Literature Review

Course: CIND820

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Submitted: October 20, 2023

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# 1. Defining research questions

The research conducted here falls into a literature known as “Growth-at-Risk” (G@R or GaR).

GaR is part of growing and innovative literature that attempts to predict the maximum loss of real GDP in the future, given a severe stress event (or “shock”) today. Macroeconomic shocks are occurring more frequently and with greater intensity than even before. A good illustration is the pandemic, where a public health crisis and the associated lockdowns, imposed stress on financial markets and led to a contraction in economic output that affected the welfare of all Canadians.

“Growth-at-Risk” provides an answer to a simple question:

* Given a shock that is measurable on some forward-looking indicator variable today, can we predict the loss of real GDP growth at the 5th quantile of the growth distribution in the next period?

For clarity: the goal is to predict a maximum estimate of lost output and this will be explained in greater detail below.

## What do you already know about the topic?

As stated in the Abstract submitted as part of Module 1, CIND820, this project replicates the GaR framework developed by the International Monetary Fund (IMF).

Growth-at-Risk is a new field of macroeconomics and can be understood by looking at a related literature known as “Value-at-Risk” (VaR).

Value-at-Risk is used in market risk to estimates a maximum trading loss (we are 95% confident that losses won’t exceed VaR – i.e. will not fall into the shaded area below the 5th quantile).

A graph with a black line

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Large banks are required by regulators to calculate their daily Value-at-Risk. The idea is simple:

* We are not interested in the mean of the loss distribution (which would represent an average loss)
* We are interested in an estimate of loss that is a reasonable proxy for the maximum loss expected
* The 5th quantile of the loss distribution is the Value-at-Risk:
  + It is a large loss that will at most be exceeded on 5 out of 100 trading days on which losses occur.

Growth-at-risk is in essence identical to Value-at-Risk. Growth-at-risk is not interested in the expected loss of output (the mean of the distribution). Instead, growth-at-risk wants to estimate the maximum loss of GDP that would occur if economic growth fell into the left tail of the GDP growth distribution (represented by the 5th quantile of the growth distribution). The GDP growth that could be lost in this tail event is considered the “vulnerable growth” or the growth “at risk”.

## What do you have to say critically about what’s known?

Like all models, the GaR approach serves certain objectives, which it generally accomplishes. Other objectives may require a different approach.

Specifically, GaR asks what the worst-case GDP growth contraction would be, given a current shock. Such an estimate is analogous to a stress test. It has several advantages:

* It can be used for planning purposes – given the worst-case GDP contraction, we can calculate the likely unemployment rate, for instance
* A worst-case estimate asks how prepared we would be and whether more can be done to mitigate the worst case
* Since GaR is forward-looking, there is time for government intervention to counteract an unfolding worst-case contraction (e.g. by expanding fiscal spending).

GaR is not a growth forecast. Economic forecasting aims to predict the expected value (the mean) of next period’s growth distribution (which is the most likely outcome). Forecasters will talk about up and downside risks to the forecast (but do not provide an estimate of tail events).

* GaR admits that its worst-case estimate is a tail event and, as such, not the expected value.
* GaR is literally the equivalent of a macroeconomic stress test – letting us anticipate what the worst case outcome is given a shock.

# 2. Introducing the approach

The approach to growth-at-risk can be described in three steps:

1. Future GDP growth is to be linked to a forward-looking indicator variable (independent variable). For example, the IMF uses a financial conditions index (FCI) as indicator variable: if financial conditions are tight today, growth will contract in the next period; if financial conditions are loosened today, growth will expand in the next period.
2. The approach uses quantile regression to estimate the entire distribution of future GDP (in contrast to a point forecast as with OLS regression). Specifically, we run quantile regressions from the fifth quantile of the GDP growth distribution to the ninety-fifth quantile, in increments of 2.5 quantiles (for a total of 37 regression estimates per quarter). This allows us to draw the full conditional growth distribution by smoothing the 37 independently estimates along the curve.
3. Conclusion: Assuming the current growth distribution is orange and financial conditions get tighter, we can draw the future blue distribution, which will have a median and 5th quantile estimate (“GaR”) that are associated with a lower GDP growth rates in the next period (graph taken from [Nellie Liang](https://www.brookings.edu/people/nellie-liang/) and [Tobias Adrian](http://www.tobiasadrian.com/), “How Growth-at-Risk can help central bankers gauge financial stability risks”, Brookings, April 11, 2019).

