aim is to replicate a simplified VAR model of the ones developed by Bernanke and Blinder (1992) and Bernanke and Mihov (1998) and apply it to the Canadian economy as done by Fung and Yuan (1999). A VAR model allows us to capture contemporaneous relationships between the economic variables by treating each variable symmetrically as both endogenous and explanatory. An economy like Canada's would have multiple feedback loops and bidirectional relationships between macroeconomic variables given an exogenous shock. As such, the VAR model was chosen as the appropriate regression model given its ability to account for such dynamic independencies. The equation for the VAR model is given as below.

$$Y_t = \sum_{i=1}^{k} \boldsymbol{B}_i Y_{t-i} + \sum_{i=1}^{k} \boldsymbol{C}_i p_{t-i} + \boldsymbol{A}^y v_t^y \qquad \text{Equation (1)}$$

$$p_t = \sum_{i=1}^{k} \boldsymbol{D}_i Y_{t-i} + \sum_{i=1}^{k} \boldsymbol{G}_i p_{t-i} + \boldsymbol{A}^p v_t^p \qquad \text{Equation (2)}$$

Equation (1) and Equation (2) show an unrestricted linear model that allows for up to k lags of any given variable to appear in the equations. The variable, Y_t, represents a vector of non-policy macroeconomic variables, whereas the variable, p_t, represents a policy vector intended to capture monetary policy stance. The boldfaced letters in the above equations represent coefficient matrices associated with the given variables. The variables, v_t^y and v_t^p, represent the residuals associated with Equation (1) and Equation (2), respectively. The residuals, v_t^y and v_t^p, are assumed to be orthogonal and independent of each other.

Equation (1) helps explain the contemporaneous relationships within the economy and between the macroeconomic variables of interest. The equation states that the non-policy macroeconomic variables, Y_t, depend on their own lagged values and the lagged values of monetary policy stance. Note that the regression model assumes that changes in the policy variables at time t have no impact on the non-policy macroeconomic variables in the same time period. Economic variables tend to respond with a lag due to adjustment costs, economic frictions, and delays in information processing. This assumption is in line with what is usually observed in reality and is empirically supported by studies such as Dupor (2023) that look at long and variable lags in monetary policy. The residuals, v_t^y, represent exogenous shocks to non-policy macroeconomic variables. The economic interpretation of these residuals depends on the macroeconomic variable associated with the respective residuals vector. When Y_t represents variables such as output or GDP, the associated residuals represent an aggregate demand shock, such as changes in consumer confidence or fiscal policy. Similarly, when Y_t represents variables such as prices or inflation, the residuals can be interpreted as supply side shocks, such as supply chain disruptions that materialized as a result of the COVID-19 pandemic. Equation (2) can be economically interpreted as a policy reaction function wherein the central bank optimizes its policy stance after observing the overall state of the economy, captured by the non-policy macroeconomic variables, and prior policy stances. The residuals, v_t^p, represent exogenous monetary policy shocks and unexpected changes in policy stance. By assuming that v_t^y and v_t^p are orthogonal, the model assumes that non-policy shocks affect the overall economy independently of policy decisions at time t. For instance, a central bank chooses its policy stance based on lagged non-policy and policy variables. However, the bank cannot respond to unexpected shocks in non-policy macroeconomic variables within the same time period due to informational lags as discussed above.

A large portion of VAR literature has focussed on measuring monetary policy stance through a scalar quantity. By focussing on the methodologies applied by Bernanke and Mihov (1998) and Fung and Yuan (1999), we can incorporate multiple measures of monetary stance and treat p_t above as a vector of policy variables. It is important to note that these two papers also quantify the central bank's operating procedure to estimate impulse response functions. Our paper adopts a simpler approach for mapping out these functions and allows us to concentrate more on the observable impacts of policy changes. Bagliano and Favero (1998) discussed the importance of modelling a central bank's operating procedures but found that the inclusion of such procedures was not highly relevant. Their paper found that differences in the impulse response functions obtained from a standard VAR model and those derived from models that incorporate operating procedures were statistically insignificant for key macroeconomic variables, such as output and inflation. Thus, it seems appropriate to exclude the estimation of such operating procedures and avoid unnecessary complexity.

Data

To estimate the above model, it was crucial to identify the appropriate non-policy macroeconomic variables to include in the non-policy block Y_t and the appropriate policy variables to include in the policy block p_t. The variables included in Y_t and p_t are given by Table 1 and Table 2 in the Appendix, respectively. Our paper focusses on quarterly data from 1972-Q1 to 2024-Q1. By focussing on post-1960 data, we avoid the structural break arising from a shift from a fixed to a flexible exchange rate regime in the Canadian dollar. Due to incomplete observations for some datasets, the time frame was unfortunately limited to 2024-Q1. Aggregating all the time series for each variable yields a balanced panel dataset with 209 observations in total. It is important to note that Fung and Yuan (1999) used monthly observations when estimating their model to better defend the identification assumption of no contemporaneous feedback from policy variables to the economy. However, due to the slight difference in variables included and the limited nature of monthly data for the GDP variables, we had to resort to using quarterly data.

While quarterly data was available for most variables, the Fisher Commodity Price Index, US unemployment rate, and bank policy rate data were provided as monthly. To convert the US unemployment rate to quarterly, the monthly values were averaged for a given quarter on the FRED Economic Data site provided in Table 1. A similar transformation was applied to the bank policy rate and M1 money supply to calculate quarterly averages and standardize the observations' frequencies to be consistent with the sampling frequency of other variables. The following transformation was applied to the Fisher Commodity Price Index to calculate quarterly returns, R_q. In the equation below, F_t represents the value of the index at month t whereas F_{t-2} represents the value of the index two months ago [i.e. at the start of the quarter].

$$R_q = \frac{F_t - F_{t-2}}{F_{t-2}} \qquad \text{Equation (3)}$$

Our paper includes two policy variables, the bank rate and M1 money supply. Fung and Yuan (1999) modelled the exchange rate as an additional policy variable. However, our paper has chosen to incorporate it as a non-policy variable since exchange rates are usually challenging to control directly given the multitude of economic forces influencing them. These policy variables were chosen due to their economic significance and the central bank's ability to directly influence such measures.

Implementation and Results

To implement the above discussed model, it was necessary to first understand the underlying distributions for the time series data. The Appendix displays line plots for a few selected variables of interest in Graphs 1 to 6. From the graphs, it can be inferred that the selected variables have a clear trend and run the risk of being non-stationary. To ensure that the VAR model is stable and can be used for out of sample forecasting, it is crucial to ensure that the variables are time series stationary. Table 3 shows ADF tests for the selected time series along with their corresponding p-values. A time trend was added for variables *lnCAD_RGDP, lnUS_RGDP*, and *CanadianM1MoneySupply* since a clear time trend can be observed from their respective line plots. The p-values for the ADF tests across some variables are greater than 0.05, indicating that those underlying time series are non-stationary as the null hypothesis of a unit root presence cannot be rejected at the 5% significance level. These p-values have an asterisk next to them to indicate non-stationarity for the respective time series.

A common approach to ensure that the time series are stationary is to first difference the underlying variables. Graphs 7 to 12 in the Appendix show the line plots for these newly differenced variables and Table 4 shows the corresponding ADF tests for stationarity. Natural logarithms of *CADUSDExchangeRate* and *CanadianM1MoneySupply* were taken before differencing the variables to retain interpretability of their respective regression coefficients. The p-values in Table 4 are all zero, indicating that these time series data are stationary as the null hypothesis of a unit root presence can be rejected at the 5% significance level. The line plots in Graphs 7 to 12 also exhibit strong data stationarity, perhaps except for 2020-Q1 observations that seem to cause large spikes and volatility in the underlying data. These observations coincide with the beginning of the COVID-19 pandemic and therefore such large moves in the data are expected given the pandemic's impact on the Canadian economy.

With the variables now stationary, the following model represented by Equation (4) and Equation (5) was estimated using a VAR framework. The variables Y_t, p_t, and X_t are as given in Equation (8) in the Appendix. The asterisks next to each variable denote first differenced transformations. The discussion below now focusses on the mode's estimation and interpretation.

$$Y_t = \sum_{i=1}^{k} \boldsymbol{B}_i Y_{t-i} + \sum_{i=1}^{k} \boldsymbol{C}_i p_{t-i} + \gamma X_t + \boldsymbol{A}^y v_t^y \qquad \text{Equation (4)}$$

$$p_t = \sum_{i=1}^{k} \boldsymbol{D}_i Y_{t-i} + \sum_{i=1}^{k} \boldsymbol{G}_i p_{t-i} + \beta X_t + \boldsymbol{A}^p v_t^p \qquad \text{Equation (5)}$$

The optimal number of lags, k, was chosen by minimizing the average MSE through a leave-one-out cross validation process [LOOCV]. A significant advantage of this approach is that it does not require any assumptions about the underlying distribution of the error terms. Information criteria, such as HQIC or AIC, assumes the underlying error terms to be normally distributed. Given the nature of the data, we suspected significant serial correlation and heteroskedasticity in the error terms. As such, we resorted to LOOCV to determine an optimal number of lags that minimizes the average leave-one-out MSE. The corresponding errors for given lags are graphed in Graph 13 in the Appendix. We can see that the average error is minimized at a lag of $k = 1$. Adding more lags plateaus the average error at around 55, except for the eighth lag that causes a spike in the average error to 60. It is important to note that there are a total of ten variables included in each regression equation and each lag adds ten more variables to every equation. As such, adding more lags leads to greater model overfitting for the i^{th}observation and thus inflates the average MSE error for lag k. Taken in conjunction with the relatively limited number of total observations, a greater number of lags would be unsuitable. As such, we proceeded with $k = 1$.

By including non-lagged values of the Fisher Index, represented by X_t, the model assumes that commodity-price shocks have an instantaneous impact on the Canadian economy. Canada's economy is heavily reliant on its large resource sector. Concurrently, with Canada being a relatively small open economy, it would have a muted impact on overall commodity prices. Modelling the Fisher Index as exogenous captures both these relationships by assuming that the Fisher Index is not bi-directionally related with the non-policy and policy blocks while still acknowledging the variable's impact on the Canadian economy. This also helps avoid an endogeneity problem by preventing the VAR model from attributing changes in the Fisher Index to domestic factors and better represents the internationally determined nature of commodity prices. Lastly, US variables were also included to capture the interdependencies between the Canadian and US economies.

The initial results from the VAR model estimation are shown in Tables 6 to 8 in the Appendix. There are a total of nine regression equations capturing the endogenous relationships between them. The numbers in the tables represent the estimated coefficients and their respective standard errors in parenthesis below. Given our paper's focus on the Canadian economy, we are most interested in the results in Table 6. Table 6 displays the regression results for Canadian real GDP, Canadian inflation rate, and Canadian unemployment rate. Given the transformations performed on the variables, they can be interpreted as the absolute percentage changes in Canadian real GDP quarterly growth, Canadian inflation rate, and the Canadian unemployment rate, respectively.

The coefficients for the policy variables in the $Y = d\_lnCAD\_RGDP$ regression equation have signs consistent with economic theory. The coefficient on the variable $p_1 = L1.CanadianPolicyRate$ is negative and the coefficient on the variable $p_2 = L1.d\_l\_CanadianMoneySupply$ is positive. The equation implies that a 100-bps point increase in the bank policy rate at quarter t leads to an approximately 0.04 percentage point decrease in the Canadian real GDP quarterly growth rate at quarter $t + 1$. The coefficient is statistically significant at the 5% level. Similarly, a one percentage point increase in the Canadian M1 money supply growth rate at quarter t leads to an approximately 0.141 percentage point increase in the Canadian real GDP growth rate at quarter $t + 1$. The coefficient is also statistically significant at the 5% level.

