



CIRANO

Allier savoir et décision

Macroeconomic Uncertainty and the COVID-19 Pandemic: Measure and Impacts on the Canadian Economy

KEVIN MORAN

DALIBOR STEVANOVIC

ADAM KADER TOURÉ

2020S-47
CAHIER SCIENTIFIQUE



Center for Interuniversity Research and Analysis on Organizations

The purpose of the **Working Papers** is to disseminate the results of research conducted by CIRANO research members in order to solicit exchanges and comments. These reports are written in the style of scientific publications. The ideas and opinions expressed in these documents are solely those of the authors.

Les cahiers de la série scientifique visent à rendre accessibles les résultats des recherches effectuées par des chercheurs membres du CIRANO afin de susciter échanges et commentaires. Ces cahiers sont rédigés dans le style des publications scientifiques et n'engagent que leurs auteurs.

CIRANO is a private non-profit organization incorporated under the Quebec Companies Act. Its infrastructure and research activities are funded through fees paid by member organizations, an infrastructure grant from the government of Quebec, and grants and research mandates obtained by its research teams.

Le CIRANO est un organisme sans but lucratif constitué en vertu de la Loi des compagnies du Québec. Le financement de son infrastructure et de ses activités de recherche provient des cotisations de ses organisations-membres, d'une subvention d'infrastructure du gouvernement du Québec, de même que des subventions et mandats obtenus par ses équipes de recherche.

CIRANO Partners – Les partenaires du CIRANO

Corporate Partners – Partenaires corporatifs

Autorité des marchés financiers
Bank of Canada
Bell Canada
BMO Financial Group
Business Development Bank of Canada
Caisse de dépôt et placement du Québec
Desjardins Group
Énergir
Hydro-Québec
Innovation, Science and Economic Development Canada
Intact Financial Corporation
Manulife Canada
Ministère de l'Économie, de la Science et de l'Innovation
Ministère des finances du Québec
National Bank of Canada
Power Corporation of Canada
PSP Investments
Rio Tinto
Ville de Montréal

Academic Partners – Partenaires universitaires

Concordia University
École de technologie supérieure
École nationale d'administration publique
HEC Montréal
McGill University
National Institute for Scientific Research
Polytechnique Montréal
Université de Montréal
Université de Sherbrooke
Université du Québec
Université du Québec à Montréal
Université Laval

CIRANO collaborates with many centers and university research chairs; list available on its website. *Le CIRANO collabore avec de nombreux centres et chaires de recherche universitaires dont on peut consulter la liste sur son site web.*

© September 2020. Kevin Moran, Dalibor Stevanovic, Adam Kader Touré. All rights reserved. *Tous droits réservés.* Short sections may be quoted without explicit permission, if full credit, including © notice, is given to the source. *Reproduction partielle permise avec citation du document source, incluant la notice ©.*

The observations and viewpoints expressed in this publication are the sole responsibility of the authors; they do not necessarily represent the positions of CIRANO or its partners. *Les idées et les opinions émises dans cette publication sont sous l'unique responsabilité des auteurs et ne représentent pas nécessairement les positions du CIRANO ou de ses partenaires.*

Macroeconomic Uncertainty and the COVID-19 Pandemic: Measure and Impacts on the Canadian Economy ^{*}

Kevin Moran [†], Dalibor Stevanovic [‡], Adam Kader Touré [§]

Abstract/Résumé

This paper constructs a measure of Canadian macroeconomic uncertainty, by applying the Jurado et al. (2015) method to the large database of Fortin-Gagnon et al.(2020). This measure reveals that the COVID-19 pandemic has been associated with a very sharp rise of macroeconomic uncertainty in Canada, confirming other results showing similar big increases in uncertainty in the United States and elsewhere. The paper then uses a structural VAR to compute the impacts on the Canadian economy of uncertainty shocks calibrated to match these recent increases. We show that such shocks lead to severe economic downturns, lower inflation and sizeable accommodating measures from monetary policy. Important distinctions emerge depending on whether the shock is interpreted as originating from US uncertainty –in which case the down-turn is deep but relatively short– or from specifically Canadian uncertainty, which leads to shallower but more protracted declines in economic activity.

Keywords/Mots-clés: COVID-19 Pandemic, Uncertainty, Forecasting, Factors Models, Vector Autoregressions

JEL Codes/Codes JEL: C53, C55, E32

* First version: September 2020. This version: December 18, 2020. We thank the Editor and an anonymous referee for valuable comments and suggestions. We also thank Hugo Couture for excellent research assistance and acknowledge financial support from the Chaire en macroéconomie et prévisions ESG UQAM. Any errors and omissions are our own.

[†] Université Laval and CIRANO

[‡] UQAM and CIRANO

[§] UQAM

1 Introduction

Many economic decisions represent bets on the future: when to make large purchases such as cars and housing, when to invest in new plants, equipment and infrastructure or whether to extend credit to entrepreneurs, households and corporations. These decisions require that economic agents forecast future conditions, who may postpone or abandon their plans when the outlook for the future becomes harder to assess. An extensive literature has examined the quantitative implications of this intuition, by measuring economic uncertainty and analyzing the macroeconomic implications of shocks to these measures.¹

The COVID-19 pandemic has undeniably increased the difficulty to assess the future, both because its consequences for public health are still developing and because of its possible long-term economic fallouts. As such, the pandemic likely embodies a very important increase in uncertainty and makes this literature more relevant than ever.

The present paper makes two contributions. First it constructs the first Canadian measure of macroeconomic uncertainty, by applying the [Jurado et al. \(2015\)](#) method to the large database of [Fortin-Gagnon et al. \(2020\)](#).² This measure provides an important historical perspective about Canadian macroeconomic uncertainty and confirms it has reached unprecedented levels since the onset of the pandemic. These dramatic increases concord with those obtained with data from other countries or using other methodologies to measure uncertainty ([Leduc and Liu, 2020a](#); [Baker et al., 2020](#); [Altig et al., 2020](#)).

Second, the paper uses vector autoregressions (VARs) to compute the macroeconomic consequences of uncertainty shocks similar in size to those recorded during the COVID-19

¹Important papers in this literature include those from [Jurado et al. \(2015\)](#), who measure uncertainty through the performance of a forecasting model applied to a large database; [Baker et al. \(2016\)](#), who use the frequency at which expressions similar to ‘economic policy uncertainty’ appear in media; [Bloom \(2009\)](#), who identifies uncertainty with measures of volatility on financial markets, or [Leduc and Liu \(2016\)](#) who employ answers to future-oriented questions in the *Michigan Survey*. See [Fernández-Villaverde and Guerrón-Quintana \(2020\)](#) for a survey of this literature.

²The uncertainty measures constructed using the methodology described in the present paper are regularly updated and available at <https://chairemacro.esg.uqam.ca/previsions-et-mesures-macroeconomiques/mesure-dincertitude/>.

pandemic. Considering the position of Canada as a small open economy tightly linked with its American neighbour, we analyze both the consequences of shocks to US uncertainty and to its Canadian counterpart, taking care to identify and control for the possible spillovers between these measures.

We show that such shocks lead to severe economic downturns, lower inflation and persistent accommodating measures from monetary policy. Important distinctions emerge, however, depending on whether the uncertainty shock is interpreted as originating from the US or from Canada. While in the former case, downturns caused by the shocks are deep but relatively short-lived, in the latter such declines in economic activity are more persistent and have been sharpened by the COVID-induced spikes in uncertainty. We show that these results are robust to a variety of specification issues and are unchanged under alternative assumptions about the ordering (identification) of the VARs or of the differencing strategy for the data.

Several recent papers analyze the COVID-induced spikes in uncertainty and assess their likely implications for the growth rate of output (Baker et al., 2020), unemployment and monetary policy (Leduc and Liu, 2020a), economic agents' expectations about the future (Dietrich et al., 2020) or the adoption of labour-saving technology (Leduc and Liu, 2020b), among several topics. These result add to the existing, pre-COVID literature establishing that increases in uncertainty lead to declines in economic activity and increases in unemployment (Bloom, 2009; Jurado et al., 2015; Caldara et al., 2016; Baker et al., 2016; Leduc and Liu, 2016; Carriero et al., 2018).

However, the great majority of research on uncertainty and its macroeconomic impacts has been conducted with US data and, when other countries do appear in this literature, the analysis usually pertains to the effect of US uncertainty on the foreign country (Colombo, 2013; Klössner and Sekkel, 2014; Kamber et al., 2016).³ The present paper

³An exception is Moore (2017), which examines the domestic impacts of Australian uncertainty.

therefore constitutes the first contribution that specifically documents the interrelated movements between Canadian uncertainty, its US counterpart, and Canadian economic activity. Considering the severity of the economic downturn caused by the pandemic and the difficult road ahead towards recovery, our results are timely and policy-relevant.

The remainder of this paper is structured as follows. Section 2 describes the [Jurado et al. \(2015\)](#) method to measure macroeconomic uncertainty. Section 3 presents our Canadian application of this method and then compares our measure to alternatives obtained using data from other countries or other methodologies. Section 4 presents our main findings about the likely macroeconomic impacts of the recent increases in uncertainty. Section 5 concludes.

2 Measuring Macroeconomic Uncertainty

A simple intuition underlies [Jurado et al. \(2015\)](#) (JLN hereafter)’s measure of macroeconomic uncertainty : the economic future is more difficult to predict when uncertainty is high; conversely, uncertainty is higher when predicting future economic outcomes becomes relatively more difficult.

JLN operationalize this intuition by measuring uncertainty as the performance of a macroeconomic forecasting model. To this end, they apply a factor-based approach to a large database containing dozens of time series. They compute forecasts, forecast errors, as well as the conditional volatility of these forecast errors, for each individual time series in the database and for every time period. Uncertainty at a given point of time is then defined as the weighted sum of all individual conditional volatilities in forecasting errors.

Specifically, let y_t^j be the value at time t of the j th time series of the database and $\hat{y}_{t+h}^j|t$ the forecast of y_{t+h}^j obtained using information known as of period t , with h the forecasting horizon. The conditional volatility in the forecast error at horizon h for time

series j at time t is

$$U_t^j(h) = \sqrt{E \left[\left(y_{t+h}^j - \widehat{y}_{t+h|t}^j \right)^2 \mid t \right]}, \quad (1)$$

where $E \left[y_{t+h}^j - \widehat{y}_{t+h|t}^j \right]^2$ represents the variance in the forecasting error, conditional on information known at time t . JLN's aggregate measure of macroeconomic uncertainty is then defined as the sum of these forecasting errors:

$$U_t(h) = \sum_j^N U_t^j(h), \quad (2)$$

The general measure (2) is flexible and can be specialized in a variety of ways. Notably, the summation can be specific to geography, using data series pertaining to a specific Canadian province, or can be conditional on sectoral criteria, retaining for example only nominal data on prices and interest rates. Our results below explore both of these avenues.⁴

This paper develops a Canadian measure of macroeconomic uncertainty by applying the JLN method to the database constructed and maintained by [Fortin-Gagnon et al. \(2020\)](#). This database contains more than 300 time series related to the Canadian economy, is available for both quarterly and monthly frequency and is updated regularly. The data begin in 1981, include both national and regional information, and cover various sectors such as production, the labour market, prices and interest rates, housing market activity and trade, among others. As is the norm for large-scale databases, individual time series are treated for seasonality, differenced when relevant and normalized. Note that the quarterly version of the database contains series drawn from Canada's National Accounts, like GDP and its various components, and thus offers a richer information set than the monthly version. We report uncertainty measures based on both quarterly and monthly data below, but the impact analysis in Section 5 is based on the quarterly version because

⁴JLN also consider the possibility that individual forecasting errors be weighted differently in the construction of the aggregate measure, so that (2) would become $U_t(h) = \sum_j^N \omega_j U_t^j(h)$.

of this informational advantage.