A graph of a graph with arrows pointing to the same line

Description automatically generated

In the approach used here, we estimate quarterly GDP growth distributions conditional on the indicator variable going back over decades to illustrate how the growth distributions change over time.

* This will allow us to visualize the usefulness of the GaR approach
* We have data going back to the 1962. We can calculate quarterly GDP growth distributions for about 60 years (= 240 quarters)
* Because we calculate GDP at 37 quantiles per quarter over 240 quarters, the project makes 8,880 independent calculations (240\*37)

To illustrate the outcome using a graph from Tobais Adrian “Vulnerable Growth”, the visualization for the US economy is as follows:

A graph of a graph

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## Has anyone else ever done research exactly the same? Is there related research? Where does your work fit in with what has gone before?

The GaR approach is a recent innovation that is used by the IMF and is referred to most of its Global Financial Stability Reports. The seminal publication laying out the model for GaR is:

* + Tobias Adrian, “Vulnerable Growth”, Federal Reserve Bank of New York, Staff Report No. 794, September 2016, Revised November 2017

In this project, important differences with the IMF’s approach are as follows:

* The GaR concept is applied to Canada, which has not been done to my knowledge
* While the IMF uses a broad financial conditions index (FCI) as the indicator value, such an index is not publicly available for Canada to my knowledge. The approach suggested here is to use total credit to the Canadian economy as the indicator variable. It is well-established in economics that future GDP growth is dependent on the flow of credit to the economy. Also, the Brookings paper on Growth-at-Risk suggests that total credit would be a suitable indicator variable. Total credit is publicly available.
* Compared to Tobias Adiran’s paper “Vulnerable Growth”, this project would likely count as a simplified version of GaR.

# 3. Searching the literature

Growth-at-risk is a relatively recent filed but it is already reasonably well documented and consistently used by the IMF. Important publications that provide a full conceptual understanding of the idea and approach include:

1. Tobias Adrian, et al., “Vulnerable Growth”, Federal Reserve Bank of New York, Staff Report No. 794, September 2016, Revised November 2017
   * Economic forecasts usually provide point estimates for the conditional mean of GDP growth
   * GaR models the full distribution of future real GDP growth as a function of current financial and economic conditions using quantile regressions
   * Once empirical estimates of the quantiles have been obtained, a distribution can be drawn by interpolating between the estimated quantiles. In addition, a skewed t-distribution (a flexible distribution function with four parameters) could be fitted to the quantile estimates. This allows the GaR model to transform the empirical quantile distribution into an estimated conditional distribution of GDP growth.
     + The procedure is computationally straightforward and transforms the inverse cumulative distribution function from the quantile regression into a density function.
2. George Cooper, “The Origin of Financial Crises: Central Banks, Credit Bubbles and the Efficient Market Fallacy”, 2012
   * Argues that the flow of credit gives rise to the boom-bust cycle
     + This is the foundation of the approach adopted in this project
     + We will use the flow of credit as the forward-looking indicator variable to estimate future distributions of GDP growth
3. Ananthakrishnan Prasad, et al., IMF Working Paper, “Growth at Risk: Concept and Application in IMF Country Surveillance”, February 2019
   * Explains how the IMF uses GaR for tracking the evolution of financial conditions and macro-financial vulnerabilities
   * This can provide valuable information for policymakers regarding risks to future growth and, hence form a basis for targeted pre-emptive action
   * GaR analysis can appreciably expand the macrofinancial surveillance toolkits of policymakers
   * The GaR approach has been incorporated into the International Monetary Fund’s macro-financial surveillance toolkit. In the context of multilateral surveillance, the Global Financial Stability Report (GFSR) has explored tail risk to global economic growth based on prevailing global financial conditions.
4. IMF, “Global Financial Stability Report” October 2017
   * Chapter 3, “Financial Conditions and Growth-at-Risk” provides a very accessible overview of the GaR model adopted by the IMF
   * Argues that financial conditions predict increased downside risks to GDP growth in most advanced economies and a more uncertain growth outlook in emerging markets.
5. Tobias Adrian, et al., “The Term Structure of Growth-at-Risk,” IMF Working Paper 2018/180.
   * Extends the GaR model into the future by modeling a “term structure” of growth-at-risk.
   * The main idea is that policy makers may reduce the probability of systemic crisis today by intervening with expansionary credit and spending policies to support growth, but this may also increase the future amount of growth that is “at risk”.
6. [Nellie Liang](https://www.brookings.edu/people/nellie-liang/) and [Tobias Adrian](http://www.tobiasadrian.com/), “How Growth-at-Risk can help central bankers gauge financial stability risks” Brookings, April 11, 2019).
   * Summary of the idea of a “term structure” of growth-at-risk
   * When asset prices fall and financial market volatility rises, monetary policymakers face a dilemma.  An interest rate cut would reduce downside risks to the economy and support economic growth.  But it could also fuel risk taking, leading to higher asset valuations, more leverage, and other buildups of financial vulnerabilities, raising future risks
7. Kevin Doyd, “Measuring Market Risk” 2nd Ed, 2005
   * Chapter 3 provides an overview to “Measuring Value-at-Risk”, which can be done with historical or parametric approaches
   * The concept of Value-at-Risk is identical to the concept of Grwoth-at-Risk. Value-at-Risk provides a more established literature that may be useful to understand the foundation of the idea of Growth-at-Risk