A similar reasoning follows as above when interpreting p_1 and p_2 in the $Y = d\_CADIR$ regression equation for Canadian inflation and the $Y = d\_CanadianUnemployment$ regression equation for Canadian unemployment. From the former equation, the regression coefficient on p_1 can be interpreted as a 100-bps point increase in the bank policy rate at quarter t leading to a 0.0078 percentage point decrease in the change in inflation rate at quarter $t + 1$. While its negative sign is as expected, the small coefficient and the lack of significance at both the 5% and 10% level requires treating the coefficient with caution. A similar level of care needs to be applied when interpreting the regression coefficient on p_2, which implies that a one percentage point increase in the Canadian M1 money supply growth rate in quarter t leads to an almost 8.2 percentage point increase in the change in the inflation rate in quarter $t + 1$. Despite being significant at the 5% level, this coefficient implies too large of an impact of money supply on Canadian inflation. Perhaps a more suitable interpretation would be that money supply, compared to the bank policy rate, has a relatively larger impact on the inflation rate, inferred by the larger absolute value of the regression coefficient and significance at the 5% level. In contrast, in the regression equation with $Y = d\_CanadianUnemployment$, p_1 and p_2 are significant at the 5% and the 10% levels, respectively. p_1 has a positive sign implying a positive relationship between policy rates and absolute changes in unemployment growth rates whereas p_2 has a negative sign implying a negative relationship between absolute changes in M1 money supply growth and absolute changes in Canadian unemployment.

Graphs 14 to 22 in the Appendix plot the residuals for each regression equation in the VAR model. From the graphs, it can be inferred that there is significant heteroskedasticity in the error terms. Graphs 23 to 31 plot the squared residuals for each regression equation. The graphs show large spikes for squared residuals in 2020 at the pandemic's onset, signifying large increases in variances for the underlying observations. Given such heteroskedasticity, the standard error estimates in the regression equations would be inconsistent. Graphs 32 to 40 also show the QQPLOTs for the respective residuals against the quantiles of a normal distribution. The closer the observations are to the 45-degree line, the more normally distributed the error terms are. From the graphs, the distributions of the respective residuals suffer from fat tails given the outliers exist at the ends of the 45-degree line, providing further signs of non-normality. Table 9 in the Appendix shows the Breusch Pagan test results for the residuals of a given variable. Except for the residuals for $d\_l\_CADUSDExchange$, all other residuals show statistical evidence of heteroskedasticity at the 5% significance level with $df = 10$.

Given the presence of heteroskedasticity, the VAR regression was re-estimated using a WLS approach with the error terms being modelled as a GARCH process defined by Engle and Bollerslev (1986) and shown in the equation below.

$$\sigma_{y,t}^2 = \alpha_y + \beta_{y,1}\varepsilon_{y,t-1}^2 + \beta_{y,2}\sigma_{y,t-1}^2 \qquad \text{Equation (6)}$$

Equation (6) implies that current conditional variance for a given variable y in the matrix Y in Equation (8) in the Appendix depends on past squared residuals of the variable y and past conditional variances of the variable y. The squared residuals ε_y^2 are obtained from the VAR equation for variable y. From graphs 23 to 31 in the Appendix, volatility clustering can be easily inferred, with large [small] spikes followed by more large [small] spikes. As such, a GARCH process was preferred over an ARCH process given that the former can better capture such volatility clustering and dynamics in conditional variances with a relatively fewer number of variables. Engle and Bollerslev (1986) provide a detailed discussion of basic GARCH models being able to capture similar relationships as higher-order ARCH models, thereby significantly reducing the risk of over parametrization. Thus, we proceeded with a GARCH(1,1) model implied by Equation (6). The fitted values, $\widehat{\sigma_{y,t}^2}$, from the above discussed GARCH process were then used to weight observations at time t for variable y to calculate $\breve{y}_t$ based on the following equation.

$$y\_h_t = y_t \times \frac{1}{\sqrt{\widehat{\sigma_{y,t}^2}}} \qquad \text{Equation (7)}$$

The re-estimated model's results based on the above approach are shown in Tables 10 to 12 in the Appendix. Looking at Table 10, while the economic relationships between the policy variables and Canadian macroeconomic non-policy variables are preserved, statistical significance on $L1.CanadianPolicyRate\_h$ in the $Y = d\_lnCAD\_RGDP\_h$ equation is lost. This perhaps could be a result of the initial VAR model underestimating the variable's standard error and thus inflating its significance in Table 6 in the Appendix. This issue can also be further perpetuated by the limited number of observations involved in estimating the underlying model. Table 13 in the Appendix shows the Breusch Pagan test statistics calculated in a similar manner as in Table 9. These test statistics are for residuals estimated using the VAR model after the above discussed transformations. Looking at the results, there is still evidence of heteroskedasticity in the underlying model. However, except for the test statistic for the residuals of d_CADIR_h and $CanadianPolicyRate\_h$, the calculated statistics for other variables decrease significantly. Moreover, this approach seems to correct for heteroskedasticity in $USUnemploymentRate\_h$ with a test-statistic below the critical value.

It is important to provide a brief discussion of the drawbacks of the above approach. Firstly, fitting the residuals to follow a GARCH(1,1) process assumes the residuals to be normally distributed. However, from the QQPLOTs in Graphs 32 to 40, in the Appendix, there is strong evidence of fat tails. Additionally, the above approach assumes a diagonal variance-covariance matrix and no contemporaneous relationships between the residuals. This is a large simplification of the covariance relationships between the error terms for the non-policy block of macroeconomic variables. For instance, any unexpected shocks to the Canadian unemployment rate will likely be related with unexpected shocks to Canadian real GDP. This can be easily seen with the COVID-19 pandemic, where such an unexpected economic change likely permeated through the individual disturbances for the non-policy macroeconomic variables, giving rise to correlations between the error terms for these variables. As such, while the above approach reduces the extent of heteroskedasticity, it is unable to eliminate it from the model given the underlying assumptions and drawbacks involved.

Table 14 in the Appendix show the resulting p-values from Granger Causality tests and joint significance tests of lagged policy variables on Canadian macroeconomic variables. For instance, the table implies that changes in Canadian real GDP are Granger caused by changes in M1 money supply growth rate but not by changes in the policy rate. The joint significance tests show the p-values for the F-tests of both policy variables being statistically insignificant for a given macroeconomic variable. The policy variables are jointly insignificant only for changes in the Canadian inflation rate with a p-value of 0.1203. However, these results still need to be treated with caution as these tests assume normality and homoskedasticity of the underlying error terms in the transformed model, which are still being violated.

Based on the above model developments, a much more interesting economic relationship to explore is how interest rate shocks impact Canadian macroeconomic variables. This is captured by the Impulse Response Functions (IRFs) graphed after estimating the VAR model. An IRF helps retain interpretability of the underlying VAR model by displaying how a shock at time t influences the system at time $t + 1$, assuming no further shocks. Sims (1980) discusses how modelling an IRF tends to result in more reasonable and smoother economic interpretations than the regression coefficients obtained in a VAR model.

Graphs 41 to 46 in the Appendix show the IRFs of Canadian macroeconomic variables in Table 14 caused by shocks in the policy variables. Graphs 41 to 43 show the impact of a positive one standard deviation shock in the policy rate on the Canadian macroeconomic variables. Similarly, graphs 44 to 46 show the impact of a positive one standard deviation shock in the change of M1 money supply growth rate on the Canadian macroeconomic variables. Looking at Graph 41, a one standard deviation shock in the policy rate almost instantaneously impacts Canadian real GDP, with real GDP dropping in the next quarter. The effect is most negative three quarters, or nine months, later and the overall relationship is consistent with economic theory. A similar interpretation applies to Graphs 42 and 43, with a positive one standard deviation shock in the policy rate being felt the most two quarters later for changes in Canadian inflation and unemployment. However, graph 42 shows a one standard deviation shock in the policy rate leads to a relatively muted change in the Canadian inflation rate when compared to the other two Canadian macroeconomic variables. In Graph 43, the impact of a standard deviation shock in the policy rate on the change in Canadian unemployment is much more pronounced.

One interesting remark here can be made about the IRF function converging to zero in Graph 41. The graph shows the impact of policy rates on Canadian real GDP converging to zero in around 15 quarters or approximately four years. This relationship is consistent with economic theory. While the Canadian economy eventually reaches a steady state in accordance with the new policy rate shock, it clearly takes a while to do so. Monetary policy acts with lags as discussed previously due to delayed informational lows and economic frictions. Moreover, such a wide encompassing variable as GDP is slow to react to changes in the policy variables due to multiple feedback loops and transmission channels. Such interdependence within the Canadian economy can easily prolong an economic recovery without further policy intervention. This can also be further explained by the cyclical nature of an economy, which can encourage persistence in underlying variables such as aggregate demand, supply, and future expectations. As such, future adjustments towards the steady state are likely to unfold over multiple periods, helping to provide an economic explanation for such a prolonged impact on Canadian real GDP.

Graphs 44 to 46 show much larger and relatively quicker impacts of a one standard deviation shock in the change in M1 money supply growth. The impact on Canadian real GDP peaks within one quarter and the impact on changes in Canadian inflation and unemployment rates peaks within two quarters. This should hold no surprise given that an increase in the money supply immediately injects liquidity into the economy and thus has a much quicker implementation speed. Another interesting observation to make here is the much quicker convergence to zero in Graphs 44 to 46 relative to Graphs 41 to 43. Compared to a shock in the policy rate, money supply shocks seem to dissipate within eight quarters. These results are consistent with what is seen in academic literature. Christiano and Eichenbaum (1995) showed that unexpected increases in money supply tend to be short-lived whereas interest rates have a much more persistent impact on macroeconomic variables. This is largely captured by the IRF functions in Graphs 41 to 46 with shocks in policy rates being much more long lived relative to shocks in M1 money supply. Moreover, the convergence to zero in Graphs 44 to 46 also align with the neutrality of money in the long term. Over time, the economy converges to a new steady state in accordance with the money supply shock. For instance, consider a money supply growth rate of $x\%$ and assume a one standard deviation shock leads to a new growth rate of $(x + h)\%$. While there would be an immediate impact on such macroeconomic variables, over time the economy will adjust to this new growth rate leading to no changes in real GDP, inflation, and unemployment metrics. Therefore, the IRF functions in Graphs 44 to 46 converge to zero.

Before concluding the paper, one exercise of consequence is considering how the IRF functions change with the exclusion of post 2019 data referring to the COVID-19 pandemic. Such an unexpected and large shock to the Canadian economy and inflation dynamics generates an interest in understanding how the IRF functions change when pandemic data is omitted. This interest is further extended by the impact of the pandemic on monetary policy, which resulted in large swings in the underlying policy rate and money supply. As such, the COVID-19 data in the above discussed models are clearly incredibly influential observations, and therefore their exclusion should have a material impact on the IRF functions.