As indicated above in (1)-(2), measuring macroeconomic uncertainty requires that a general forecasting framework for each individual time series be established. To this end, consider the following factor model for forecasting future values of series y_j :

$$\mathbf{X}_t = \mathbf{\Lambda}^F \mathbf{F}_t + \mathbf{u}_t; \quad (3)$$

$$\mathbf{X}_t^2 = \mathbf{\Lambda}^W \mathbf{W}_t + \mathbf{v}_t; \quad (4)$$

$$y_{j,t+h} = \rho(\mathbf{L}) y_{j,t} + \beta(\mathbf{L}) \mathbf{F}_t + \gamma(L) \mathbf{F}_{1,t}^2 + \delta(\mathbf{L}) \mathbf{W}_t + e_{j,t+h}. \quad (5)$$

The expressions (3) and (4) first describe how the information contained in the many hundred time series of the database are efficiently summarized. First, (3) describes how the vector \mathbf{X}_t , which contains all the database's variables, is expressed as a linear function of a small number of common factors \mathbf{F}_t and idiosyncratic components \mathbf{u}_t .⁵ Since the linear form of (3) limits its ability to account for possible non-linear links between the variables in \mathbf{X}_t , (4) is then added to the model to identify a second set of factors \mathbf{W}_t related to the square of the variables in \mathbf{X}_t . Overall, (3) and (4) deliver an efficient synthesis of the information contained in more than three hundred time series through the vectors \mathbf{F}_t and \mathbf{W}_t and the factor loadings $\mathbf{\Lambda}^F$ and $\mathbf{\Lambda}^W$.⁶

Equation (5) then shows how forecasts for the future values of each individual time series j are obtained on the basis of information known at time t , represented by lagged values of the factors, of the variable itself, and of the square of the first element of \mathbf{F}_t .⁷

⁵We use the Bai and Ng (2002) test to determine the number of factors required to adequately summarize the variability in \mathbf{X}_t .

⁶The relevance of the non-linear terms in (4) is an empirical question. While Gorodnichenko and Ng (2017) find some evidence on such volatility factors in a similar setup –particularly for housing sector variables– our aggregate uncertainty measure appears less affected by them: abstracting from (4) leads to a measure that is very highly correlated (around 0.98) with our benchmark.

⁷Following Jurado et al. (2015), we use four lags of y_t^j and two each for \mathbf{F}_t , $\mathbf{F}_{1,t}^2$ and \mathbf{W}_t . A robustness check conducted by allowing 4 lags of each factor in (5) yields uncertainty measures highly correlated (above the 0.99 mark) with our benchmark. One could alternatively use Lasso techniques to identify

This type of factor-based forecasting paradigm has become a standard in the literature (Stock and Watson, 2006).

JLN argue that it is important to distinguish between periods where time series become more volatile from episodes where they become intrinsically difficult to forecast. To that end, the variance of the residuals $e_{j,t+h}$ is assumed to be affected by stochastic volatility, so that $e_{j,t+h}$ is governed by the process $e_{j,t+h} = \sigma_{j,t}^y \epsilon_{j,t}^y$ with $\epsilon_{j,t}^y \stackrel{iid}{\sim} \mathcal{N}(0, 1)$ and

$$\log \sigma_{j,t}^y = \alpha_j^y + \beta_j^y \log \sigma_{j,t-1}^y + \tau_j^y \eta_{j,t}, \quad \eta_{j,t} \stackrel{iid}{\sim} \mathcal{N}(0, 1), \quad (6)$$

where $\beta_j^y > 0$ indicates that episodes of heightened volatility are persistent. In addition, autoregressive processes are specified and estimated for the factors \mathbf{F}_t and \mathbf{W}_t themselves, with the residuals for these processes also affected by conditional volatility similar to (6).

Finally, note that the predictive analysis (3)-(6) underlying our uncertainty measure is conducted as in-sample predictions (fitting), rather than by a recursive out-of-sample approach. This follows JLN, who compute uncertainty measures using both approaches and show they are highly correlated. This is probably due to the good predictive performance of the factor model, which has been shown to be robust to temporal structural breaks (Stock and Watson, 2002) and to efficiently deal with overfitting (Goulet Coulombe et al., 2019).⁸

2.1 Adjustment of the measure to the COVID-19 Episode

The COVID-19 episode has created serious challenges to the estimation of a factor and predictive models like (3)-(6): some variables have registered extreme observations in

how many and which lags to include in (5), but we consider the approach with a fixed and parsimonious specification preferable, as penalized versions of (5) appear not to improve the predictive power of factor models such as (3)-(5) (Goulet Coulombe et al., 2019).

⁸Rogers and Xu (2019) show that various uncertainty measures, including JLN, have no forecasting power when assessed in *real time*, although they have in-sample explanatory power for several macroeconomic variables. Hence, their lack of predictive power may be related to real-time considerations instead of the out-of-sample versus in-sample nature of the measures.

March and April 2020, to the point where they could be modelled as draws from a different distribution. This situation naturally affects the measurement of macroeconomic uncertainty. Although the COVID-19 shock cannot be considered predictable, even at the one-month-ahead horizon, this regime switch ought to be taken into account going forward, when forecasting with April data in hand. Indeed, the uncertainty measure, as stated in (1), assumes that any forecastable component is removed before computing the conditional volatility.

In that context, [Jurado et al. \(2020\)](#) propose to model the regime switch attributable to COVID-19 as a mean-shift adjustment on every series y_j . We follow their approach and assume that the main *unpredictable* COVID-19 shock affected April 2020 data but not subsequent ones.⁹ Hence, assuming that the shock happens in April means that we were not able to predict the extreme magnitude of the subsequent downturn. In the case of our quarterly uncertainty measure, we assume that the main unpredictable COVID-19 shock happened in the second quarter of 2020. Relatedly, the descriptive analysis in the next section singles out the increases in uncertainty that occurred in March 2020 (monthly data) or 2020Q1 (quarterly) as the onset of the pandemic’s impact on uncertainty.

Starting in April 2020 (monthly measure) and 2020Q2 (the quarterly one) and rolling forward, our strategy is to compute the difference between the observed value for a series $y_{j,t}$ and its predicted value on the basis of one month (quarter)-old information. This difference is an estimate of the regime shift in the mean of each series and it is used to adjust our uncertainty measures going forward.¹⁰ Technical details are described in [Appendix D](#).

⁹A closer look at March and April data shows that several of the extreme values were recorded in April. For instance, the aggregate unemployment rate went from 5.6% to 7.8% in March, but then increased to 13% in April. In addition, the Labour Force Survey is conducted in the third week of a month so it accidentally captured a part of the confinement.

¹⁰From the modeling point of view, this is a second-best solution. A fully-specified regime-switching model would be a better choice, but the extreme values occur at the very end of the sample and in real-time, which makes this optimal procedure infeasible.

The natural question is when to stop the adjustment, if the COVID-19 shock has no permanent effect on time series. We compared the monthly uncertainty measures obtained with and without this mean-shift adjustment for the sample ending in August 2020. The correlation coefficients between the two measures are around 0.85. Hence, 4 months after the unpredictable shock, mean-shift adjustment starts losing its effect, suggesting that the shock is probably transitory.

Overall, this adjustment allows our measure to continue to be updated, while taking into account the recent large volatility in some variables of the database and, at the same time, retaining the spirit of the JLN’s method as an aggregation of the unpredictable components of these variables’ evolution.

3 A Canadian Measure of Macroeconomic Uncertainty

Figure 1 reports the results of applying JLN’s method to the quarterly version of [Fortin-Gagnon et al. \(2020\)](#)’s database. It thus depicts our Canadian macroeconomic uncertainty measure $U_t^{CAN}(h)$ for the one-quarter, two-quarter, and four-quarter-ahead horizons over the period from 1982Q1 to 2020Q2, with shaded areas representing recessions as defined by the *C.D. Howe* Institute ([Cross and Bergevin, 2012](#)).

Three general features of uncertainty emerge from the figure. First, uncertainty is most often higher for longer forecasting horizons, reflecting the fact that forecasting far away in the future may generally be harder. Second, and relatedly, uncertainty is less volatile as forecasting horizons lengthen and forecasts converge to their unconditional values: this is particularly noticeable for the measure based on four-quarters-ahead forecasts. Third, the various measures are nonetheless very correlated with each other (correlation coefficients between them are all higher than 0.98) and negatively correlated to the business cycle: all three measures increase simultaneously during the early-1990s and 2008 recessions, as well as during episodes of milder turbulences such as the 2001 crash of the technology

bubble and after the negative oil price shock in 2015. In addition, all three measures are significantly and negatively correlated with HP-detrended GDP.

Figure 1: Canadian Macroeconomic Uncertainty

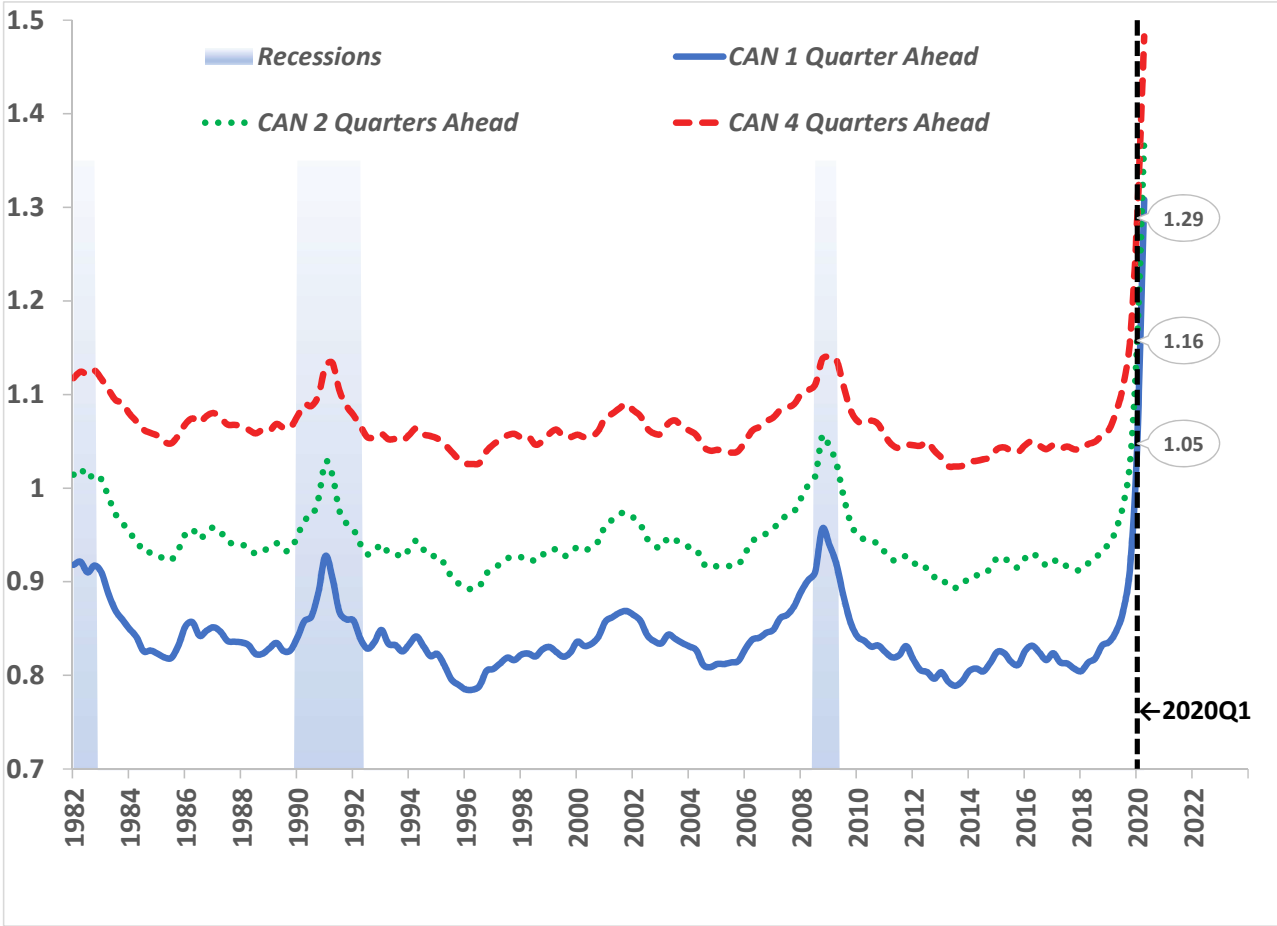


Figure 1 also reveals the impact of the COVID-19 pandemic. All three uncertainty measures report very sharp increases in 2020: figures for 2020Q1, the onset of the pandemic in our interpretation of the data, indicate that they rise to 1.05, 1.16, and 1.29, respectively, increases equivalent to between 4 and 5 standard deviations away from their respective long time averages. The figure also shows that 2020Q2 uncertainty levels remain unprecedently high. Our measure therefore reveals, as expected, that COVID-19 pandemic has coincided

with extremely sharp increases in Canadian macroeconomic uncertainty.

