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Vector Autoregressive Analysis of the Impacts of Canadian Natural Gas on the Economy

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ABSTRACT

The economic impacts of natural gas markets are closely tied with oil market fundamentals. Canada is well known for its oil markets and the value of our currency in closely tied with the price of oil. Despite this, the dynamic interactions between oil and natural gas markets are not well understood. In this paper, I use a Vector Autoregressive (VAR) approach to model the Impulse Response Functions (IRF) for a host of interrelated Canadian macroeconomic variables. Of most interest are the impacts on trade from oil prices and Canadian natural gas prices. I find positive relationships between oil prices and demand for natural gas. I also find positive income effects from increases in real Canadian and US GDP on demand for natural gas, consistent with the trade relations between the two countries.

Key words: natural gas; vector autoregressive; impulse response function

1. INTRODUCTION

Natural gas is an important part of Canadian trade and there exist future opportunities to increase participation in global markets. According to the Canada Energy Regular (2017), "Canada's natural gas resources are abundant," and 72% are in Alberta and British Columbia alone. Canada was the second largest exporter of natural gas for many years and, as of 2017, was the fourth largest (Natural Resources Canada, 2017). This seems to be the direction where Canada is heading as there is currently only one operating natural gas import facility and several export facilities are proposed (Natural Resources Canada, 2019). The current import facility is in New Brunswick, there few export facilities though. Given that the vast majority of domestic production occurs in Western Canada, there is good reason to expand the current infrastructure.

In this paper I use a VAR model (Sims, 1980) to examine how a host of interrelated macroeconomic variables are affected by the market for natural gas in Canada. These variables include the price of oil, price of natural gas, and natural gas exports, among others. This model examines the stochastic components of macroeconomic variables as separate from the trend components to isolate the impacts of deviations. This detrending approach is further explained in section 4.

2. VECTOR AUTOREGRESSIVE MODEL

For a set of eight related variables in a vector Y_t, we can separate its deterministic and stochastic components into two parts (Luetkepohl, 2011):

$$Y_t = \mu_t + X_t \tag{1}$$

where μ_t is the deterministic component that essentially captures the trend of these variables over time, X_t is the stochastic component that I am interested in modelling, and the components of Y_t are listed in Table 1.

Table 1: Model variables

Variable	Description
P_{oil}	The price of oil in \$CAD
P_{NG}	The price of natural gas in \$CAD/GJ
Q_{NG}	Volume of Canadian natural gas exports, $10^3 m^3$
er	CAD/USD exchange rate
r	Short-term interest rate in Canada (3 month)
lr	10-year long term government bond rate
$RGDP^{Can}$	Real Canadian Gross Domestic Product in chained 2012 \$CAD (x 1,000,000)
$RGDP^{US}$	Real US Gross Domestic Product in chained 2012 \$USD (x 1,000,000)[a]

Notes:
[a] The inclusion of *er* makes different monetary units for Canadian and US GDP non-problematic—it accounts for differences from appreciation and depreciation of currencies.

The general VAR(p) model with p lags that captures the behaviour of the stochastic component of the variables of interest is written as

$$X_t = \Phi_1' X_{t-1} + \Phi_2' X_{t-2} + \cdots + \Phi_p' X_{t-p} + \varepsilon \quad (2)$$

Φ_i (i = 1, …, p) are the coefficient matrices associated with each of the p lags, and ε is the error structure vector of the model and is assumed to have a mean zero process. The first coefficient matrix, Φ_1, for example, would capture the impact of past period values of all variables in X on each of their current values, separately.

3. DATA COLLECTION

The price of oil and short-term interest rate for Canada are obtained from the Global Vector Autoregression (GVAR) toolbox (Mohaddes and Raissi, 2016); the price and volume of natural gas exports from the Canada Energy Regulator (2020); data on 10-year long-term government bond yields in Canada, CAD/USD exchange rates, and US real GDP from Federal Reserve Economic Data (2020); and Canadian real GDP is obtained from Statistics Canada (2020).