Graphs 47 to 52 in the Appendix plot the IRF functions for the same policy and macroeconomic variables with pre-2020 data. The VAR model for pre-2020 data was estimated in the exact same way as for the entire sample with post 2019-Q4 data dropped. These IRF functions can be interpreted in a similar manner to Graphs 41 to 46 in the Appendix. An interesting dynamic to mention here is the relatively muted response of inflation in Graphs 48 and 51. When compared with the full sample IRF functions, inflation in the pre-2020 sample shows less movement to a positive one standard deviation shock to the policy rate and change in Canadian M1 money supply growth. A potential economic explanation could be attributed to the stability of the economic environment and inflation expectations in the pre-pandemic regime. Moreover, the Bank of Canada also maintained strong credibility in their inflation targeting regime, anchoring inflation expectations and minimizing impacts of policy rate and money supply on inflation. Additionally, the pre-2020 IRF functions in Graphs 50 to 52 also exhibit quicker convergences to zero. Given the fewer structural shocks to the Canadian economy pre-pandemic, monetary mechanisms were more predictable. This predictability perhaps helped anchor expectations more strictly and can be seen as a potential explanation as to why the economy seems to converge to a steady state relatively quicker. Another potential explanation arises from how liquidity conditions evolved post 2020. At the pandemic's onset, liquidity conditions were drastically distorted given the excessive undertaking of quantitative easing to support capital markets. As such, the full sample IRF functions exhibit longer convergences to a steady state given the multiplier effects of greater money supply and excess liquidity. A final comment needs to be made on the relatively smoother IRF functions for the pre-2020 sample in Graphs 47 to 49, when compared to Graphs 41 to 43. This is as expected and perhaps reflects greater predictability of the monetary transmission effects pre-pandemic. The pandemic encouraged the Bank of Canada to adopt unconventional monetary policies, which would have had a material impact on market expectations and on the interdependencies of the variables included in the VAR model. This issue was further intensified by greater volatility in post-pandemic data. As such, the full sample IRF functions in Graphs 41 to 43 show more jagged responses to shocks in the policy variables, reflecting not only a structural economic change but also incorporating greater heterogeneity in the data samples. Nonetheless, this comparison of pre-pandemic and post-pandemic IRF functions demonstrates the impact of COVID-19 on monetary mechanisms, policy uncertainty, and the relatively prolonged convergences to steady states.

Policy Implications and Conclusion

From the above discussions, we can infer that COVID-19 has had a material impact on monetary transmissions in the Canadian economy. The IRF functions for the full sample exhibit more sudden and long-lasting policy shocks on the non-policy variables. This has a direct impact on the central bank's policy framework that encourages the bank to adopt a relatively more cautious approach to policy implementation. A key consequence of this analysis also underpins the need for the central bank to adopt transparent communications that appropriately anchor market expectations. This will help in offsetting the increased data volatility and longer adjustment periods to policy shocks post-pandemic.

To conclude, while the above analysis provides a fundamental understanding of the impact of policy variables on the Canadian macroeconomic environment, the study is still limited by the number of observations and heteroskedasticity in the error terms. The limited number of observations in the panel dataset questions the stability of the regression coefficients. Incorporating a greater number of observations, especially post-pandemic observations, can help improve the model's precision and bring down standard errors and provide cleaner IRF functions. Additionally, including dummy variables for breaks in structural regimes would also help in insolating the unique impact of such shocks from traditional monetary mechanisms. More focus can also be placed on estimating a robust variance-covariance matrix from MGARCH models to capture the contemporaneous dependencies in the variances. Our paper's focus on running a GARCH model assumed a diagonal covariance matrix, a simplification of the underlying relationships between the error terms.

Our paper provides a fundamental understanding of the impact of policy variables on Canadian macroeconomic variables using a full sample dataset and a pre-pandemic dataset. The analysis demonstrates a need to reassess monetary policy frameworks post-pandemic given the changes in the IRF functions. However, further research into incorporating MGARCH models with the underlying VAR model can significantly help improve the stability and precision of volatility forecasts to more accurately map out policy innovations and their resulting IRF functions.

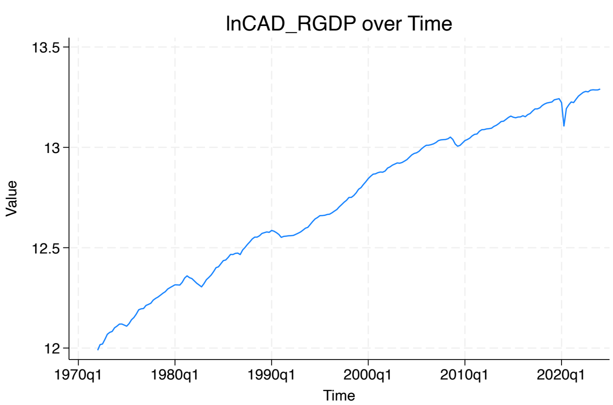
Appendix

Table 1

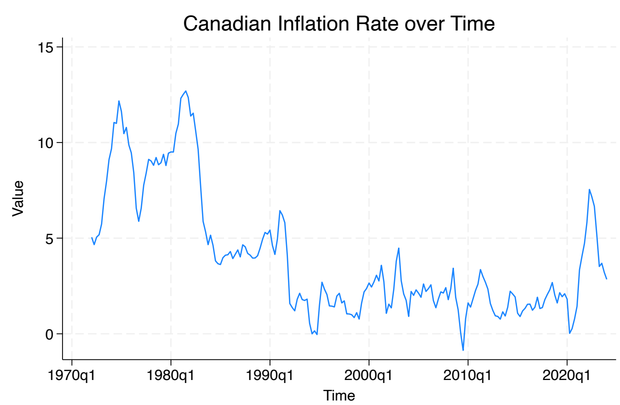
Variable Name	Description	Source
ln (Canadian Real GDP)	Natural logarithm of Canadian Real GDP	FRED Economic Data
Canadian CPI	The inflation rate for the Canadian Economy	FRED Economic Data
Canadian Unemployment Rate	The unemployment rate for the Canadian Economy	FRED Economic Data
Fisher Commodity Price Index	Fisher price index of spot prices in USD of 26 commodities	StatCan
CAD/USD Exchange Rate	The exchange rate between the Canadian and US Dollar	FRED Economic Data
US PCE	The inflation rate for the US Economy	Bureau of Economic Analysis
ln (US Real GDP)	Natural logarithm of US Real GDP	FRED Economic Data
US Unemployment Rate	The unemployment rate for the US Economy	FRED Economic Data

Table 2

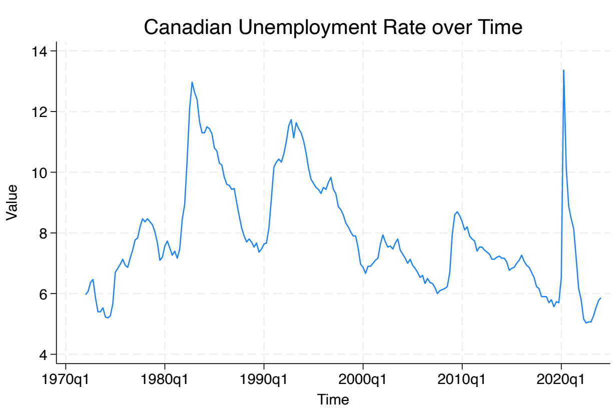
Variable Name	Description	Source
Bank Rate	The main policy rate set by the Bank of Canada	StatCan
ln (Canadian M1 Money Supply)	Natural logarithm of M1 Money Supply for the Canadian Economy	StatCan



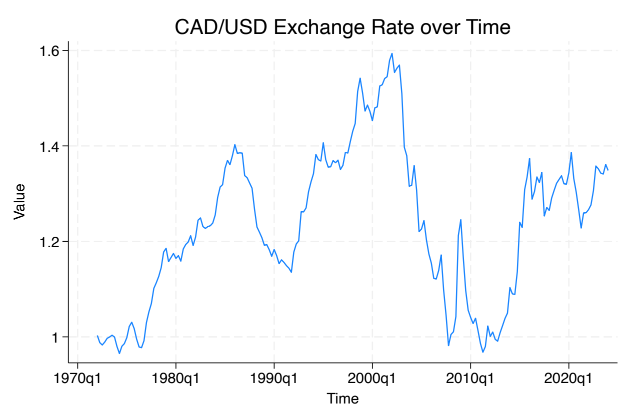
Graph 1- Natural Logarithm of Canadian Real GDP



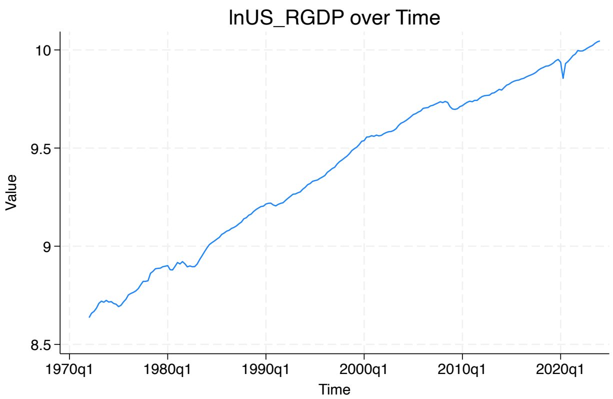
Graph 2 - Canadian Inflation Rate



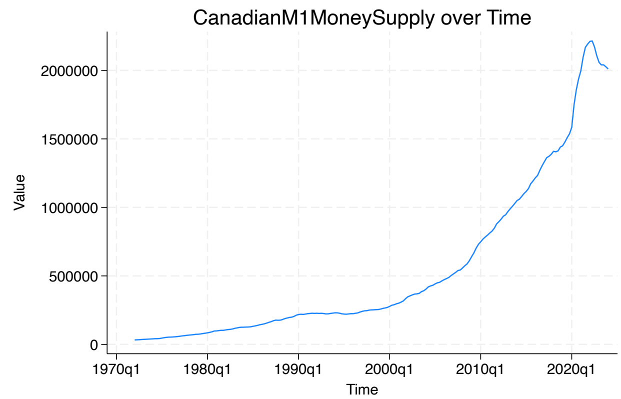
Graph 3 - Canadian Unemployment Rate



Graph 4 - CAD/USD Exchange Rate



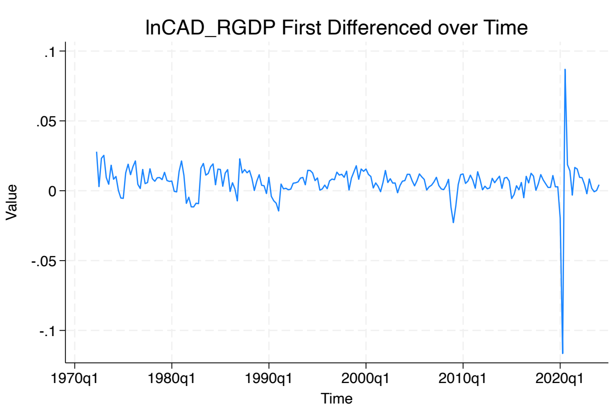
Graph 5 - Natural Logarithm of US Real GDP



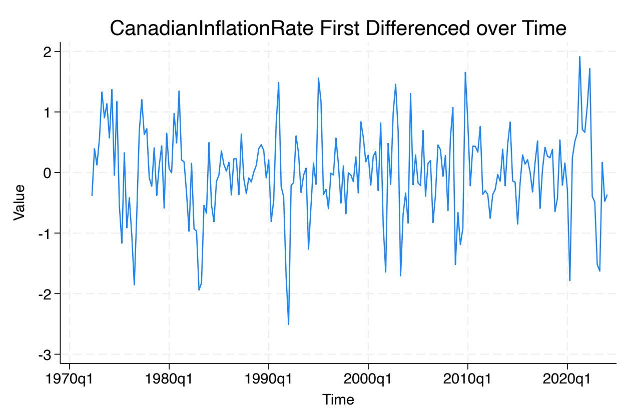
Graph 6 - Canadian M1 Money Supply

Table 3

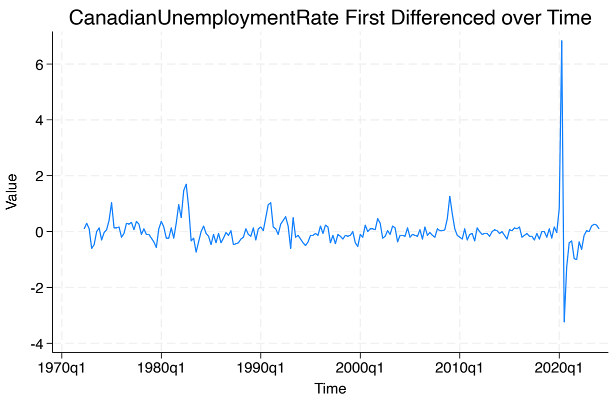
Variable Name	**Time Trend Included**	**P-Value**
lnCAD_RGDP	Yes	0.3227*
CanadianInflationRate	No	0.4628*
CanadianUnemploymentRate	No	0.0910*
FisherIndex	No	0.000
CADUSDExchangeRate	No	0.4137*
USPCE	No	0.000
lnUS_RGDP	Yes	0.7906*
USUnemploymentRate	No	0.0178
CanadianM1MoneySupply	Yes	1.000*