As mentioned above, uncertainty measures can be conditioned on geographic or sectoral aspects of the data underlying the forecasting model. In that context, Figure 2 compares the evolution of uncertainty obtained using provincial data only (Quebec, Ontario and Alberta) with the overall Canadian measure discussed so far, for the period 2000-2020.¹¹

Figure 2: Canadian Macroeconomic Uncertainty: Provincial Measures

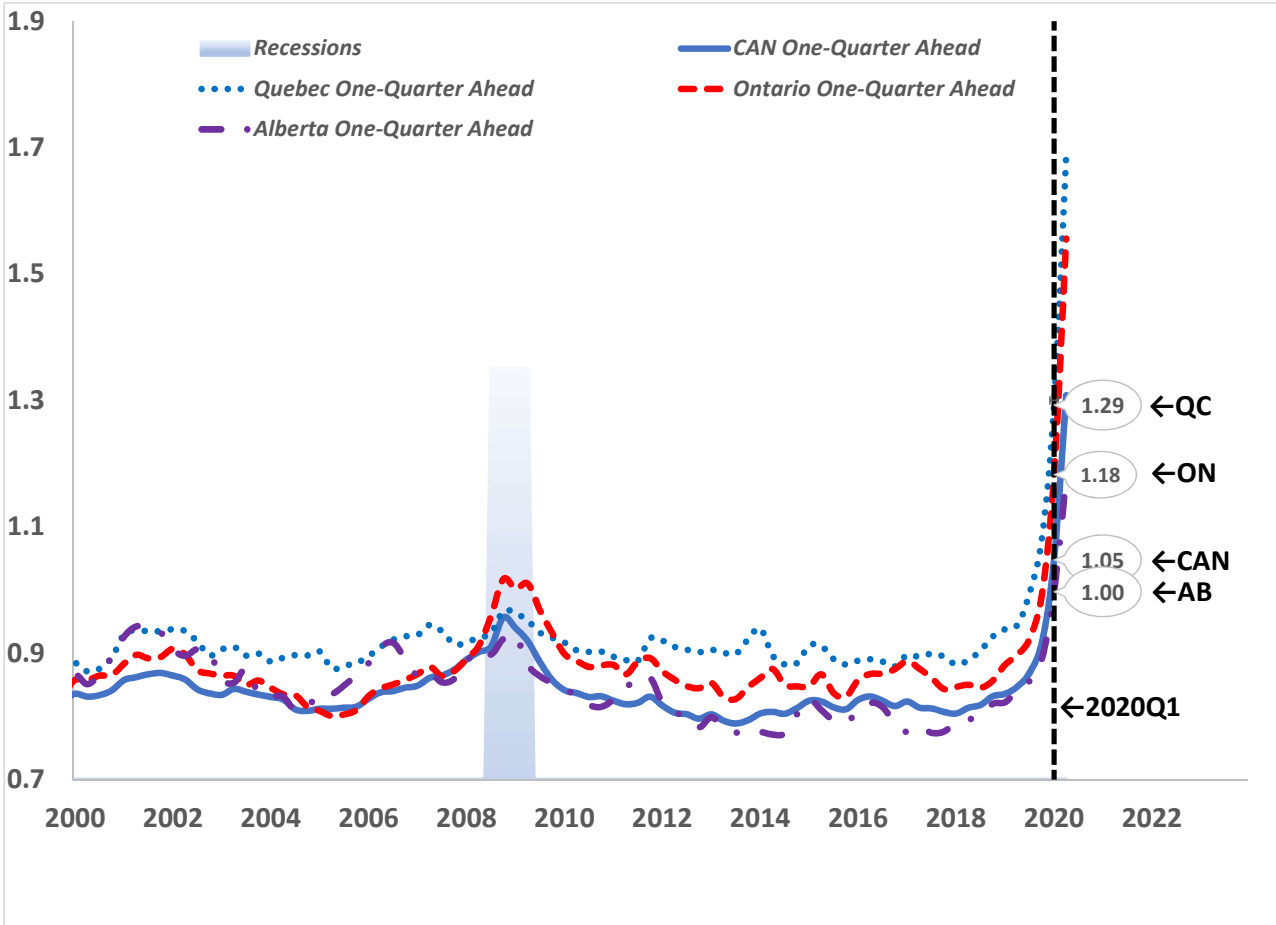
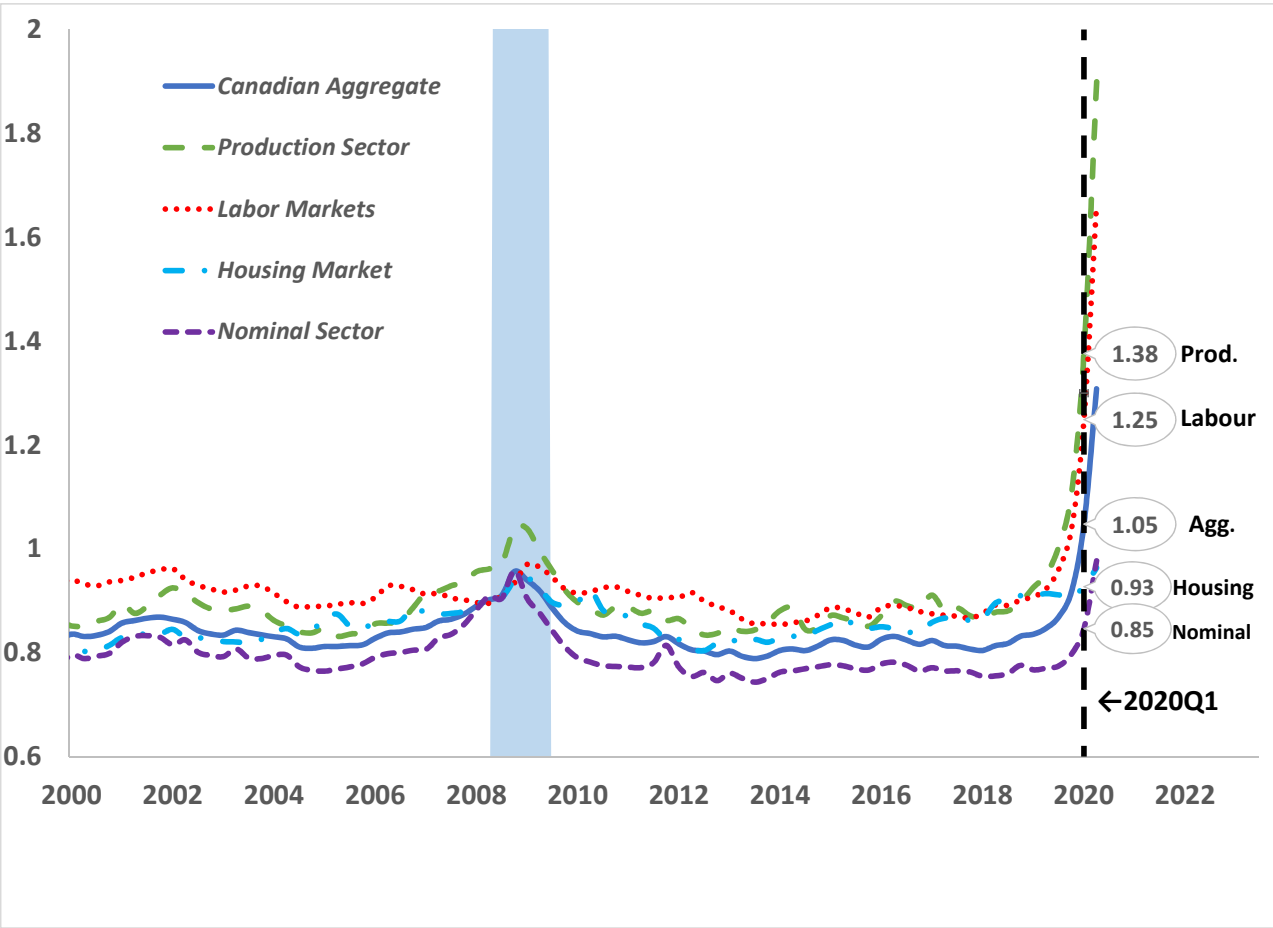


Figure 2 reveals that the various provincial measures examined are significantly cor-

¹¹Note that provincial data for GDP and its components are not available for Alberta, which makes the data coverage less comprehensive for this province. Uncertainty measures for other provinces may also be computed, although the number of time series specific to some provinces is limited.

related to overall Canadian uncertainty: correlation coefficients are above 0.9 for Ontario and Quebec but slightly lower (0.83) for Alberta. Interesting distinctions appear nonetheless: measures for Quebec and Alberta appear to have been slightly less affected by the 2008-2009 period than Ontario, for example. More importantly, all measures report unprecedented increases following the onset of COVID-19, although the Quebec and Ontario-specific increases (1.29 and 1.18 for 2020Q1, respectively) are both higher than the Canadian average (1.05) while the one for Alberta is slightly lower (1.0).

Figure 3: Canadian Macroeconomic Uncertainty: Sectoral Measures



Next, Figure 3 shows how conditioning on the broad sector of economic activity can

uncover different facets of uncertainty and provide clues about the likely sources for its fluctuations. To do so, the figure again depicts the evolution of the overall measure for Canada alongside three alternatives: the first, labelled *Production Sector*, is constructed from (1)-(2) using data series related to (real) GDP and its components, such as capital formation, exports and imports or manufacturing orders. The second, noted *Labor Market*, arises from Labour Force Survey (LFS) data and other labour market information. Finally, the line labelled *Nominal Sector* relates to data on prices, interest rates, exchange rates and credit while the line denoted *Housing* refers to information from housing markets. Although all series are once highly correlated, some important contrasts emerge in the wake of COVID-19: the rise in *nominal* uncertainty has been relatively subdued, as was that of uncertainty related to the housing sector; by contrast the *Production Sector* (1.38 in 2020Q1) and *Labor Market* measures (1.25) have increased significantly more than the aggregate, most probably reflecting the production shutdowns that followed federal and provincial governments’ directives.