The data span from 1985Q1 to 2016Q4. This provides a long enough time horizon to capture how certain prominent events such as recessions and resource booms among others, impact the Canadian economy and how the market for natural gas factors into this. The statistical program R (R Core Team, 2013) is used to carry out all analyses. The VAR model is run using the *vars* package in R (Pfaff, 2018).

4. ANALYSIS

Stationarity

I use the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992) to determine which series have unit root processes and which do not. The KPSS test evaluates the null hypothesis that the series is stationary. A small p-value implies a rejection of this hypothesis and indicates the trend is non-stationary and follows a unit root process. If a series is non-stationary, all analysis becomes fraught and unlikely to uncover any reliable results, nor does it have a meaningful interpretation. I check the KPSS test statistic for each variable in levels, log transformation, and first log differences. The results are reported in Table 2. Looking at the Levels column in Table 2, the only series which exhibits evidence of stationarity is the long-run interest rate. The test statistics for all other series show evidence of non-stationarity as indicated by the small p-values. Not much improvement is made by taking the logarithm of each series; in fact, the long-run interest rate no longer exhibits stationarity. To effectively detrend the series, the first difference in logs is taken. The p-values associated with the KPSS tests show evidence of stationarity after this transformation is taken.

Table 2: KPSS Test of Stationarity[a]

Variable	Levels	Logs	Log First Differences
P_{oil}	<0.01	<0.01	>0.1
P_{NG}	<0.01	<0.01	>0.1
Q_{NG}	<0.01	<0.01	>0.1
er	<0.01	<0.01	0.096
r	0.064	0.069	>0.1
lr	>0.1	<0.01	>0.1
$RGDP^{Can}$	<0.01	<0.01	>0.1
$RGDP^{US}$	<0.01	<0.01	>0.1

Notes:
[a] p-values associated with test statistics are reported. A small p-value implies non-stationarity.

A further comparison between five of the eight series before and after transforming with log differences is shown in Figure 1. It is clear from this depiction that rather than observing the general change over time, I am looking at deviations from this trend, and hence, the stochastic component of each time series. Since taking log differences removes the non-stationarity in each time series, these are used throughout the remainder of the analysis.