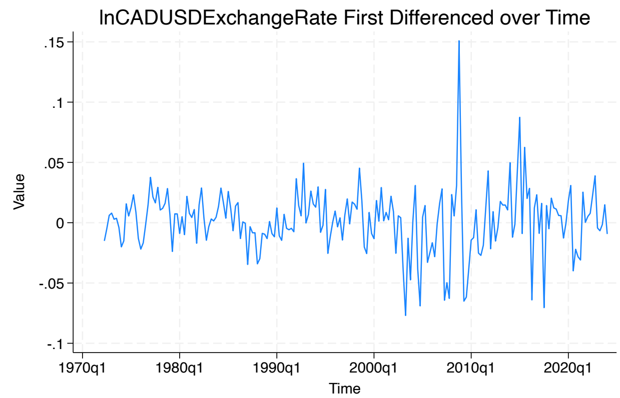
Graph 7 - Natural Logarithm of Canadian Real GDP First Differenced



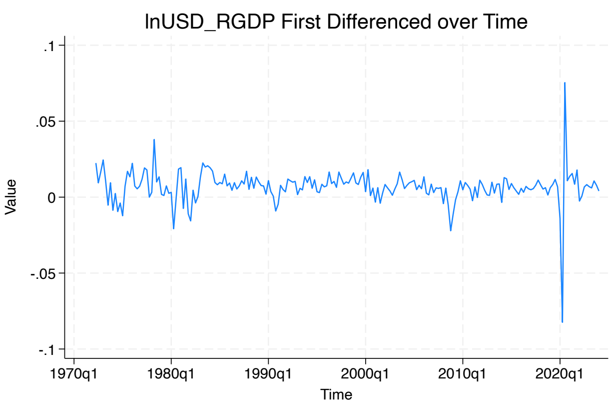
Graph 8 - Canadian Inflation Rate First Differenced



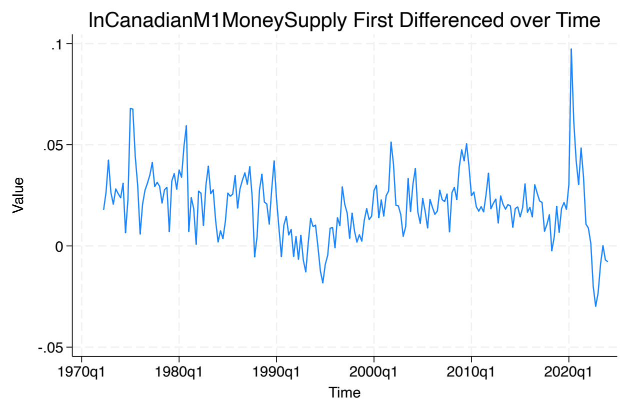
Graph 9 - Canadian Unemployment Rate First Differenced



Graph 10 – Natural Logarithm of CAD/USD Exchange Rate First Differenced



Graph 11 - Natural Logarithm of US Real GDP First Differenced



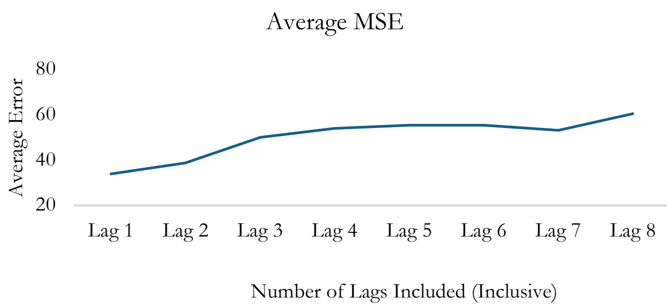
Graph 12 - Natural Logarithm of Canadian M1 Money Supply First Differenced

Table 4

Variable Name	**P-Value**
lnCAD_RGDP First Differenced	0.000
CanadianInflationRate First Differenced	0.000
CanadianUnemploymentRate First Differenced	0.000
ln(CADUSDExchangeRate) First Differenced	0.000
lnUS_RGDP First Differenced	0.000
ln(CanadianM1MoneySupply) First Differenced	0.000

$$Y_t = \begin{bmatrix} \ln(Canadian\ Real\ GDP)_t * \\ Canadian\ Inflation\ Rate_t * \\ Canadian\ Unemployment_t * \\ \ln(CAD/USD\ Exchange\ Rate)_t * \\ \ln(US\ Real\ GDP)_t * \\ US\ PCE_t \\ US\ Unemployment\ Rate_t \end{bmatrix} \qquad p_t = \begin{bmatrix} Canadian\ Policy\ Rate_t \\ \ln(CanadianM1MoneySupply)_t * \end{bmatrix} \qquad X_t = FisherIndex_t$$

Equation (8)



Graph 13 – Average Leave-One-Out MSE Error Graph

Lags Included	Average MSE
1	33.97113492
2	38.78024047
3	50.03258144
4	53.96339177
5	55.52647529
6	55.51104862
7	53.31129874
8	60.60835995

Table 5 – Average Leave-One-Out MSE Error Table

Y = d_lnCAD_RGDP		Y = d_CADIR		Y = d_CanadianUnemployment	
L1.d_lnCAD_RGDP	0.0708 (0.1401)	L1.d_lnCAD_RGDP	8.0252 (8.2538)	L1.d_lnCAD_RGDP	-8.6984 (7.0605)
L1.d_CADIR	0.0002 (0.0012)	L1.d_CADIR	0.3018** (0.0694)	L1.d_CADIR	-0.0388 (0.0594)
L1.d_CanadianUnemployment	0.0072** (0.0026)	L1.d_CanadianUnemployment	0.0144 (0.1513)	L1.d_CanadianUnemployment	-0.2448* (0.1294)
L1.d_l_CADUSDExchange	-0.0451 (0.0308)	L1.d_l_CADUSDExchange	0.7656 (1.8148)	L1.d_l_CADUSDExchange	2.6612* (1.5524)
L1.d_lnUS_RGDP	0.2318 (0.1518)	L1.d_lnUS_RGDP	-5.4134 (8.9440)	L1.d_lnUS_RGDP	-2.4281 (7.6509)
L1.USPCE	0.0003 (0.0004)	L1.USPCE	0.0057 (0.0205)	L1.USPCE	-0.0187 (0.0175)
L1.USUnemploymentRate	0.0009* (0.0005)	L1.USUnemploymentRate	-0.0437 (0.0320)	L1.USUnemploymentRate	-0.0374 (0.0274)
L1.CanadianPolicyRate	-0.0004** (0.0002)	L1.CanadianPolicyRate	-0.0078 (0.0114)	L1.CanadianPolicyRate	0.0316** (0.0098)
L1.d_l_CanadianMoneySupply	0.1414** (0.0560)	L1.d_l_CanadianMoneySupply	8.1518** (3.3008)	L1.d_l_CanadianMoneySupply	-4.6500* (2.8235)
FisherIndex	-0.0005** (0.0001)	FisherIndex	0.0074 (0.0062)	FisherIndex	0.0274** (0.0053)
_cons	-0.0027 (0.0032)	_cons	0.1074 (0.1868)	_cons	0.2399 (0.1598)

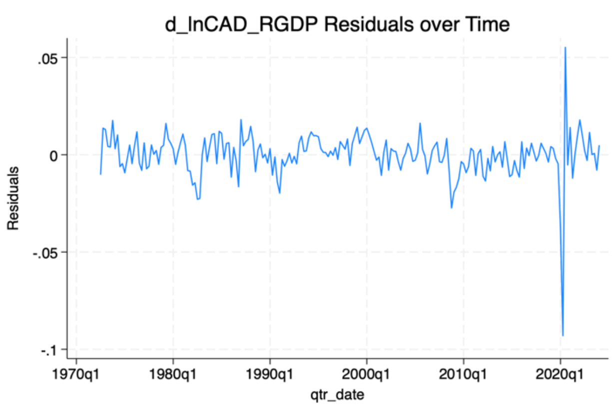
Table 6 – VAR Regression Output 1 (** $p < 0.05$, * $p < 0.10$)

Y = d_l_CADUSDExchange		Y= d_lnUS_RGDP		Y = USPCE	
L1.d_lnCAD_RGDP	-0.0074 (0.2973)	L1.d_lnCAD_RGDP	0.0278 (0.1200)	L1.d_lnCAD_RGDP	16.1106 (47.8205)
L1.d_CADIR	-0.0018 (0.0025)	L1.d_CADIR	-0.0021** (0.0010)	L1.d_CADIR	-0.5204 (0.4020)
L1.d_CanadianUnemployment	-0.0051 (0.0055)	L1.d_CanadianUnemployment	0.0057** (0.0022)	L1.d_CanadianUnemployment	3.4607** (0.8765)
L1.d_l_CADUSDExchange	0.2616** (0.0654)	L1.d_l_CADUSDExchange	-0.029 (0.0264)	L1.d_l_CADUSDExchange	-14.6315 (10.5144)
L1.d_lnUS_RGDP	-0.4026 (0.3222)	L1.d_lnUS_RGDP	0.0193 (0.1301)	L1.d_lnUS_RGDP	16.2593 (51.8198)
L1.USPCE	0.0008 (0.0007)	L1.USPCE	0.0007** (0.0003)	L1.USPCE	0.2056* (0.1188)
L1.USUnemploymentRate	-0.0004 (0.0012)	L1.USUnemploymentRate	0.0008 (0.0005)	L1.USUnemploymentRate	0.3785** (0.1854)
L1.CanadianPolicyRate	0.0001 (0.0004)	L1.CanadianPolicyRate	-0.0003** (0.0002)	L1.CanadianPolicyRate	-0.1405** (0.0661)
L1.d_l_CanadianMoneySupply	-0.0659 (0.1189)	L1.d_l_CanadianMoneySupply	0.0876* (0.0480)	L1.d_l_CanadianMoneySupply	22.1483 (19.1238)
FisherIndex	-0.0009** (0.0002)	FisherIndex	-0.0003* (0.0001)	FisherIndex	-0.1264** (0.0357)
_cons	0.0054 (0.0067)	_cons	0 (0.0027)	_cons	0.3459 (1.0822)

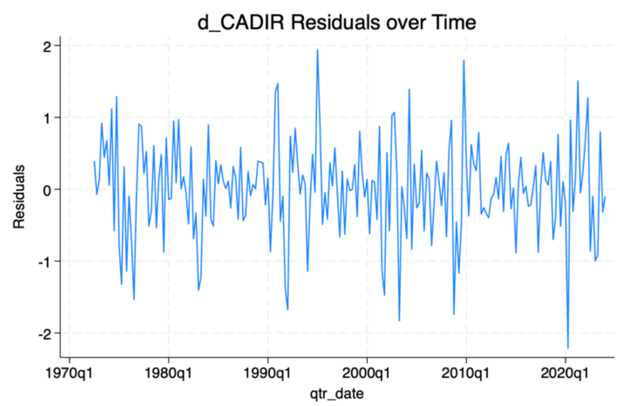
Table 7 – VAR Regression Output 2 (** $p < 0.05$, * $p < 0.10$)