3.1 Comparison with Alternative Measures

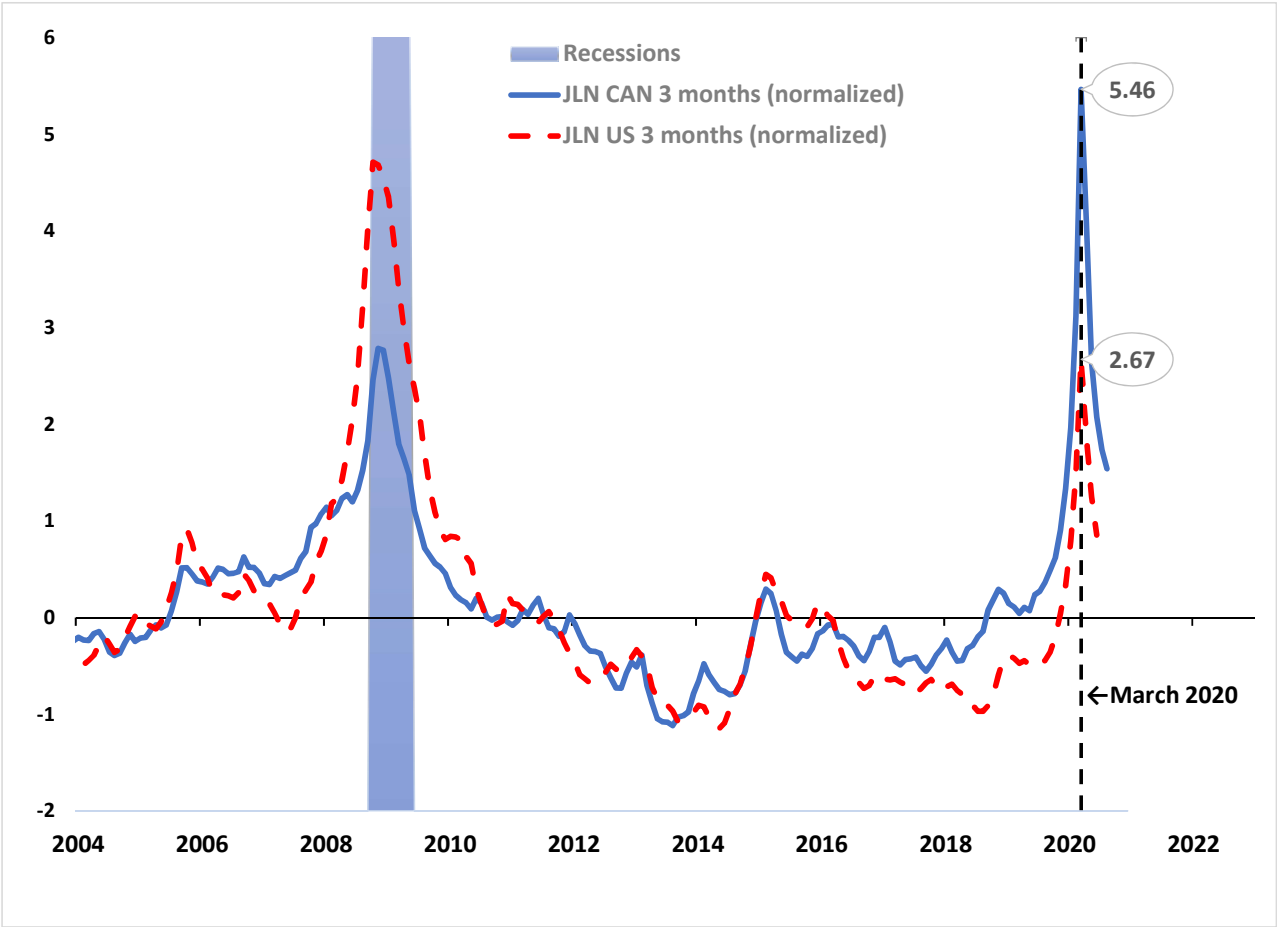
Jurado et al. (2015) apply their method to U.S. data and their measure is updated regularly, enabling comparisons between their results and ours. Since JLN’s measure is based on monthly-frequency data, the comparison is with our *monthly-frequency* measure of Canadian uncertainty, which is obtained by repeating the forecasting exercise (3)-(6) using the monthly-frequency version of Fortin-Gagnon et al. (2020). Figure 4 reports the results, displaying the (normalized) *three-months-ahead* measure for both countries.¹²

The figure reports that both measures are highly correlated (the correlation coefficient is 0.82) but that the rise in US uncertainty during the 2008-2009 financial crisis was

¹²As indicated above, the impact analysis of Section 5 employs the quarterly version of our macroeconomic uncertainty measure because of its higher informational content. It is interesting to compute and analyze monthly-frequency versions of uncertainty measures, which can respond more rapidly to unfolding events.

sharper than the one in Canada. The most striking feature of Figure 4 however is the most recent rise in measured uncertainty: for both Canada and the US, these increases are very significant, with the rise in the Canadian measure (5.46 in March 2020) even more significant than its American counterpart. Section 5 below calibrates uncertainty shocks to match these very significant increases and provide evidence of the likely macroeconomic impacts of such high levels of uncertainty.

Figure 4: Macroeconomic Uncertainty: Canada versus the US



As discussed above, two popular alternatives to the macroeconomic uncertainty constructed by JLN are the economic policy uncertainty indexes (EPU), proposed originally

by Baker et al. (2016), and measures of volatility in financial markets, as analyzed in Bloom (2009). To provide a comparative view of the similarities and dissimilarities between alternative measures, Figure 5 depicts the evolution of our Canadian measure of macroeconomic uncertainty (at the three-months-ahead horizon) and that of these two measures (data have once again been normalized to facilitate the comparison).

Figure 5: Canadian Uncertainty: Alternative Measures

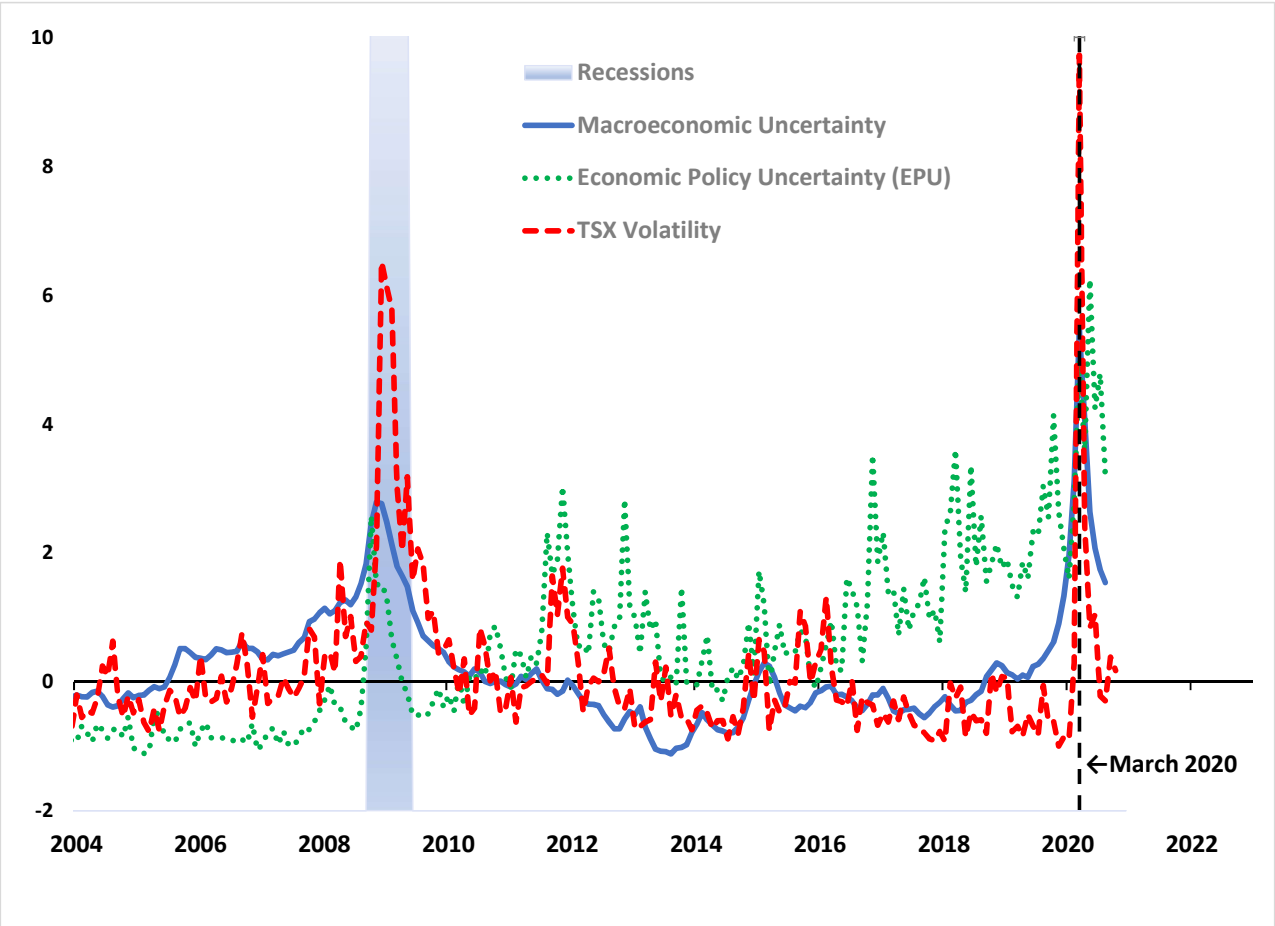


Figure 5 reveals distinct patterns in the evolution of our measure of macroeconomic uncertainty and the two alternatives. Although all three report exacerbated levels during the 2008-2009 financial crisis and the recent COVID-19 episode, both the economic policy

uncertainty (EPU) and financial volatility indexes are significantly more volatile and less serially correlated than our measure. This feature, also discussed in [Jurado et al. \(2015\)](#), gives our macroeconomic uncertainty measure a more gradual evolution, perhaps more related to business cycles and markedly distinct from the more volatile nature of the alternatives. Further, correlations between these other measures and ours, while still positive, is significantly smaller (0.30 and 0.56, respectively) than those between the Canadian and US macroeconomic uncertainty measures discussed above. As such, one may conclude that these three strategies capture different facets of the phenomenon.

Overall therefore, our measure of Canadian macroeconomic uncertainty, obtained by applying JLN’s method to [Fortin-Gagnon et al. \(2020\)](#)’s database, produces intuitive and rich information about uncertainty in Canada and shows how it affects different geographical or sectoral facets of the economy. In addition, it reveals the extent to which the COVID-19 pandemic has coincided with unprecedented rises in uncertainty. Finally, its historical evolution is shown to be highly correlated to JLN’s own US-specific measure, but less so to other measures such as those obtained with textual research or financial markets’ information, which tend to be highly volatile. The next section computes the impacts of macroeconomic uncertainty shocks on the Canadian economy and applies these results to the context of the COVID-19 pandemic.

4 Macroeconomic Impacts of Uncertainty Shocks

As discussed above, a negative relationship between macroeconomic uncertainty and the business cycle is apparent, both from [Figure 1](#) and from the negative (-0.3) correlation between uncertainty and (HP-detrended) GDP. This section discusses how this negative correlation may arise from a causal link whereby shocks to uncertainty lead to decreases in activity and then computes the impacts of the large COVID-induced uncertainty shocks on the Canadian economy.

Bloom (2009) describes how, in a context of heightened uncertainty, firms are likely to postpone or cancel major projects and scale back hiring. In addition, households and consumers might themselves reduce their planned purchases of durables or housing. Finally, banks may choose to tighten credit availability or its terms. At the economy-wide level, Leduc and Liu (2016) argue that rises in uncertainty constitute decreases in aggregate demand and lead to reduced economic activity, higher unemployment and lower inflation. We now verify that this intuition obtains when analyzing our measure of Canadian macroeconomic uncertainty and the Canadian business cycle.

Our analysis employs structural Vector Autoregressions (VARs) to identify and assess the impacts of uncertainty shocks. Such methods are used by much of the literature on uncertainty as well as numerous papers examining the impact of monetary policy shocks (Christiano et al., 2005), technology shocks (Gali, 1999) or fiscal shocks (Blanchard and Perotti, 2002), among many others.

In that context, consider the following six-variable VAR

$$\mathbf{Y}_t = \mathbf{A}_1 \mathbf{Y}_{t-1} + \mathbf{A}_2 \mathbf{Y}_{t-2} + \cdots + \mathbf{A}_p \mathbf{Y}_{t-p} + \epsilon_t, \quad (7)$$

where \mathbf{Y}_t contains four key Canadian macroeconomic indicators (GDP, investment, inflation and the term spread), in addition to our Canadian uncertainty measure and its American counterpart as computed by JLN. The term spread is included to account for the reaction of monetary policy to economic developments: a policy of loosening rates in the wake of an adverse shock –likely to reduce short-term rates more than long-term ones– would thus show up as an increase in the term spread.

The data span the period of 1982Q1 - 2020Q1.¹³ Nonstationary variables like GDP,

¹³We follow Lenza and Primiceri (2020) and abstract from 2020Q2 data, which contains observations for variables like investment and GDP that are outliers relative to their historical averages. These authors argue that including such outliers in a VAR calls into question the validity of parameter estimates and the appropriateness of computed impulse responses. Note that this is coherent with our choice of interpreting the spike in uncertainty recorded in 2020Q1 (March 2020 for monthly data) as the COVID-19 shock.

investment and the GDP deflator are transformed in growth rates by taking the first difference of logs. The term spread is the difference between the 10-year government bonds and the 3-month Treasury bond (A full description of data sources and transformations used appears in Table 2 of Appendix A). The VAR order is set to 3, consistent with the Bayesian information criterion.

We use a Cholesky decomposition to identify shocks and the ordering of variables is therefore important. For our baseline results, \mathbf{Y}_t is ordered as follows: US uncertainty, Canadian GDP, investment, inflation and term spread and, finally, the quarterly measure of Canadian macroeconomic uncertainty discussed above. Reflecting the small-open economy nature of Canada, US uncertainty is thus ordered first so that American macroeconomic developments immediately affect Canadian activity, as well as Canadian uncertainty, while the reverse is not true.