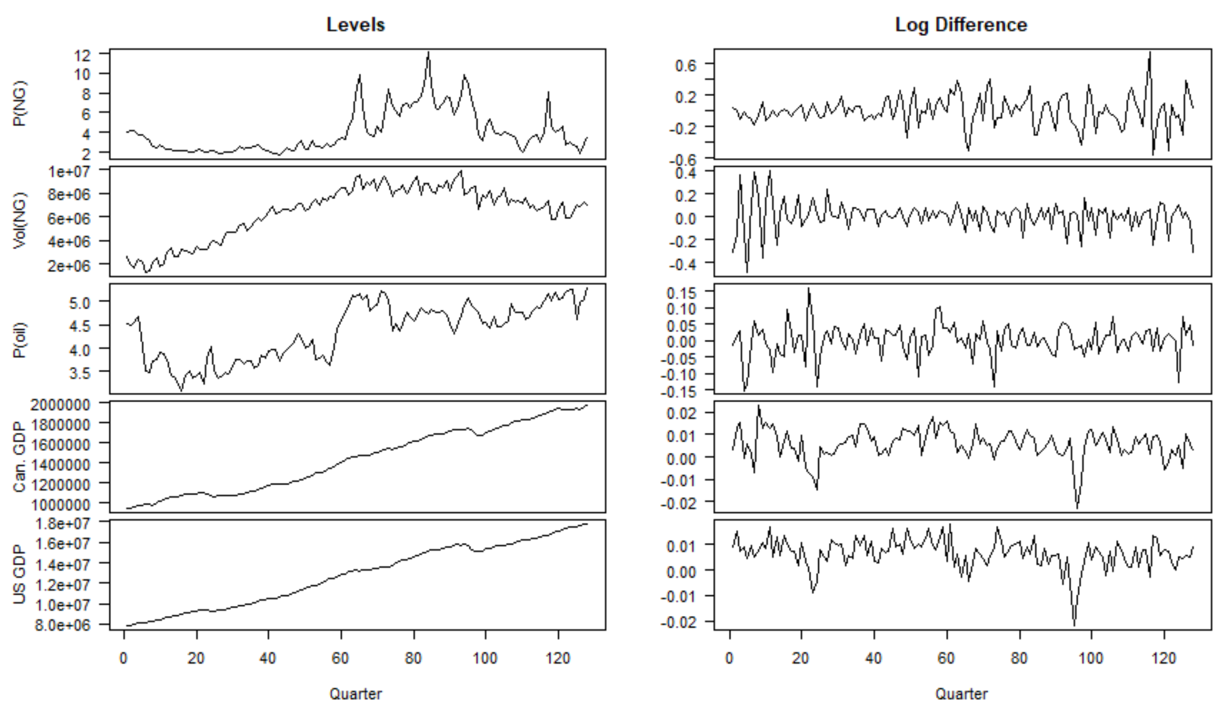

Figure 1: Detrending the Time Series

Lag Selection

I employ the Akaike Information Criterion (AIC) test (Akaike, 1973) on the VAR model with all variables at various lag lengths to see which model best fits the relationship among the variables whilst reducing information loss. The test also accounts for the loss in degrees of freedom from the need to estimate more parameters by decreasing the value, leading to a lower likelihood of choosing a model with less degrees of freedom (Giles, 2013). The AIC with the smallest value among others is indicative of best fit. The results are reported in Table 3.

Table 3: Akaike Information Criterion Test

Model	Number of lags	AIC
VAR1	1	-3447.871
VAR2	2	-3424.331
VAR3	3	-3351.597
VAR4	4	-3367.337
VAR5	5	-3332.745
VAR6	6	-3285.683
VAR7	7	-3288.676
VAR8	8	-3297.085

Since the model run with one lag has the smallest AIC, it is the preferred model. This is the model that will be used in the analysis of impulse responses. It is also the least restrictive in that less parameters are estimated in the regression allowing for greater degrees of freedom. Little value in terms of estimation is gained from adding more than a one-period lag.

Impulse Response Function

The impact of a one standard deviation unit change in each of the nine variables is examined. The shocks in question enter the system by increasing the residuals in one of the equations and mapping out the resulting impacts on other variables (Sims, 1980). Since all variables are functions of past period values of all other variables, a shock to any given equation will have impacts on the future values depending on the extent to which any given variable relies on the variable being shocked.

It should be noticed that the impulses examined are heterogeneous due to different underlying distributions in each variable. The package does this to maintain a certain level of certainty around impacts by not using shocks you would not usually see over the time horizon. For the sake of brevity, the only impacts that will be discussed at any length will be positive shocks to the price of oil, price of natural gas, Canadian GDP, and US GDP. The impulse responses of interest are shown in Figures 2 through 5.