Y = USUnemploymentRate		Y = CanadianPolicyRate		Y = d_l_CanadianMoneySupply	
L1.d_lnCAD_RGDP	-3.9184 (8.2870)	L1.d_lnCAD_RGDP	20.3216** (10.0376)	L1.d_lnCAD_RGDP	0.0944 (0.1418)
L1.d_CADIR	0.0013 (0.0697)	L1.d_CADIR	0.0186 (0.0844)	L1.d_CADIR	0.0001 (0.0012)
L1.d_CanadianUnemployment	-0.3622** (0.1519)	L1.d_CanadianUnemployment	-0.0437 (0.1840)	L1.d_CanadianUnemployment	0.0002 (0.0026)
L1.d_l_CADUSDExchange	1.8876 (1.8221)	L1.d_l_CADUSDExchange	-2.1887 (2.207)	L1.d_l_CADUSDExchange	-0.0969** (0.0312)
L1.d_lnUS_RGDP	-5.4384 (8.9801)	L1.d_lnUS_RGDP	7.1771 (10.8771)	L1.d_lnUS_RGDP	-0.4141** (0.1537)
L1.USPCE	-0.0497** (0.0206)	L1.USPCE	-0.0411** (0.0249)	L1.USPCE	0.0002 (0.0004)
L1.USUnemploymentRate	0.9139** (0.0321)	L1.USUnemploymentRate	-0.0632 (0.0389)	L1.USUnemploymentRate	0.0001 (0.0005)
L1.CanadianPolicyRate	0.0350** (0.0115)	L1.CanadianPolicyRate	0.9860** (0.0139)	L1.CanadianPolicyRate	0.0001 (0.0002)
L1.d_l_CanadianMoneySupply	-3.4278 (3.3141)	L1.d_l_CanadianMoneySupply	10.3854* (4.0141)	L1.d_l_CanadianMoneySupply	0.6072** (0.0567)
FisherIndex	0.0404** (0.0062)	FisherIndex	-0.007 (0.0075)	FisherIndex	0.0003** (0.0001)
_cons	0.5636** (0.1875)	_cons	0.2238 (0.2272)	_cons	0.0080** (0.0032)

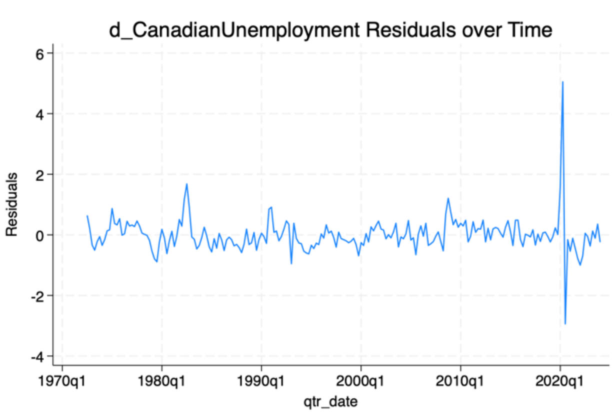
Table 8 – VAR Regression Output 3 (** $p < 0.05$, * $p < 0.10$)



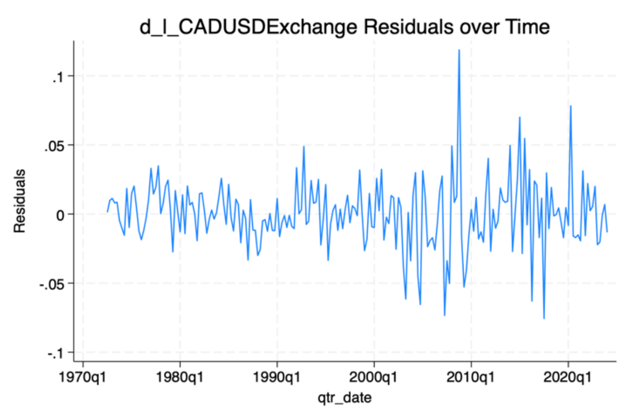
Graph 14 – Residuals for Natural Logarithm of Canadian Real GDP First Differenced



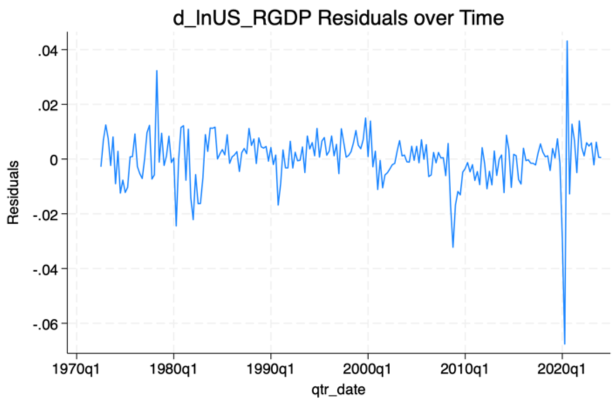
Graph 15 – Residuals for Canadian Inflation Rate First Differenced



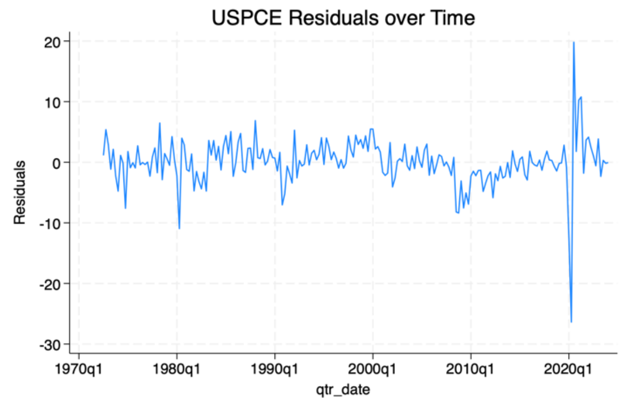
Graph 16 – Residuals for Canadian Unemployment Rate First Differenced



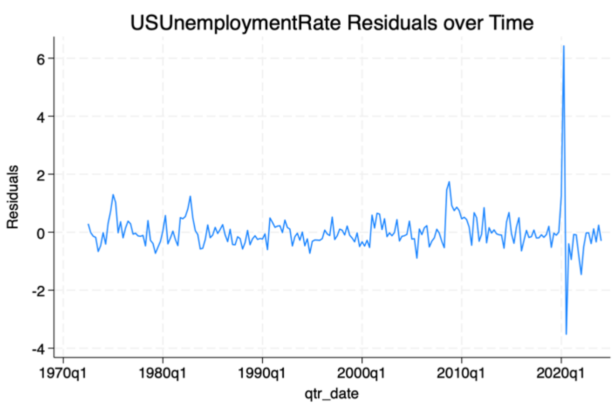
Graph 17 – Residuals for Natural Logarithm of CAD/USD Exchange Rate First Differenced



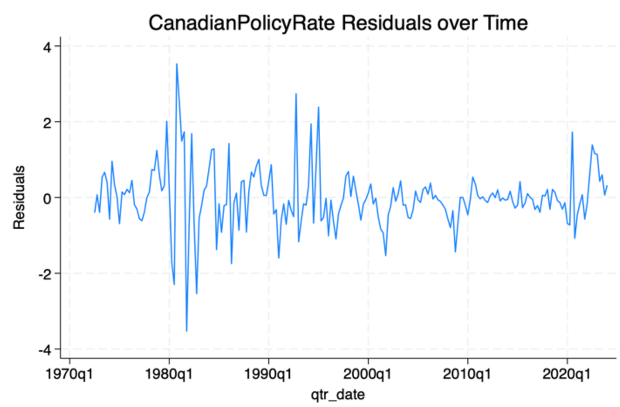
Graph 18 – Residuals for Natural Logarithm of US Real GDP First Differenced



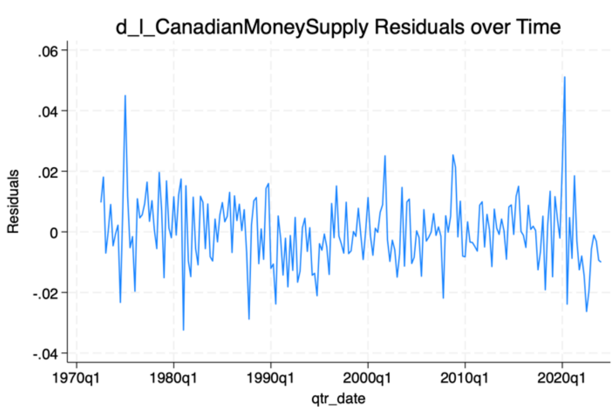
Graph 19 – Residuals for US Inflation Rate



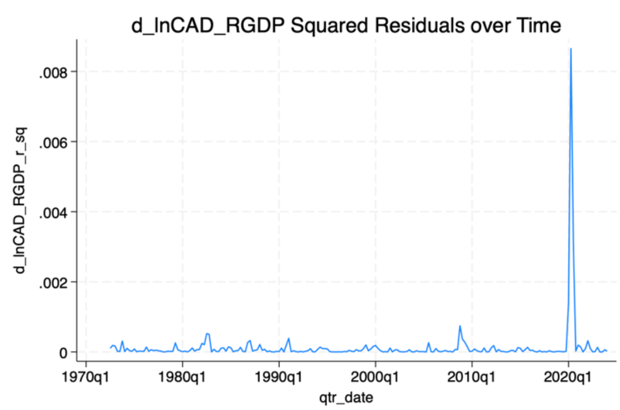
Graph 20 – Residuals for US Unemployment Rate



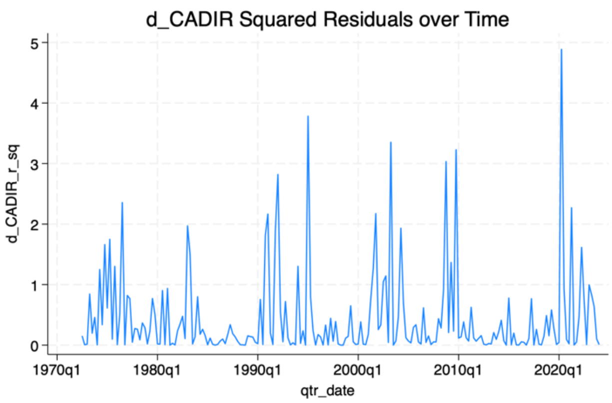
Graph 21 – Residuals for Canadian Policy Rate



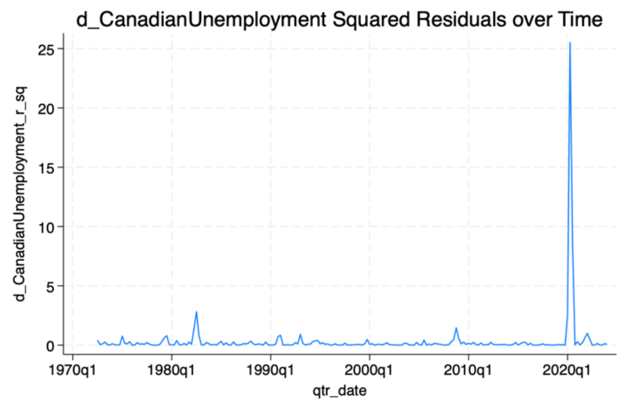
Graph 22 – Residuals for Natural Logarithm of Canadian M1 Money Supply First Differenced



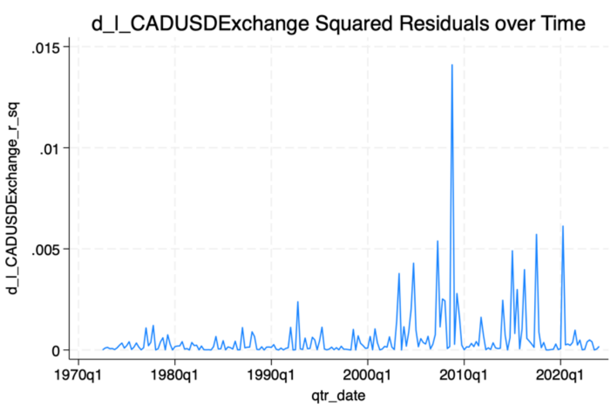
Graph 23 – Squared Residuals for Natural Logarithm of Canadian Real GDP First Differenced