The ordering of Canadian uncertainty is potentially more controversial. One can first interpret uncertainty as an endogenous variable, which reacts to macroeconomic events and serves as a transmission mechanism for shocks. This interpretation is the one favoured by Ludvigson et al. (forthcoming) and it suggests that Canadian uncertainty be placed last in \mathbf{Y}_t . Our baseline results reflect that ordering and the shocks to Canadian uncertainty analyzed below therefore do not affect any variable contemporaneously. Placing Canadian uncertainty last in \mathbf{Y}_t is also a conservative strategy, limiting the extent to which fluctuations are attributed to uncertainty shocks.

An alternative vision of uncertainty stems from work by Carriero et al. (2018) and assigns it a more structural and exogenous interpretation, in the sense that innovations to uncertainty are assumed to have contemporaneous impacts on the macroeconomy. This suggests placing Canadian uncertainty second in \mathbf{Y}_t , just after its US counterpart. We verify below that our results are robust to this assumption.¹⁴

¹⁴The question of how best to interpret uncertainty in a VAR does not apply to the US measure for our work : whether this variable is endogenous or exogenous to the US economy, it is likely to be mostly

4.1 Results

The COVID-19 pandemic constitutes a worldwide event and a first reasonable assumption is that much of the observed increases in both US and Canadian uncertainty are reflections of this global shock. Our first set of results therefore analyze the impact of a shock to US uncertainty, as a proxy for the global nature of the event. However, one can also argue that the pandemic has affected Canada in specific ways, notably because of the country’s reliance on commodity exports or its small-open economy stature. We therefore also analyze the consequences of a Canadian-specific shock to uncertainty.

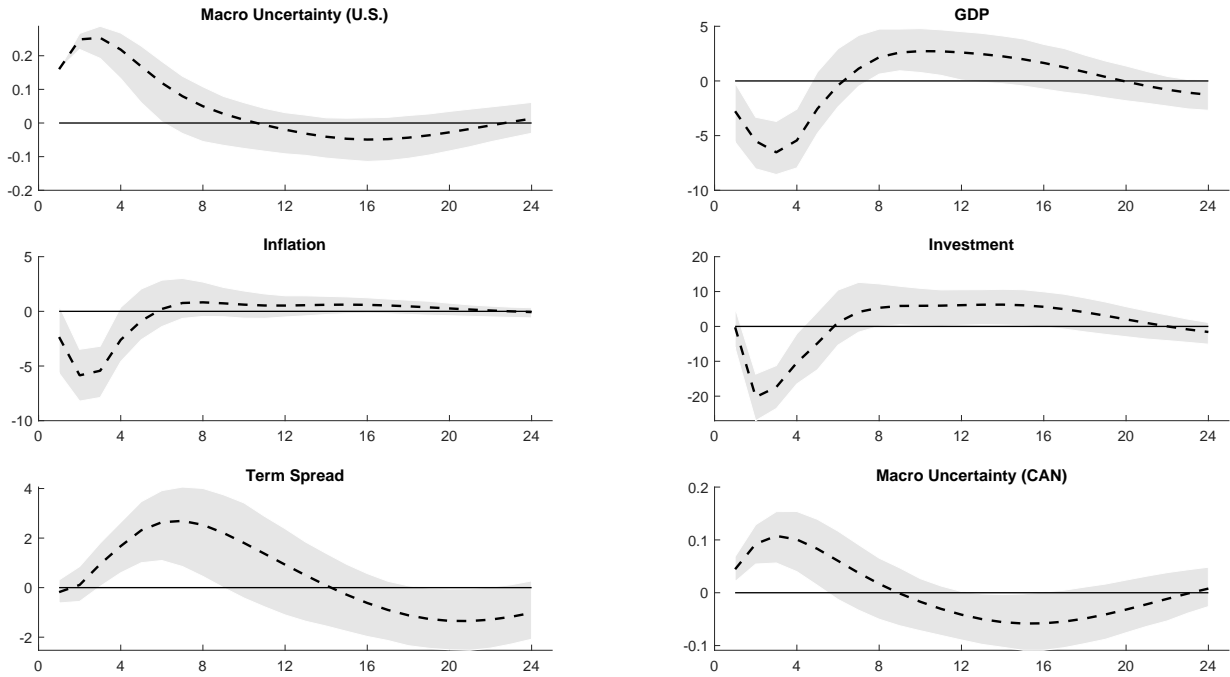
Figure 6 and 7 report our baseline results. Figure 6 depicts the macroeconomic impacts of a shock to US uncertainty whose size has been calibrated to the observed rise observed in 2020Q1, the onset of the COVID shock in our interpretation. Figure 7 then reports impulse response functions following a shock to Canadian uncertainty, calibrated in a similar manner. The shaded areas in both figures represent 90% confidence intervals for the responses, obtained via bootstrapping with 1000 replications.

Examine Figure 6 first. As indicated above, it reports the macroeconomic impacts of a positive shock to US uncertainty under the assumption that this shock can immediately affect all other variables, including Canadian uncertainty. Any contemporaneous correlation between Canadian uncertainty and the macroeconomy in the figure thus arises from their simultaneous responses to the US shock.

Figure 6 shows that a spike in US uncertainty of the order of magnitude observed during 2020Q1 has important negative impacts on the Canadian economy. On the real side, investment and GDP fall by very significant margins, with GDP’s decline reaching -7% in the third quarter after the shock, while investment declines by almost 20%, although it bottoms out faster. On the nominal side, inflation decreases by over 5% while the term spread increases gradually and remains elevated for a protracted period, indicating

exogenous relative to the Canadian economy, which justifies placing it first in \mathbf{Y}_t .

Figure 6: Macroeconomic Impacts of a Shock to U.S. Uncertainty



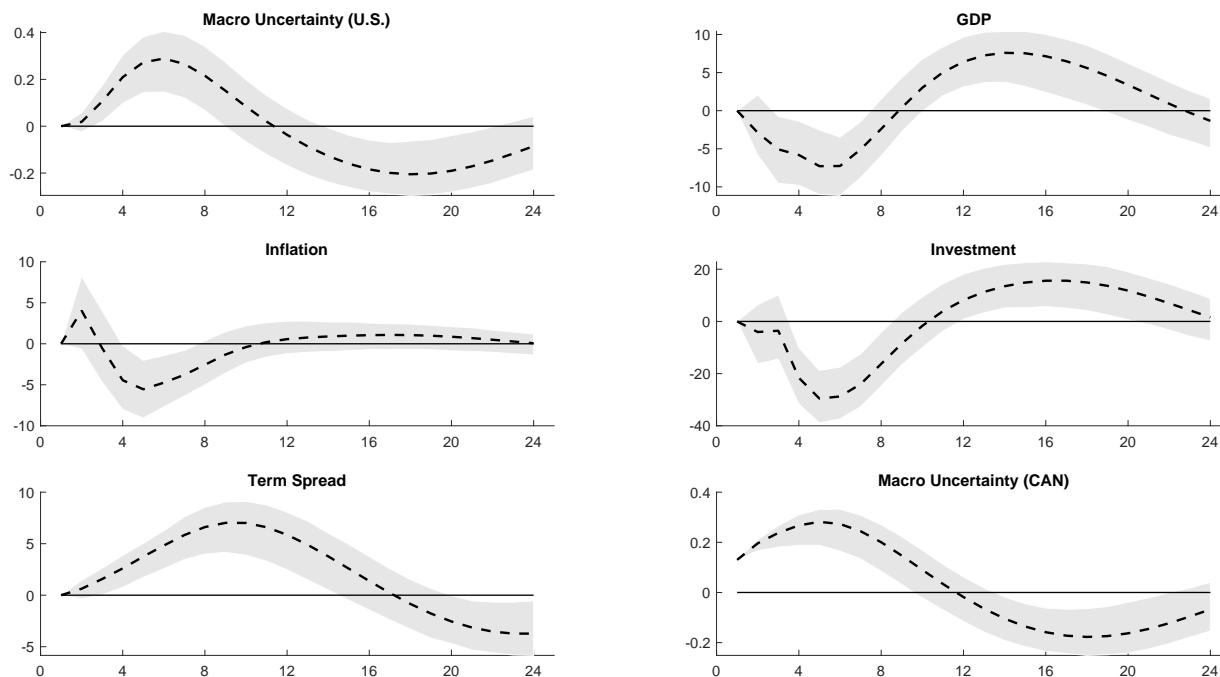
NOTES: Impacts of a shock to US macro uncertainty in a VAR where it is ordered first. Shaded areas represent 90% confidence bands.

persistent loosening interventions by monetary authorities. Finally, the figure shows that spillovers from US to Canadian uncertainty are sizeable. Overall, Figure 6 suggests that the rise in US economic uncertainty coinciding with the 2020Q1 onset of the COVID-19 pandemic may have been one key source of the severe slowdown experienced by the Canadian economy in 2020; that these negative effects have been attenuated by the response of monetary authorities; and that the slowdown is likely to be moderately short-lived.

Next, Figure 7 reports the macroeconomic impacts of a positive shock to Canadian uncertainty. In accordance with our identifying assumptions, the responses depicted in the figure arise from a specifically-Canadian source, after controlling for contemporaneous spillovers from US uncertainty. In addition, the ordering of Canadian uncertainty as the last variable in the vector \mathbf{Y}_t implies that this shock has no immediate effects on the

VAR's macroeconomic variables.

Figure 7: **Macroeconomic Impacts of a Shock to Canadian Uncertainty**



NOTES: Impacts of a shock to Canadian macro uncertainty in a VAR where it is ordered last. Shaded areas represent 90% confidence bands.

Figure 7 shows that the impacts of the Canadian uncertainty shock are qualitatively similar to those described above: both investment and GDP decline sizeably, as does inflation. In addition, monetary accommodation, as represented by the increases in the term spread, is aggressive and long-lived. However, important quantitative differences emerge: economic responses to the shock are slightly above those in Figure 6 for some variables (notably investment) and all responses are more persistent: investment and GDP bottom out between 5 and 6 quarters after the shock and monetary accommodation persists for over two years. The more persistent nature of the impact from the Canadian-specific shock could originate because the US shock decreases demand for specific commodities that Canada export, while the Canadian shock to uncertainty affects the general economy

Table 1: Variance Decomposition

Variables	Shock to US uncertainty					Shock to Canadian uncertainty				
	h=1	h=4	h=8	h=16	h=24	h=1	h=4	h=8	h=16	h=24
US Uncert.	100.00	85.48	59.36	46.94	41.11	0.00	12.89	23.54	25.05	30.83
GDP	3.71	27.27	24.95	25.18	23.90	0.00	8.25	11.94	23.24	24.69
Inflation	2.11	19.93	18.91	19.29	19.32	0.00	5.02	7.98	8.23	8.44
Investment	0.00	26.58	21.61	23.64	22.80	0.00	11.76	21.71	24.39	26.74
Term Spread	0.28	7.45	22.12	17.86	19.12	0.00	10.30	32.69	43.67	43.70
CAN Uncert.	26.66	34.64	22.08	20.41	18.80	67.10	60.74	63.05	53.39	56.22

NOTES: This table presents the variance decomposition (in %) of the series included in the VAR, following shocks to US and Canadian macroeconomic uncertainty.

more, notably the production of non-traded goods or services, industries that react more durably to shocks.

The visual impression gained from Figures 6 and 7 about the relative impacts of uncertainty shocks on the Canadian macroeconomy is confirmed by examining Table 1. This table reports the results of a variance decomposition exercise (from horizons $h = 1$ quarter-ahead to $h = 24$ quarters-ahead) outlining how much of the volatility observed in our four macroeconomic aggregates and two uncertainty measures is attributable to shocks in US and Canadian uncertainty. The table shows that US uncertainty shocks explain between 20 and 27% of GDP and investment's volatility at relatively short horizons (4 quarters ahead) and that these fractions do not vary considerably as the horizons examined lengthen. By contrast, the shock to Canadian uncertainty explains a lower fraction of the aggregates' volatility at short term horizons: just over 8% for GDP at the four-quarters-ahead mark (relative to 27% for the US shock) and around 12% for Investment (27% for the US shock). However, the importance of the Canadian shock increases as the horizon rises and it becomes as important a source of volatility as the US shock.