# 4. Analyzing materials

The data used in this project has been documented in the Abstract as part of Module 1 but is referenced here again for convenience.

* + Quarterly GDP data for Canada -- publicly available from Stats Canada at [The Daily — Gross domestic product, income and expenditure, fourth quarter 2021 (statcan.gc.ca)](https://www150.statcan.gc.ca/n1/daily-quotidien/220301/dq220301a-eng.htm)
  + Total credit to the Canadian economy -- publicly available from the Bank for International Settlements at: [Credit to the non-financial sector (bis.org)](https://www.bis.org/statistics/totcredit.htm)

For Module 2, the raw GDP and Credit read is read into R and the R Markdown has been attached. Here, we provide some highlights of the data:

## The GDP data

The summary statistics shows that the mean of the distribution is very close to the median. We can conclude that the data is not significantly skewed. The left tail is longer than the right. That’s important – it seems there’s more potential to lose GDP in a recession than there is upside risk to GDP growth.

A screenshot of a graph

Description automatically generated

We check the hypothesis that the left tail may be longer than the right. The histogram confirms that this is true.

A graph on a screen

Description automatically generated

The histogram confirms a longer left tail and suggests that we may have outliers. We check with a boxplot and confirm the outliers – which lie predominantly to the downside (left tail).

A graph with a bar graph

Description automatically generated with medium confidence

We note an important implication. The predictive work planned in this project consists in estimating tail risks to GDP growth. Outliers provide important information and will not be removed from the data set. Moreover, we highlight that outliers and skew do not represent any challenges to the approach proposed here,noting:

* While OLS regression makes parametric assumptions, such as requiring normal distribution of the error terms, quantile regression makes no parametric assumptions. Each of the 37 quantiles in our regression is fitted independently.
* While OLS brakes down given outliers and skew, quantile regression is robust to outliers and highly skewed distributions.

Given evidence of some degree of skew, we test how skewed the distribution is where the skew lies with a QQ plot. It turns out that the skew is mainly in the tails (especially the left tail). Otherwise, the distribution is remarkable normal.

A graph with a line

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## The credit data

The BIS data provides various measures of credit and we graph and examine all data in order to choose which series to use as indicator variable:

A screenshot of a computer screen

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Only two series go back to the 1960s and we have GDP data going back to the 1960.

* “Total Credit to the non-financial sector from all sources” is more comprehensive than “total credit o the private non-financial sector from bank”.
* We choose the more comprehensive credit data series: “Total Credit to the non-financial sector from all sources”

We require rates of change as follows:

A graph showing the growth of the stock market

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We go through the same steps to examine the statistical characteristics of the data and conclude that empirical series is approximately normally distributed (with less skew and much fewer outliers than the GDP data).

A screenshot of a computer

Description automatically generated

The data appears approximately normally distributed. We test with a histogram for more nuance

A graph on a screen

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It appears that there are few outliers and that they lie mainly to the right. We confirm with a boxplot

A screenshot of a graph

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We want to know whether the deviations from normal are significant and where they occur. We use a QQ plot to test. We conclude that the data is approximately normally distributed.

A graph with a line

Description automatically generated

# 5. Managing results

The results will be managed via the following GitHub repository:

* [CJRitschl/TMU (github.com)](https://github.com/CJRitschl/TMU)

The current RMD and the excel files have been uploaded

For convenience, the RMD and excel files have also been submitted with the assignment