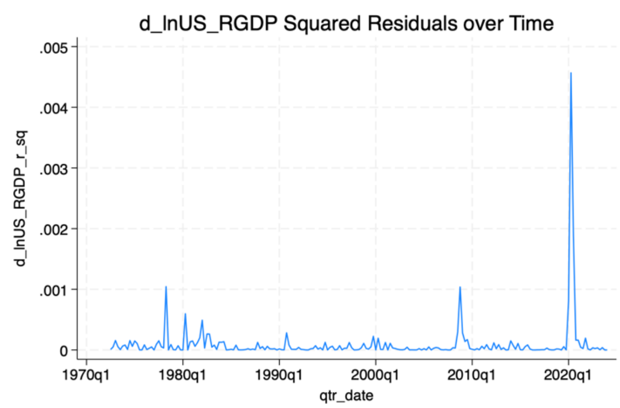
Graph 24 – Squared Residuals for Canadian Inflation Rate First Differenced



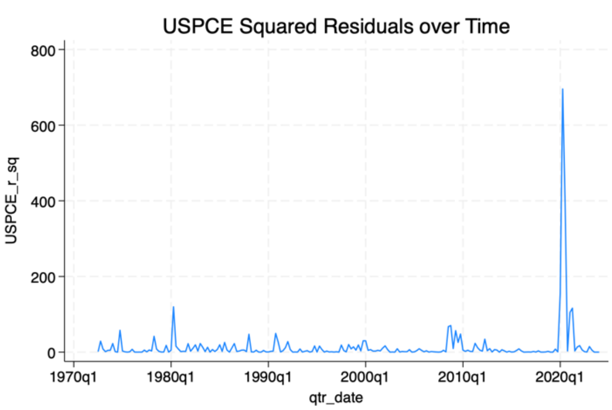
Graph 25 – Squared Residuals for Canadian Unemployment Rate First Differenced



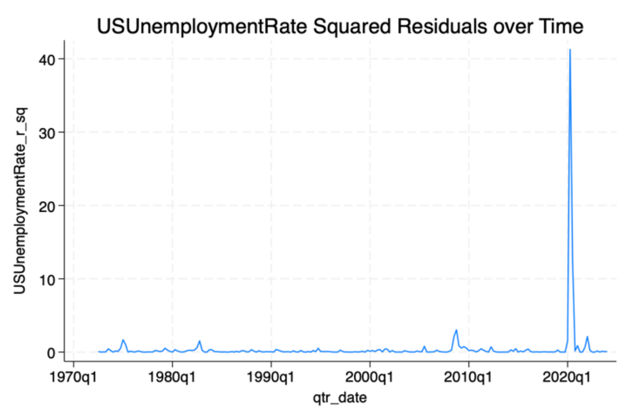
Graph 26 – Squared Residuals for Natural Logarithm of CAD/USD Exchange Rate First Differenced



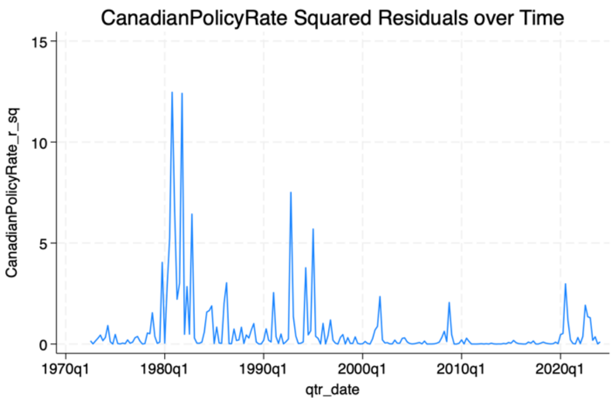
Graph 27 – Squared Residuals for Natural Logarithm of US Real GDP First Differenced



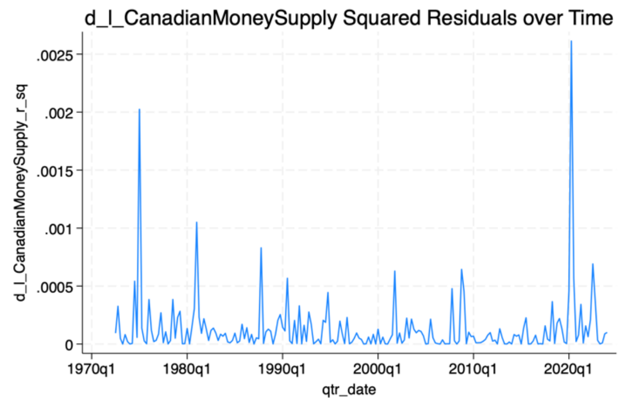
Graph 28 – Squared Residuals for US Inflation Rate



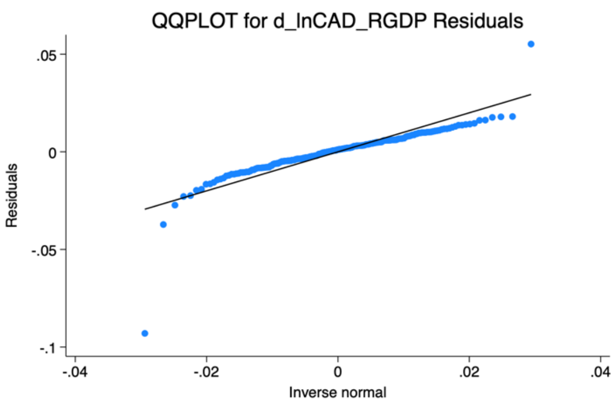
Graph 29 – Squared Residuals for US Unemployment Rate



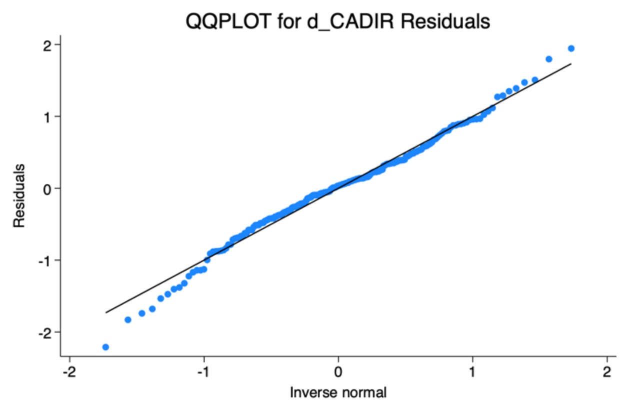
Graph 30 – Squared Residuals for Canadian Policy Rate



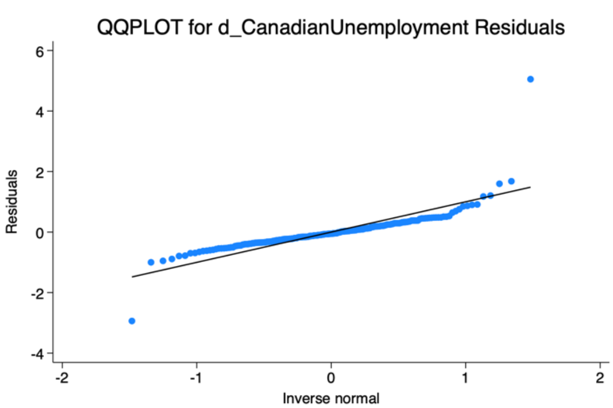
Graph 31 – Squared Residuals for Natural Logarithm of Canadian M1 Money Supply First Differenced



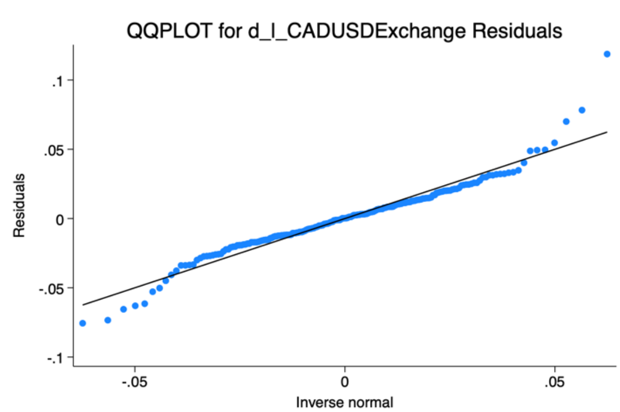
Graph 32 – QQPLOT for Residuals for Natural Logarithm of Canadian Real GDP First Differenced



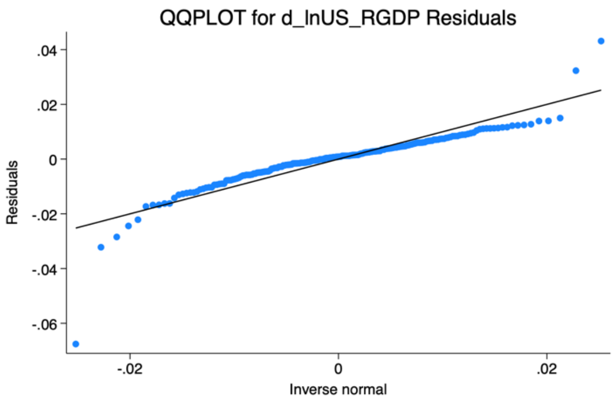
Graph 33 – QQPLOT for Residuals for Canadian Inflation Rate First Differenced



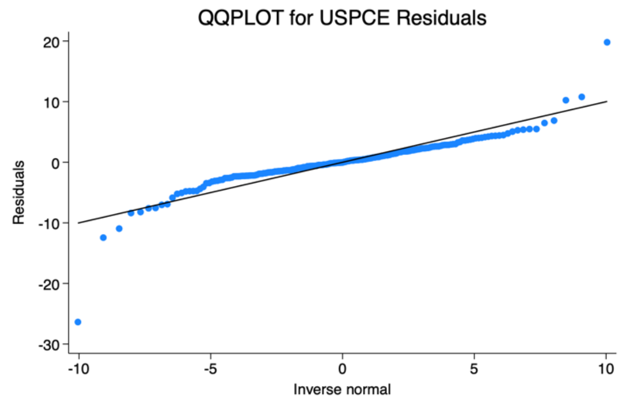
Graph 34 – QQPLOT for Residuals for Canadian Unemployment Rate First Differenced



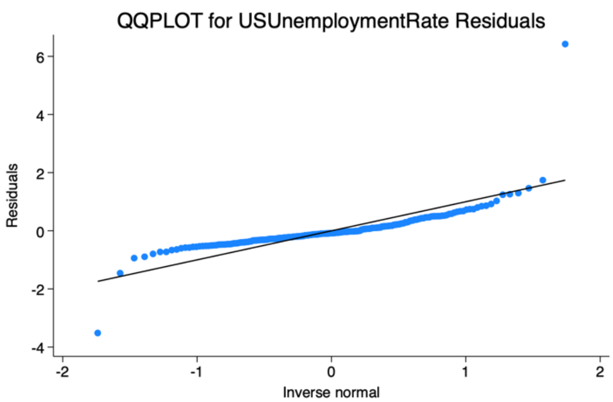
Graph 35 – QQPLOT for Residuals for Natural Logarithm of CAD/USD Exchange Rate First Differenced



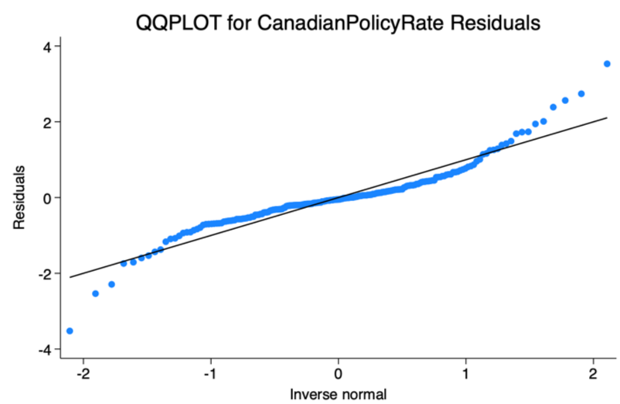
Graph 36 – QQPLOT for Residuals for Natural Logarithm of US Real GDP First Differenced