In short, the effects of US and Canadian-specific uncertainty shocks on the Canadian economic activity are unambiguous, quantitatively significant, and in line with observed declines in GDP. During the first three quarters of 2020, Canadian real GDP has fallen by

4.4% and its level is predicted to remain between -7.1 and -5.8% under its pre-COVID levels by the end of the year, according to IMF and Consensus Forecasts (Feroni et al., 2020). Hence, and in accordance with related work by Baker et al. (2020), the COVID-induced spike in uncertainty explains a sizeable part of the recent declines in real activity and suggest that further weakness in the quarters ahead.

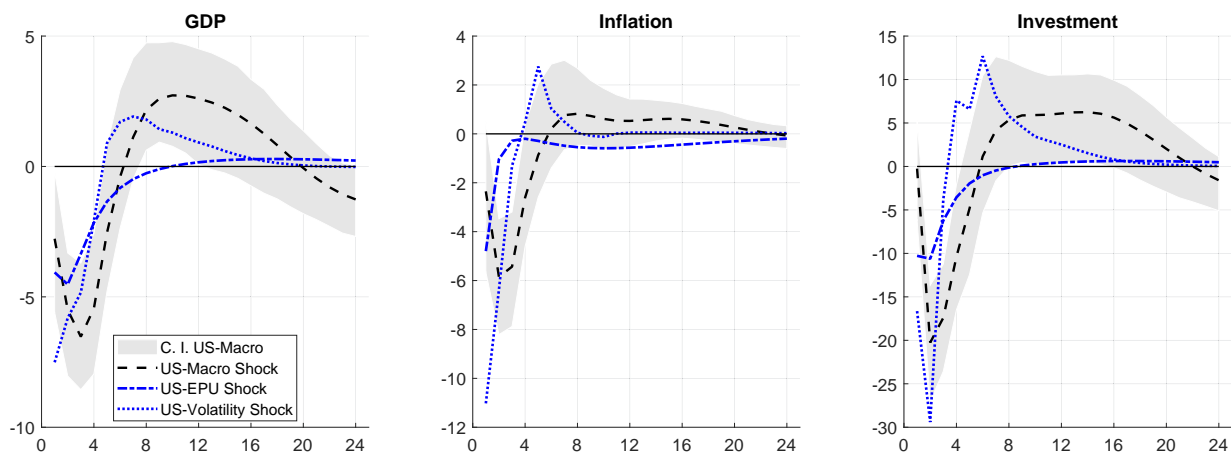
The sensitivity of our results to the COVID-19 episode is an important issue. To assess its importance, we have repeated our VAR estimation with data ending in 2019Q4 and re-examined the quantitative impact of uncertainty shocks similar in size to the ones examined above. Results are presented in Appendix B. First, Figure 10 shows that the impulse responses following a shock to US uncertainty are largely similar to those reported in Figure 6 above: notably, GDP and Investment experience sizeable declines following the US shock and these slowdowns are relatively short-lived. By contrast, Figure 11 shows that our view of the macroeconomic impacts of a Canadian shock to uncertainty has been affected by the COVID pandemic. In Figure 11 (pre-COVID), the amplitude of the downturn created by such a shock is less significant, although its effects continue to be more persistent than those of the US shock. In addition, a variance decomposition exercise similar to the one analysed above (Table 3) now signals that Canadian uncertainty shocks are a smaller source of macroeconomic fluctuations. Overall, results in Appendix B suggest that the COVID-19 is a very large disturbance that has sharpened our evaluation of the macroeconomic consequences of Canadian uncertainty shocks.

Finally, one additional aspect of the comparison between Figure 7 and 11 accords well with the view that including post-COVID data reinforces the impacts of uncertainty shocks. Figure 7, which takes into account 2020Q1 (post pandemic) data, reports that shocks to Canadian uncertainty have statistically significant and persistent impacts on their US counterpart, while Figure 11 doesn't. This suggests that the COVID shock had a truly global impact on uncertainty which affected both the Canadian and US measures.

4.2 The Macroeconomic Impact of Alternative Measures of Uncertainty

Recall that two alternative measures of uncertainty, one derived from textual research about economic policy uncertainty (EPU) and the other related to financial markets' volatility, have been proposed and were depicted above in Figure 5. These measures can be introduced as the chosen proxies for uncertainty in alternative versions of our VAR (7). In that context, Figures 8 and 9 report the responses of the three main macro aggregates to US (Figure 8) and Canadian (Figure 9) uncertainty shocks for the three measures of uncertainty.

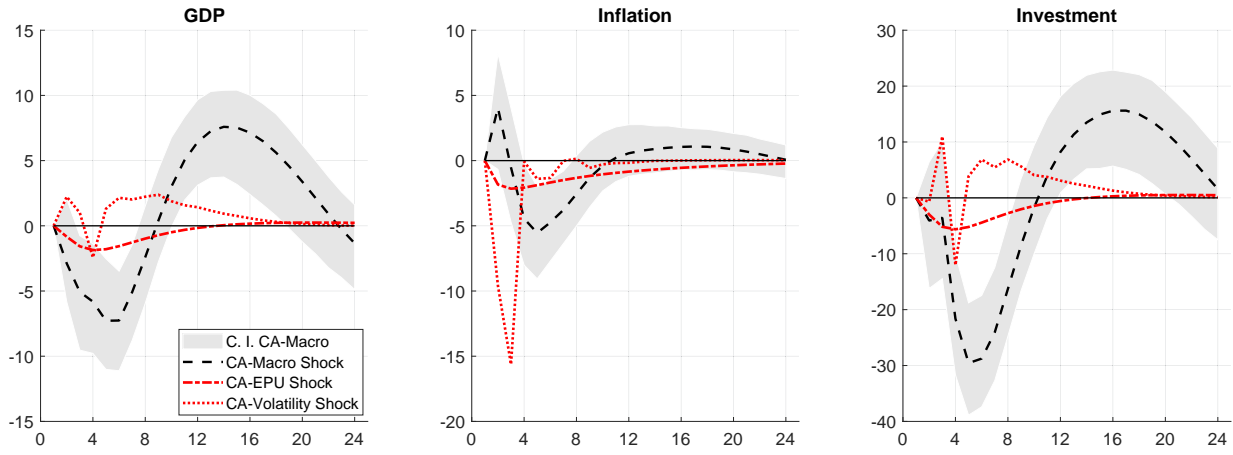
Figure 8: Macroeconomic Impacts of a Shock to US Uncertainty: Comparison with Alternative Measures



NOTES: This figure compares the baseline IRFs of GDP, Inflation and Investment to shocks on alternative measures of US uncertainty.

Figure 8 first shows that the aggregates' responses to the US shock are qualitatively similar, with a sudden increase in uncertainty leading to a deep but relatively short-lived economic decline. However, Figure 9 reports that results pertaining to the Canadian shock are not as robust. Notably, while the adverse shock to US financial markets' volatility generated a short-lived but substantial economic slowdown in Canada, the (Canadian) shock to TSX volatility does not generate any important dynamic responses. Canadian shocks to financial volatility appear to have no specific impact on the Canadian economy, a result

Figure 9: Macroeconomic Impacts of a Shock to Canadian Uncertainty: Comparison with Alternative Measures



NOTES: This figure compares the baseline IRFs of GDP, Inflation and Investment to shocks on alternative measures of Canadian uncertainty.

in line with those in [Bedock and Stevanovic \(2017\)](#) who report similar contrasts between the effects of Canadian and US shocks when estimating the macroeconomic impacts of credit shocks. This is likely due to the dominant position of the United States in financial markets.

Overall, however, the computed impacts of US and Canadian uncertainty shocks on the Canadian economy are consistent with the interpretation advanced in [Bloom \(2009\)](#) and [Leduc and Liu \(2016\)](#): sudden increases in uncertainty lead firms, households and financial intermediaries to delay or cancel plans, which depresses aggregate demand and leads to declines in economic activity, increases in unemployment and lower inflation.

4.3 Robustness Analysis

Several robustness checks have been considered and the results are presented in Appendix [C](#). An alternative ordering of the vector \mathbf{Y}_t in the VAR, with the Canadian uncertainty placed second –exogenous to the rest of Canadian variables and in the spirit of [Carriero et al. \(2018\)](#)– does not change the qualitative nature of our results, as shown in Figure

12. The impacts of uncertainty shocks on consumption and labour market indicators are similar to those on GDP and Investment, as depicted in Figure 13. Notably, the consumption of durables reacts more than the aggregate measure, as expected. Finally, Figures 14 and 15 plot the dynamic responses when GDP, investment and GDP deflator are kept in levels as opposed to the growth rates employed in our baseline specification.

5 Conclusion

This paper develops a measure of Canadian macroeconomic uncertainty, to help formalize discussions about uncertainty and analyze its consequences. Our measure shows that the events linked to the COVID-19 pandemic have led to very sharp increases in Canadian uncertainty, in line with results obtained when using data from other countries. Our VAR analysis then reveals that uncertainty shocks similar in size to the COVID-induced spikes lead to deep slowdowns that may persist for several quarters. We also show that the macroeconomic impacts of uncertainty shocks are different whether they are assumed to affect first US uncertainty or its Canadian-specific counterpart, an interesting contrast that should be the subject of further research. In addition, the question as to whether uncertainty should be a specific input into monetary policy reaction functions remains open.

Looking past the immediate economic effects of the pandemic, analysts and policy makers are turning their attention to the long term and the road to recovery and recent work by [Barrero and Bloom \(2020\)](#) and [Forni et al. \(2020\)](#) suggests that this recovery will be very gradual. The exacerbated state of uncertainty documented in this paper will most probably contribute to slow this return to pre-COVID economic trends and uncertainty should continue to be monitored by fiscal and monetary authorities.

References

- D. A. Altig, S. R. Baker, J. M. Barrero, N. Bloom, P. Bunn, S. Chen, S. J. Davis, , J. Leather, B. H. Meyer, E. Mihaylov, P. Mizen, N. B. Parker, T. Renault, P. Smietanka, and G. Thwaites. Economic uncertainty before and during the covid-19 pandemic. Working Paper No. 27418, NBER, June, 2020.
- J. Bai and S. Ng. Determining the number of factors in approximate factor models. *Econometrica*, 70(1):191–221, 2002.
- S. R. Baker, N. Bloom, and S. J. Davis. Measuring economic policy uncertainty. *Quarterly Journal of Economics*, 131(4):1593–1636, 2016.
- S. R. Baker, N. Bloom, S. J. Davis, and S. J. Terry. Covid-induced economic uncertainty. Working Paper No. 26983, NBER, April, 2020.
- B. Barrero and N. Bloom. Economic uncertainty and the recovery. 2020 Jackson Hole Symposium, August 2020.
- N. Bedock and D. Stevanovic. An empirical study of credit shock transmission in a small open economy. *Canadian Journal of Economics/Revue canadienne d'économique*, 50(2):541–570, 2017.
- O. Blanchard and R. Perotti. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, 117(4):1329–1368, 2002.
- N. Bloom. The impact of uncertainty shocks. *Econometrica*, 77(3):623–685, 2009.
- D. Caldara, C. Fuentes-Albero, S. Gilchrist, and E. Zakrajsek. The macroeconomic impact of financial and uncertainty shocks. *European Economic Review*, 88:185–207, 2016.
- A. Carriero, T. E. Clark, and M. Marcellino. Measuring uncertainty and its impact on the economy. *The Review of Economics and Statistics*, 100:799–815, 2018.
- L. J. Christiano, M. Eichenbaum, and C. L. Evans. Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45, 2005.
- V. Colombo. Economic policy uncertainty in the US: Does it matter for the Euro area? *Economics Letters*, 121:39–42, 2013.
- P. Cross and P. Bergevin. Turning Points: Business Cycles in Canada Since 1926. *C.D. Howe Institute Commentary*, (366), October 2012.
- A. M. Dietrich, K. Kuester, G. J. Muller, and R. S. Schoele. News and uncertainty about covid-19: Survey evidence and short-run economic impact. Federal Reserve Bank of Cleveland Working Paper no. 2020-12, April, 2020.