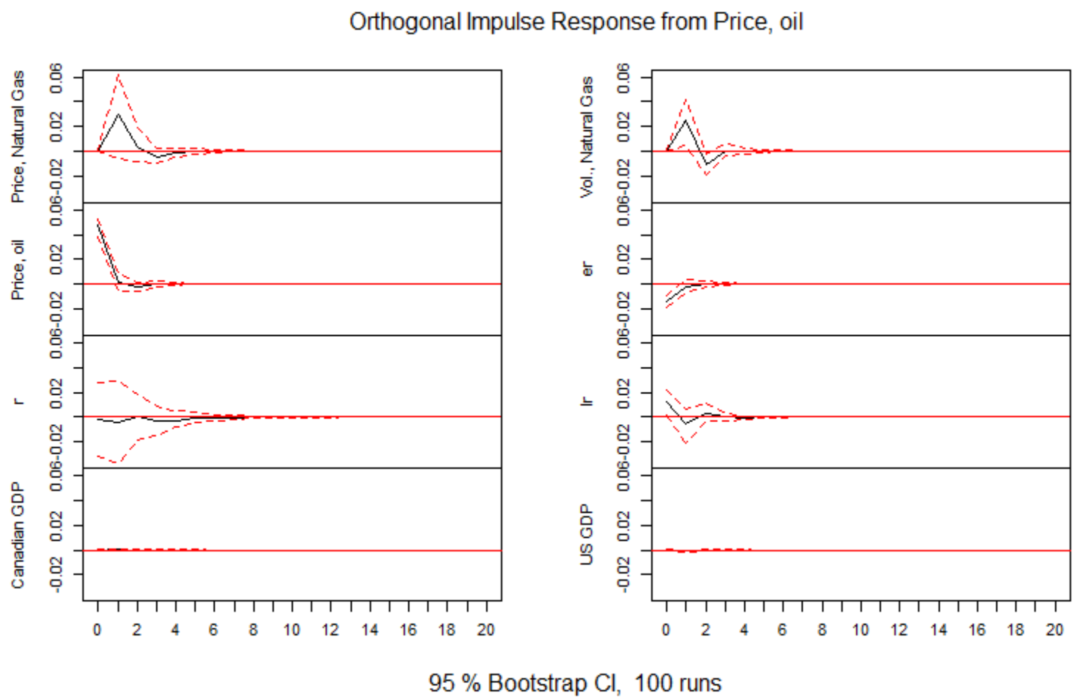

Figure 2: Impulse Response from a Shock to the Price of Oil

A 5% increase in the price of oil increases the price of natural gas by 3%, increases the volume of natural gas exports by 2%, and depreciates the exchange rate by nearly 2%. The price of natural gas being positively correlated is interesting as standard microeconomic theory would imply the two are substitutes; however, natural gas and oil serve very different purposes. The impact on the price of natural gas peaks in the quarter following and dissipates by the end of the fourth quarter after the oil price impulse. The impact on natural gas exports dissipates within two quarters. The decrease in the exchange rate can be interpreted as depreciation of the Canadian dollar against the US dollar, which makes sense given the reliance of the Canadian dollar on oil prices. When the price of oil is high, there is less demand from Canada, and hence, less demand for Canadian currency. The depreciation of Canadian currency does not persist and only lasts for the quarter following the oil price shock. There also appears to be uncertainty around impacts on short-term interest rates and a small increase in the long-term interest rate that returns to normal within one quarter. Interestingly, there seems to be too little an impact on Canadian and US GDP from a 5% increase in the price of oil captured by the model.