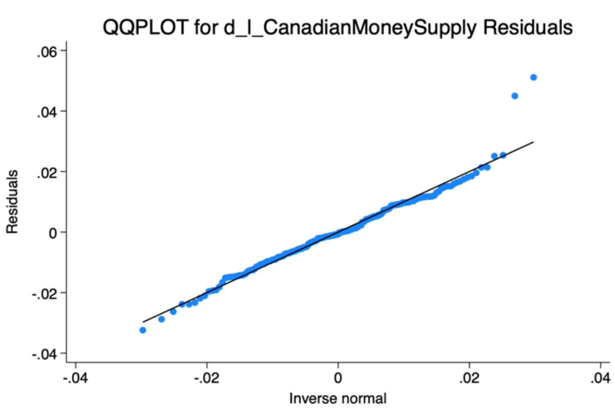
Graph 37 – QQPLOT for Residuals for US Inflation Rate



Graph 38 – QQPLOT for Residuals for US Unemployment Rate



Graph 39 – QQPLOT for Residuals for Canadian Policy Rate



Graph 40 – QQPLOT for Residuals for Natural Logarithm of Canadian M1 Money Supply First Differenced

Residuals Squared	**Test-Statistic**	**Result**
d_lnCAD_RGDP	71.12495	Evidence of Heteroskedasticity
d_CADIR	19.12677	Evidence of Heteroskedasticity
d_CanadianUnemployment	73.8679	Evidence of Heteroskedasticity
d_l_CADUSDExchange	15.97812	Fail to Reject
d_lnUS_RGDP	61.10712	Evidence of Heteroskedasticity
USPCE	77.80016	Evidence of Heteroskedasticity
USUnemploymentRate	74.80587	Evidence of Heteroskedasticity
CanadianPolicyRate	42.9591	Evidence of Heteroskedasticity
d_l_CanadianMoneySupply	35.4888	Evidence of Heteroskedasticity

Table 9 – Test Statistics for Breusch Pagan Tests for Squared Residuals

Critical Value $\chi^2_{10,0.95} = 18.307$ for all regression equations as independent variables are same across all Breusch Pagan equations

Y = d_lnCAD_RGDP_h		Y = d_CADIR_h		Y = d_CanadianUnemployment_h	
L1.d_lnCAD_RGDP_h	0.1644** (0.0798)	L1.d_lnCAD_RGDP_h	0.0837 (0.1020)	L1.d_lnCAD_RGDP_h	-0.2696** (0.0763)
L1.d_CADIR_h	-0.0316 (0.0548)	L1.d_CADIR_h	0.2612** (0.0701)	L1.d_CADIR_h	-0.0290 (0.0524)
L1.d_CanadianUnemployment_h	-0.1516** (0.0772)	L1.d_CanadianUnemployment_h	-0.1358 (0.0986)	L1.d_CanadianUnemployment_h	0.2088** (0.0738)
L1.d_l_CADUSDExchange_h	0.0209 (0.0524)	L1.d_l_CADUSDExchange_h	0.0678 (0.0669)	L1.d_l_CADUSDExchange_h	0.0425 (0.0500)
L1.d_lnUS_RGDP_h	0.1515* (0.0842)	L1.d_lnUS_RGDP_h	-0.0319 (0.1076)	L1.d_lnUS_RGDP_h	-0.0603 (0.0805)
L1.USPCE_h	0.1756** (0.0853)	L1.USPCE_h	0.0128 (0.1090)	L1.USPCE_h	-0.0720 (0.0815)
L1.USUnemploymentRate_h	0.0032 (0.011)	L1.USUnemploymentRate_h	0.0008 (0.0140)	L1.USUnemploymentRate_h	0.0071 (0.0105)
L1.CanadianPolicyRate_h	-0.0092 (0.0095)	L1.CanadianPolicyRate_h	-0.0029 (0.0121)	L1.CanadianPolicyRate_h	0.0322** (0.0091)
L1.d_l_CanadianMoneySupply_h	0.1776** (0.0424)	L1.d_l_CanadianMoneySupply_h	0.1114** (0.0542)	L1.d_l_CanadianMoneySupply_h	-0.1276** (0.0405)
FisherIndex_h	-0.0038 (0.0072)	FisherIndex_h	0.0125 (0.0092)	FisherIndex_h	0.0084 (0.0069)
_cons	0.0500 (0.1990)	_cons	-0.2564 (0.2543)	_cons	0.1240 (0.1902)

Table 10 – VAR Regression Output 1 after GARCH Modelling (** p < 0.05, * p < 0.10)

Y = d_l_CADUSDExchange_h		Y= d_lnUS_RGDP_h		Y = USPCE_h	
L1.d_lnCAD_RGDP_h	0.0102 (0.1001)	L1.d_lnCAD_RGDP_h	0.1348 (0.0882)	L1.d_lnCAD_RGDP_h	0.1098 (0.0888)
L1.d_CADIR_h	-0.0526 (0.0688)	L1.d_CADIR_h	-0.2048** (0.0606)	L1.d_CADIR_h	-0.1980** (0.0610)
L1.d_CanadianUnemployment_h	0.0294 (0.0968)	L1.d_CanadianUnemployment_h	-0.1651* (0.0853)	L1.d_CanadianUnemployment_h	0.0015 (0.0859)
L1.d_l_CADUSDExchange_h	0.2464** (0.0657)	L1.d_l_CADUSDExchange_h	-0.0254 (0.0579)	L1.d_l_CADUSDExchange_h	-0.0382 (0.0583)
L1.d_lnUS_RGDP_h	-0.1523 (0.1056)	L1.d_lnUS_RGDP_h	-0.0708 (0.0931)	L1.d_lnUS_RGDP_h	0.0927 (0.0937)
L1.USPCE_h	0.1937* (0.1070)	L1.USPCE_h	0.3969** (0.0943)	L1.USPCE_h	0.1448 (0.0949)
L1.USUnemploymentRate_h	0.0055 (0.0138)	L1.USUnemploymentRate_h	0.013 (0.0121)	L1.USUnemploymentRate_h	0.0048 (0.0122)
L1.CanadianPolicyRate_h	-0.0019 (0.0119)	L1.CanadianPolicyRate_h	-0.0094 (0.0105)	L1.CanadianPolicyRate_h	-0.0044 (0.0105)
L1.d_l_CanadianMoneySupply_h	-0.0111 (0.0532)	L1.d_l_CanadianMoneySupply_h	0.0985* (0.0469)	L1.d_l_CanadianMoneySupply_h	0.0220 (0.0472)
FisherIndex_h	-0.0295** (0.0090)	FisherIndex_h	-0.0093 (0.0079)	FisherIndex_h	-0.0134* (0.0080)
_cons	0.0034 (0.2497)	_cons	0.1761 (0.2199)	_cons	0.5854** (0.2214)

Table 11 – VAR Regression Output 2 after GARCH Modelling (** p < 0.05, * p < 0.10)

Y = USUnemploymentRate_h		Y = CanadianPolicyRate_h		Y = d_l_CanadianMoneySupply_h	
L1.d_lnCAD_RGDP_h	0.6482 (0.4237)	L1.d_lnCAD_RGDP_h	0.6142** (0.2617)	L1.d_lnCAD_RGDP_h	-0.0251 (0.1024)
L1.d_CADIR_h	0.0124 (0.2912)	L1.d_CADIR_h	-0.1419 (0.1799)	L1.d_CADIR_h	0.0345 (0.0704)
L1.d_CanadianUnemployment_h	0.1315 (0.4098)	L1.d_CanadianUnemployment_h	0.0509 (0.2531)	L1.d_CanadianUnemployment_h	-0.0002 (0.0991)
L1.d_l_CADUSDExchange_h	0.2788 (0.2781)	L1.d_l_CADUSDExchange_h	-0.3729** (0.1718)	L1.d_l_CADUSDExchange_h	-0.2632** (0.0672)
L1.d_lnUS_RGDP_h	0.6050 (0.4472)	L1.d_lnUS_RGDP_h	-0.1325 (0.2763)	L1.d_lnUS_RGDP_h	-0.2095* (0.1081)
L1.USPCE_h	0.3024 (0.4529)	L1.USPCE_h	0.4352 (0.2798)	L1.USPCE_h	-0.0279 (0.1095)
L1.USUnemploymentRate_h	0.4871** (0.0583)	L1.USUnemploymentRate_h	0.0026 (0.0360)	L1.USUnemploymentRate_h	0.0042 (0.0141)
L1.CanadianPolicyRate_h	0.0173 (0.0503)	L1.CanadianPolicyRate_h	0.8756** (0.0311)	L1.CanadianPolicyRate_h	0.0137 (0.0122)
L1.d_l_CanadianMoneySupply_h	0.3120 (0.2252)	L1.d_l_CanadianMoneySupply_h	0.1328 (0.1391)	L1.d_l_CanadianMoneySupply_h	0.5569** (0.0545)
FisherIndex_h	-0.0108 (0.0381)	FisherIndex_h	-0.0201 (0.0235)	FisherIndex_h	0.0155* (0.0092)
_cons	5.4478** (1.0568)	_cons	0.0865 (0.6528)	_cons	0.8336** (0.2555)

Table 12 – VAR Regression Output 3 after GARCH Modelling (** $p < 0.05$, * $p < 0.10$)

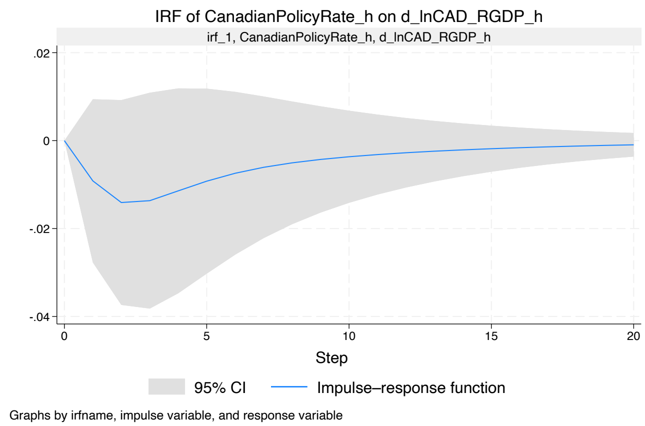
Residuals Squared	**Test-Statistic**	**Result**
d_lnCAD_RGDP_h	23.51482	Evidence of Heteroskedasticity
d_CADIR_h	25.30287	Evidence of Heteroskedasticity
d_CanadianUnemployment_h	47.25832	Evidence of Heteroskedasticity
d_l_CADUSDExchange_h	8.633159	Fail to Reject
d_lnUS_RGDP_h	24.57509	Evidence of Heteroskedasticity
USPCE_h	21.21712	Evidence of Heteroskedasticity
USUnemploymentRate_h	15.52845	Fail to Reject
CanadianPolicyRate_h	75.55013	Evidence of Heteroskedasticity
d_l_CanadianMoneySupply_h	34.61494	Evidence of Heteroskedasticity

Table 13 – Test Statistics for Breusch Pagan Tests for Squared Residuals after GARCH Modelling