- J. Fernández-Villaverde and P. A. Guerrón-Quintana. Uncertainty shocks and business cycle research. *Review of Economic Dynamics*, 37:118 – 146, 2020.
- C. Forni, M. Marcellino, and D. Stevanovic. Forecasting the covid-19 recession and recovery: Lessons from the financial crisis. *International Journal of Forecasting*, 2020. forthcoming.
- O. Fortin-Gagnon, M. Leroux, D. Stevanovic, and S. Surprenant. A large Canadian database for macroeconomic analysis. Cahier de recherche 2020-07, Chaire en macroéconomie et prévisions, mai, 2020.
- J. Gali. Technology, employment, and the business cycle: do technology shocks explain aggregate fluctuations? *The American Economic Review*, 89:249–271, 1999.
- Y. Gorodnichenko and S. Ng. Level and volatility factors in macroeconomic data. *Journal of Monetary Economics*, 91:52–68, 2017.
- P. Goulet Coulombe, M. Leroux, D. Stevanovic, and S. Surprenant. How is machine learning useful for macroeconomic forecasting? CIRANO Working Papers, 2019s-22, 2019.
- K. Jurado, S. C. Ludvigson, and S. Ng. Measuring uncertainty. *The American Economic Review*, 105:1117–1216, 2015.
- K. Jurado, S. C. Ludvigson, and S. Ng. Adjustments to JLN uncertainty for COVID-19 mean shift. 2020.
- G. Kamber, O. Karagedikli, M. Ryan, and T. Vehbi. International spill-overs of uncertainty shocks: Evidence from a FAVAR. Working paper 61/2016, CAMA, 2016.
- S. Klössner and R. Sekkel. International spillovers of policy uncertainty. *Economics Letters*, 124:508–512, 2014.
- S. Leduc and Z. Liu. Uncertainty shocks are aggregate demand shocks. *Journal of Monetary Economics*, 82:20–35, 2016.
- S. Leduc and Z. Liu. The uncertainty channel of the coronavirus. FRBSF Economic Letter 2020-07, Mars, 2020a.
- S. Leduc and Z. Liu. Can pandemic-induced job uncertainty stimulate automation. Federal Reserve Bank of San Francisco Working Paper 2020-19, May, 2020b.
- Michele Lenza and Giorgio E Primiceri. How to estimate a VAR after March 2020. Working Paper 27771, National Bureau of Economic Research, September 2020.
- S. C. Ludvigson, S. Ma, and S. Ng. Uncertainty and business cycles: Exogenous impulse or endogenous response? *American Economic Journal: Macroeconomics*, forthcoming.

- A. Moore. Measuring economic uncertainty and its effects. *Economic Record*, 93(303): 550–575, 2017.
- J. Rogers and J. Xu. How well does economic uncertainty forecast economic activity? Technical report, Finance and Economics Discussion Series 2019-085. Washington: Board of Governors of the Federal Reserve System, 2019.
- J. H. Stock and M. W. Watson. Forecasting using principal components from a large number of predictors. *Journal of the American Statistical Association*, 97:1167–1179, 2002.
- J. H. Stock and M. W. Watson. Forecasting with many predictors. *Handbook of Economic Forecasting*, 1:515–554, 2006.

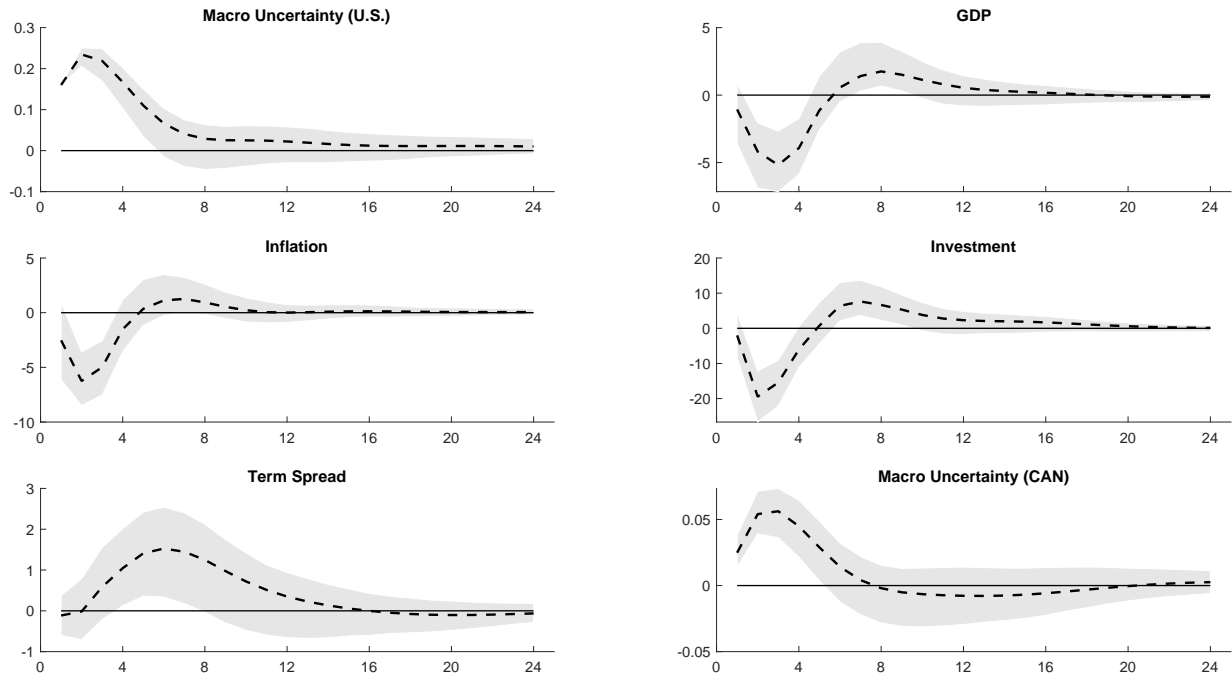
A Data

Table 2: Data description

Series	Description	Source	Vector	Transformation
Macro Uncertainty US	www.sydneyludvigson.com/macro-and-financial-uncertainty-indexes			
GDP	Real Gross domestic product , chained (2012) dollars	statcan	v62305752	level
Investment	Real Gross fixed capital formation, chained (2012) dollars	statcan	v62305732	log-difference
Inflation	Implicit price index : Gross domestic product, 2012 = 100	statcan	v62307282	log-difference
10-year Governmental bonds	Governmental bonds (average rate) (10+ years)	statcan	v122487	level
Treasury bills (3 months)	Treasury bills (3 months)	statcan	v122541	level
Term Spread	Government Bonds (10+ years) - Treasury Bond (3 months)	v122487-v122541		level
Prices	Implicit price index : Gross domestic product, 2012 = 100	statcan	v62307282	level
Consumption	Real Final consumption expenditure, chained (2012) dollars	statcan	v62305723	log-difference
Durable Consumption	Real Final consumption expenditure, Durable goods, chained (2012) \$	statcan	v62305726	log-difference
Employment	Employment total	statcan	v24793	log-difference
Unemployment rate	Unemployment rate	statcan	v2062815	log-difference

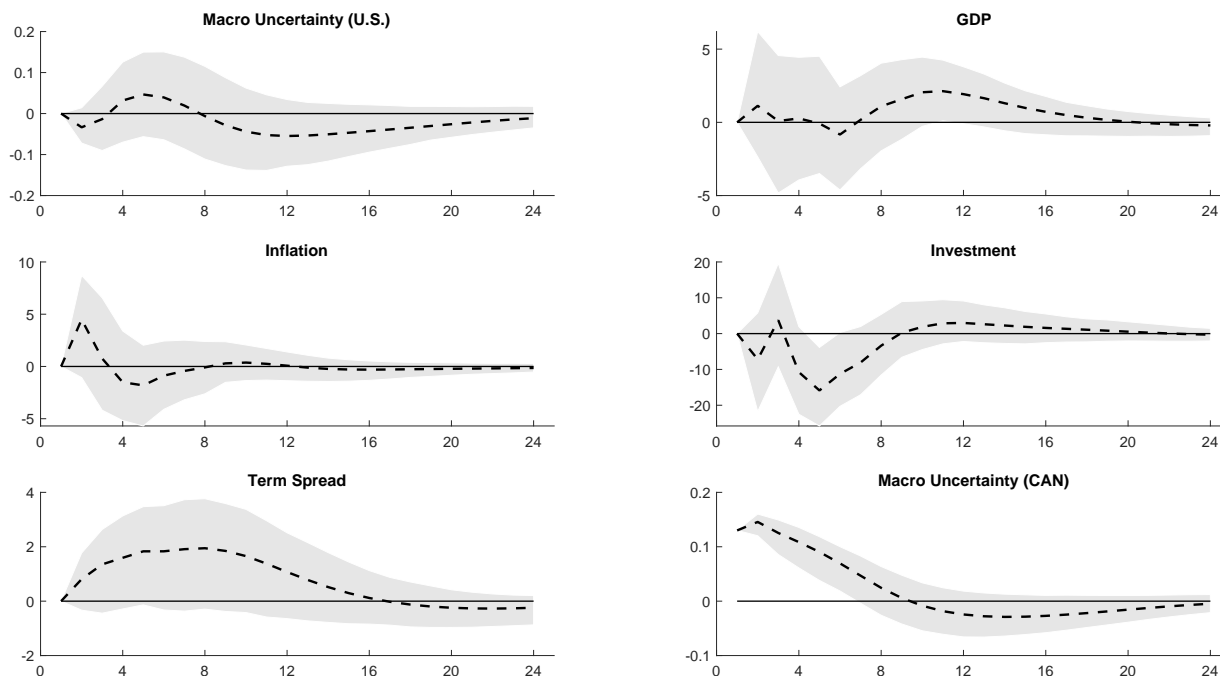
B VAR Analysis with pre-COVID Data

Figure 10: Impacts of a Shock to U.S. Uncertainty before COVID-19



NOTES: Impacts of a shock to US macro uncertainty in a VAR where it is ordered first. Shaded areas represent 90% confidence bands.

Figure 11: Impacts of a Shock to Canadian Uncertainty before COVID-19



NOTES: Impacts of a shock to Canadian macro uncertainty in a VAR where it is ordered last. Shaded areas represent 90% confidence bands.

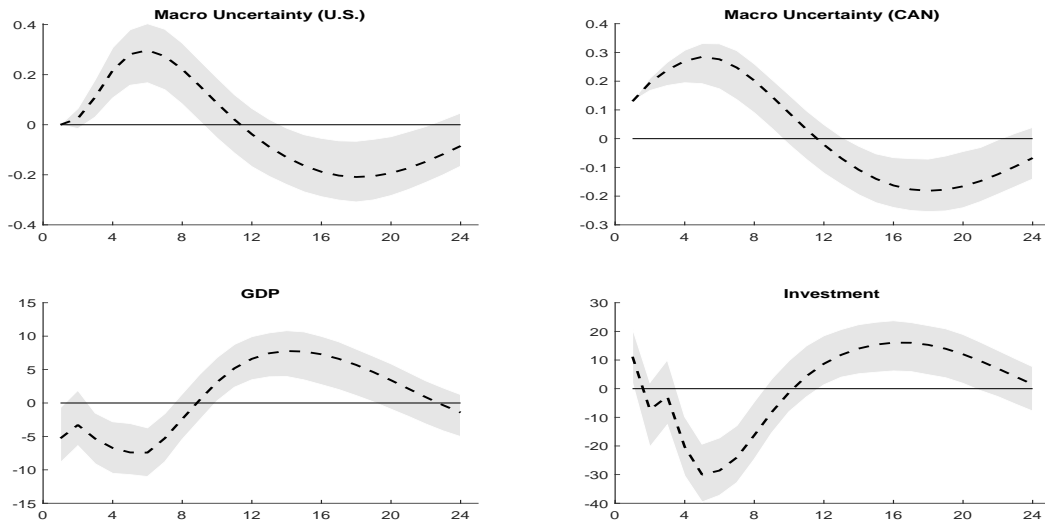
Table 3: Variance Decomposition before COVID-19

Variables	US shock					CAN shock				
	h=1	h=4	h=8	h=16	h=24	h=1	h=4	h=8	h=16	h=24
US Uncert.	100.00	89.99	73.21	62.23	61.22	0.00	0.30	0.60	1.90	2.27
GDP	0.52	17.21	17.58	17.83	17.80	0.00	0.09	0.19	1.32	1.35
Inflation	2.07	17.03	17.55	17.48	17.46	0.00	1.21	1.40	1.41	1.43
Investment	0.20	20.62	22.36	23.06	23.11	0.00	1.27	3.96	3.98	3.99
Term Spread	0.10	2.70	10.69	11.84	11.74	0.00	2.09	4.85	6.83	6.83
CAN Uncert.	13.73	35.50	25.44	18.05	17.67	83.70	59.53	47.20	33.89	33.80

NOTES: This table presents the variance decomposition (in %) of the series included in the VAR to US and Canadian macroeconomic uncertainty shocks respectively.