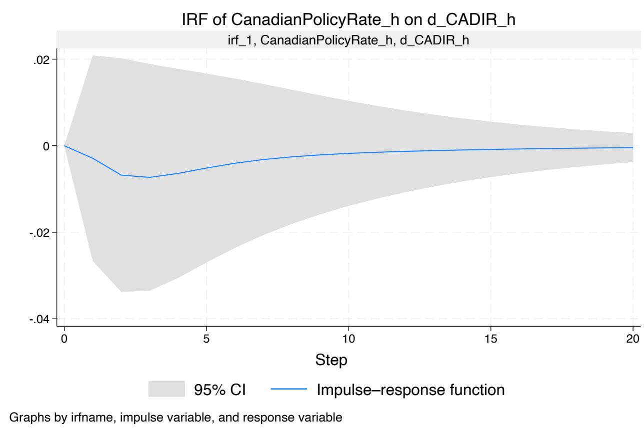
Critical Value $\chi^2_{10,0.95} = 18.307$ for all regression equations as independent variables are same across all Breusch Pagan equations

Dependent Variable	Independent Variable(s)	P-value
d_lnCAD_RGDP_h	L1.CanadianPolicyRate_h	0.3340
	L1.d_l_CanadianMoneySupply_h	0.0000**
	Joint Significance	0.0001**
d_CADIR_h	L1.CanadianPolicyRate_h	0.8110
	L1.d_l_CanadianMoneySupply_h	0.0400**
	Joint Significance	0.1203
d_CanadianUnemployment_h	L1.CanadianPolicyRate_h	0.0000**
	L1.d_l_CanadianMoneySupply_h	0.0020**
	Joint Significance	0.0000**

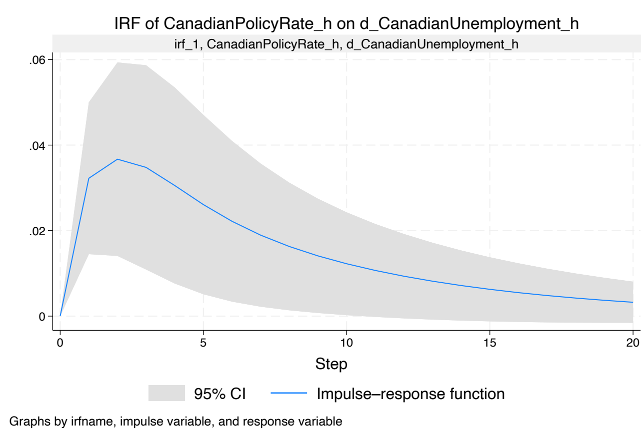
Table 14 – Granger Causality Tests for Selected Policy and Canadian Macroeconomic Variables



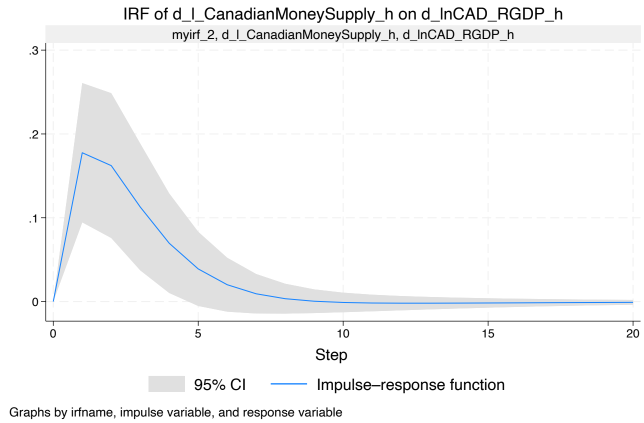
Graph 41 – IRF of Canadian Policy Rate on Canadian Real GDP



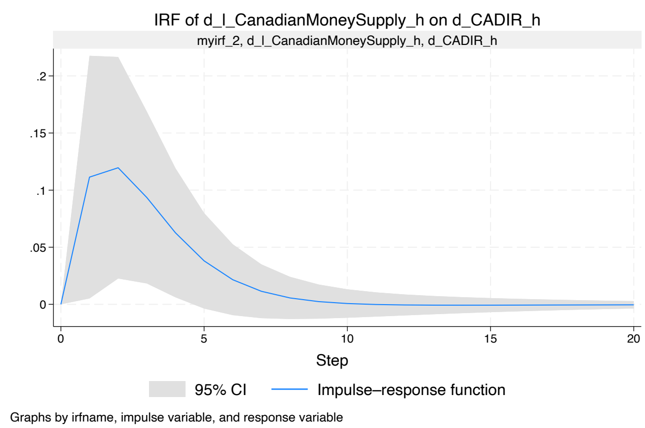
Graph 42 – IRF of Canadian Policy Rate on Canadian Inflation Rate



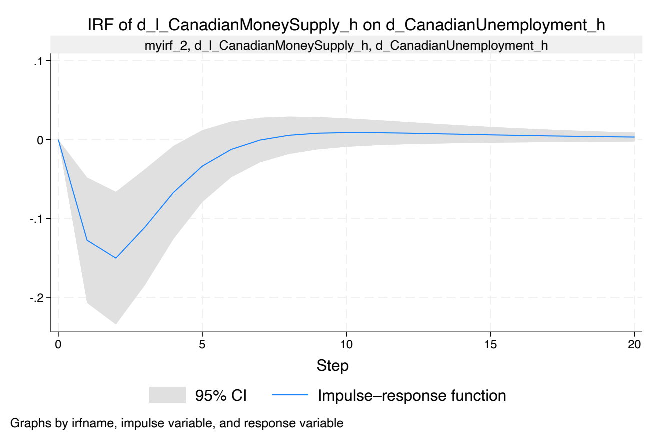
Graph 43 – IRF of Canadian Policy Rate on Canadian Unemployment Rate



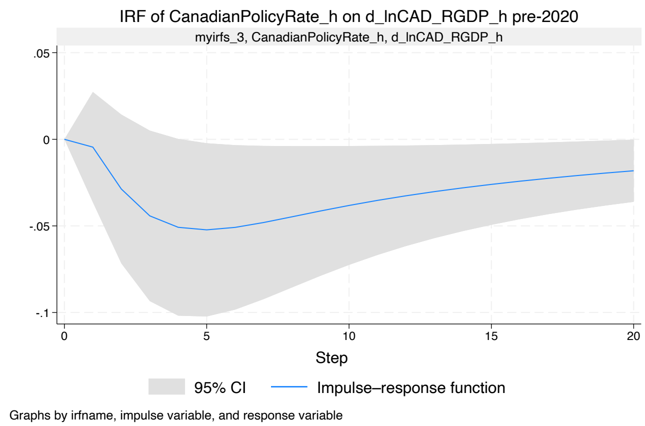
Graph 44 – IRF of Canadian Money Supply on Canadian Real GDP



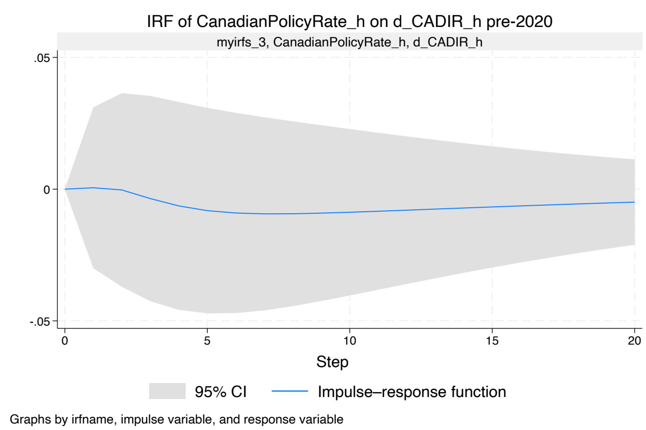
Graph 45 – IRF of Canadian Money Supply on Canadian Inflation Rate



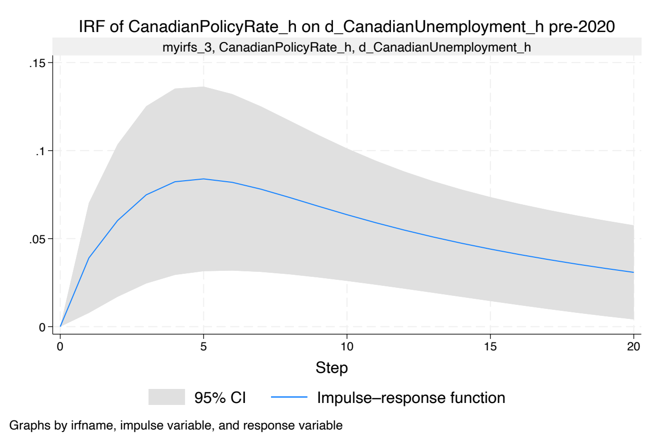
Graph 46 – IRF of Canadian Money Supply on Canadian Unemployment Rate



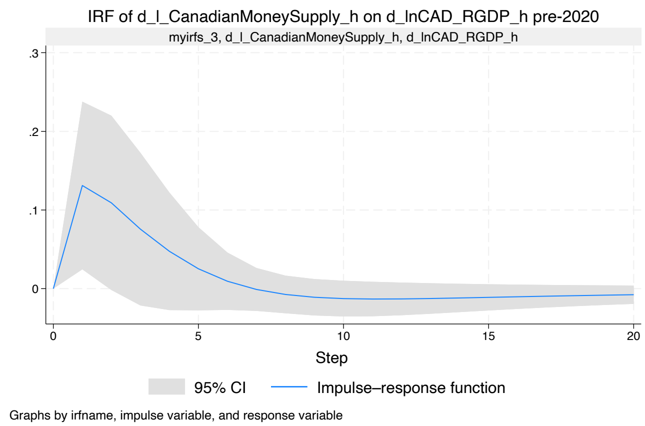
Graph 47 – IRF of Canadian Policy Rate on Canadian Real GDP Pre-2020



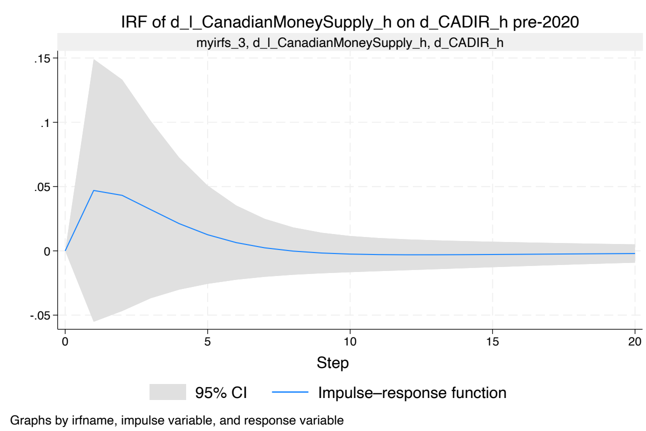
Graph 48 – IRF of Canadian Policy Rate on Canadian Inflation Rate Pre-2020



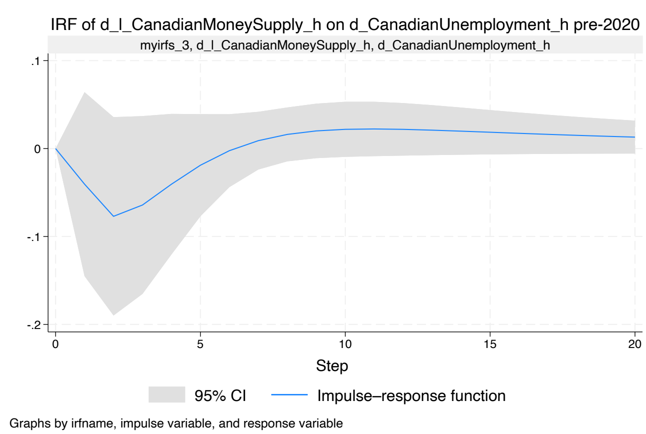
Graph 49 – IRF of Canadian Policy Rate on Canadian Unemployment Rate Pre-2020



Graph 50 – IRF of Canadian Money Supply on Canadian Real GDP Pre-2020



Graph 51 – IRF of Canadian Money Supply on Canadian Inflation Rate Pre-2020



Graph 52 – IRF of Canadian Money Supply on Canadian Unemployment Rate Pre-2020

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