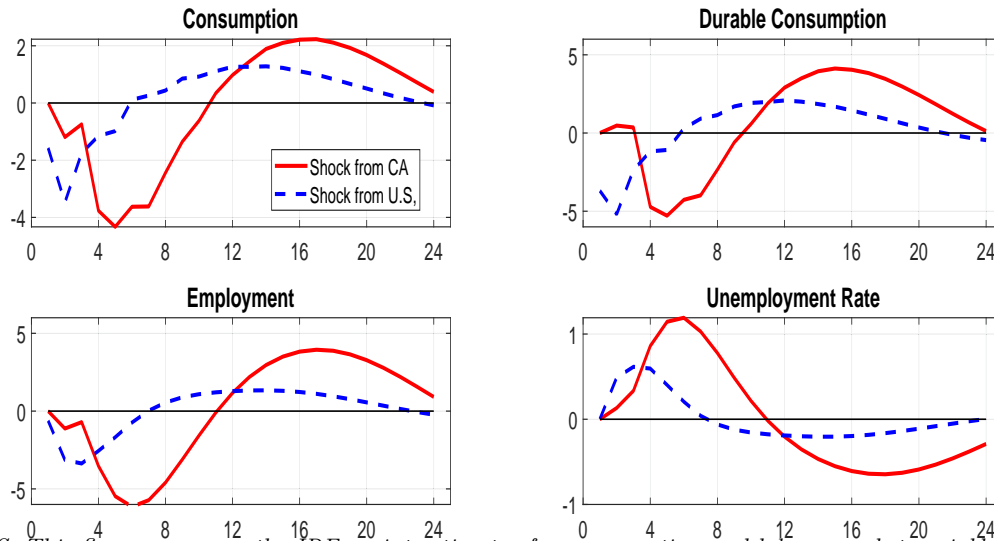
C Robustness Analysis

Figure 12: Macroeconomic Impacts of a Shock to Canadian Uncertainty: Alternative Ordering



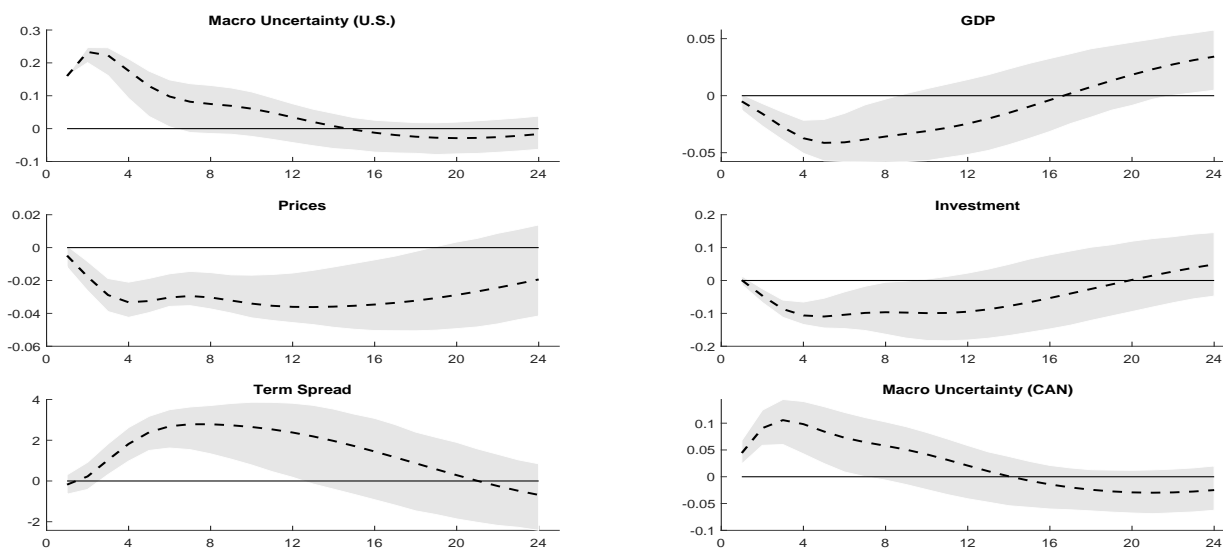
NOTES: This figure shows IRFs from a VAR where our Canadian uncertainty measured is ordered second.

Figure 13: Impacts of Uncertainty Shocks on Consumption and Labor Market



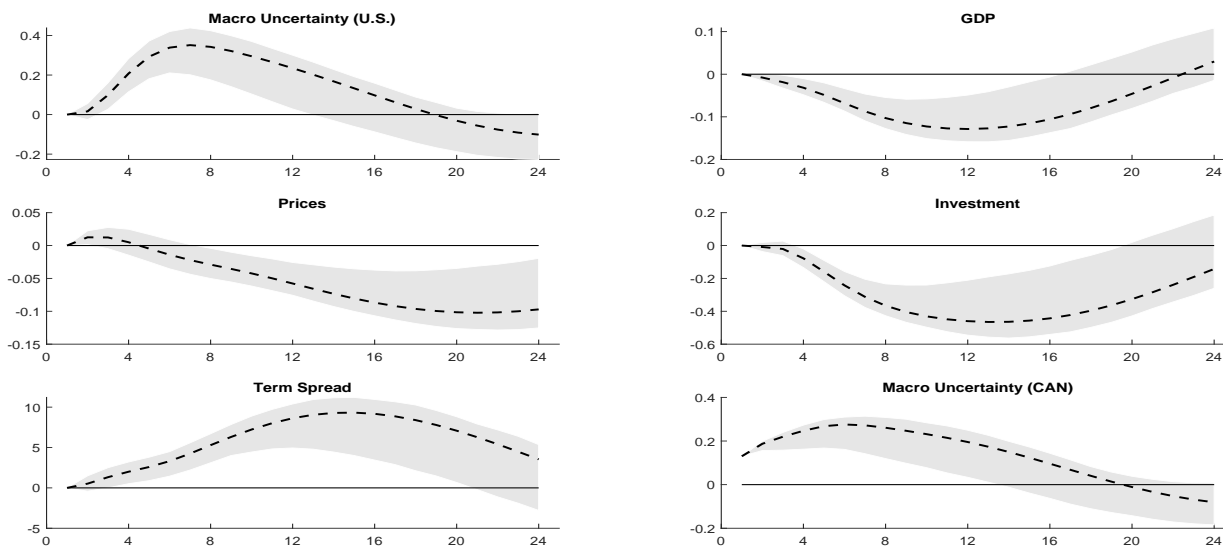
NOTES: This figure compares the IRFs point estimates for consumption and labour market variables.

Figure 14: Macroeconomic Impacts of a Shock to US Uncertainty: VAR in Levels



NOTES: This figure shows IRFs to the US uncertainty shock from the VAR containing log-level variables rather than growth rates. A linear trend is also included.

Figure 15: Macroeconomic Impacts of a Shock to Canadian Uncertainty: VAR in Levels



NOTES: This figure shows IRFs to the Canadian uncertainty shock from the VAR containing log-level variables rather than growth rates. A linear trend is also included.

D Mean-Shift Adjustment for COVID-19 Period

As discussed in section 2.1, the COVID-19 shock to macroeconomic variables is so big that it potentially shifts economy to another equilibrium. We follow the procedure proposed by Jurado et al. (2020) and apply the mean-shift adjustment to uncertainty measurement from the second quarter of 2020 (and April 2020 for the monthly series).

Assume that the shock happens at the period $t = \tau$. Let F_t be a collection of R latent factors. Without loss of generality, consider only level factors from (3), the same procedure can be done with the factors from squared data in (4). Let $\mathbf{\Lambda}$ be the corresponding $N \times R$ matrix of factor loadings. Denote y_i , $j = 1, \dots, N$, a macroeconomic series used to form factors. The method is detailed in following steps.

1. Compute the mean and standard deviation of each series y_j with data up to $t = \tau - 1$: μ_j and σ_j .
2. $\forall t < \tau$, generate factors F_t and factor loadings $\hat{\mathbf{\Lambda}}$ using $Z_j = (y_j - \mu_j) / \sigma_j$. Denote these matrices $\hat{\mathbf{F}}^{\tau-1}$, and $\hat{\mathbf{\Lambda}}_{\tau-1}$ such that

$$\hat{\mathbf{F}}^{\tau-1} = \mathbf{Z} \hat{\mathbf{\Lambda}}_{\tau-1} / N$$

where $\mathbf{Z} = [Z_1, \dots, Z_j, \dots, Z_N]$ is a $T_{\tau-1} \times N$ matrix of data.

3. Denote $y_{j,\tau}$ a value of macro series y_j at time τ . Calculate conditional forecasts of each macro series $y_{j,\tau}$ on the basis of $\tau - 1$ data in $\hat{\mathbf{F}}^{\tau-1}$, and define the ‘‘mean shift’’ at τ as the following forecast error

$$\text{ms}_{j,\tau} = y_{j,\tau} - \hat{y}_{j,\tau|\tau-1}$$

where $\hat{y}_{j,\tau|\tau-1}$ is the forecast of $y_{j,\tau}$ obtained from (5) on the basis of data available at $\tau - 1$, including $\hat{\mathbf{F}}^{\tau-1}$.

4. Generate estimates of factors for τ , denoted by an $R \times 1$ vector \hat{F}_τ , from

$$\hat{F}_\tau = \hat{\mathbf{\Lambda}}'_{\tau-1} Z_\tau / N$$

where j^{th} row of Z_τ is

$$Z_{j,\tau} = \frac{y_{j,\tau} - \text{ms}_{j,\tau} - \mu_j}{\sigma_j}$$

Add the τ value of factors to form $\hat{\mathbf{F}}^\tau = \begin{bmatrix} \hat{\mathbf{F}}^{\tau-1} & \hat{F}_\tau \end{bmatrix}$

5. Move forward from τ to $\tau + 1$. Calculate the corresponding mean shift as

$$\text{ms}_{j,\tau+1} = y_{j,\tau+1} - \hat{y}_{j,\tau+1|\tau}$$

where $\hat{y}_{j,\tau+1|\tau}$ is the conditional forecast using $\hat{\mathbf{F}}^\tau$.

6. Add the τ observations to \mathbf{Z} and recompute the loadings matrix $\hat{\mathbf{\Lambda}}_\tau$. Generate the matrix of factors $\hat{\mathbf{F}}^\tau$ as in step 4.
7. Repeat steps 4-6 until the end of sample (or the end of COVID-19 adjustment period) to get the updated factors $\hat{\mathbf{F}}_t, t = 1, \dots, \tau, \dots, T$.
8. Use updated factors to generate new forecast errors. Demean and standardize each time series $y_{j,t}$ as follows

$$\begin{aligned}
Z_{j,t} &= \frac{y_{j,t} - \mu_j}{\sigma_j} && \text{for } t < \tau \\
Z_{j,\tau} &= \frac{y_{j,\tau} - \mu_j}{\sigma_j} && \text{for } t = \tau \\
Z_{j,t} &= \frac{y_{j,t} - \text{ms}_{j,t} - \mu_j}{\sigma_j} && \text{for } \tau < t \leq T
\end{aligned}$$

Hence, these adjustments assume that the COVID-19 shock was not predictable at time τ , but not thereafter when we take into account a regime shift in the mean of the series. Then, Use the predictive model (5) to obtain forecast errors (residuals) $\hat{e}_{j,t}$.

9. Given the updated forecast errors, generate uncertainty measures as described in Section 2.