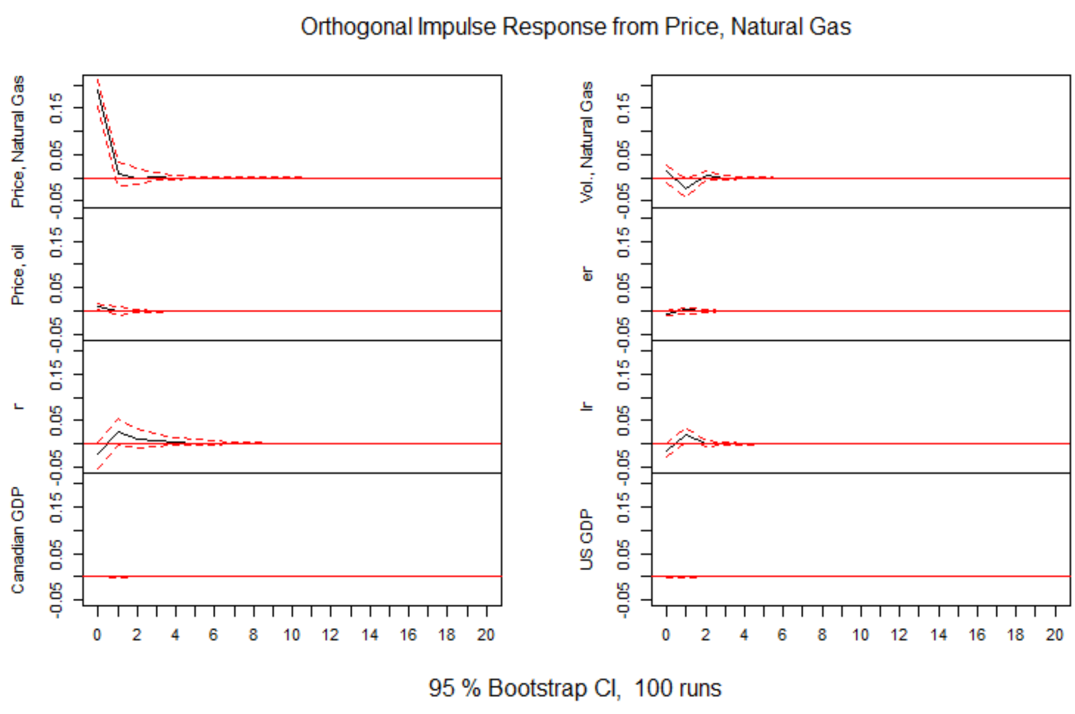

Figure 3: Impulse Response from a Shock to the Price of Natural Gas

There is surprisingly little impact from a positive shock to the price of natural gas. A nearly 20% increase leads to short-run positive impacts on the short- and long-term interest rates, although they are quite small—they both increase by less than 5% one quarter out. There is very little effect on the price of oil. Contrasted with the results from the impulse to the price oil, one can make a structural interpretation and say that there may be one-way substitution from oil to natural gas only when the oil becomes more expensive but not when natural gas does. This type of interpretation, however, would require a cointegration approach—something that is not explored in the present analysis. Perhaps the small amount of oil that is used to generate electricity is displaced in circumstances of sufficiently high oil prices.

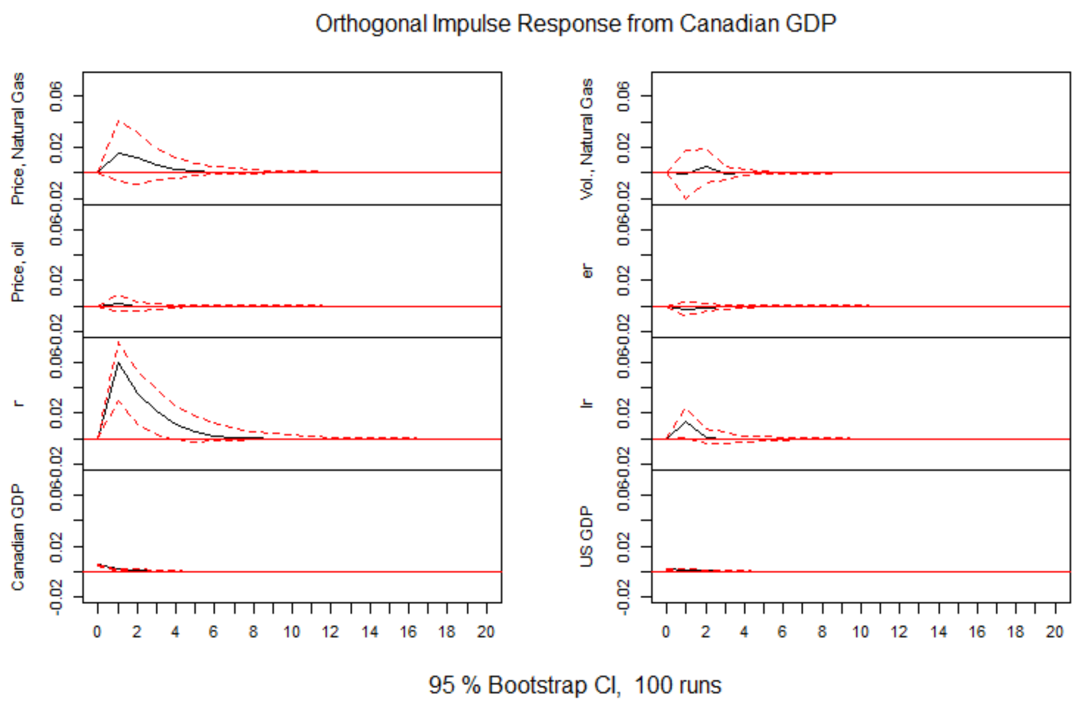

Figure 4: Impulse Response from a Shock to Canadian GDP

A 1% increase in real Canadian GDP has a positive lasting effect on the price of natural gas. The price of natural gas increases by 2% two quarters out and persists, in a diminishing manner, for about four quarters. An increase in real Canadian GDP can be directly interpreted as an increase in income which leads to an increase in domestic demand of natural gas products. This increase in demand will push the price of natural gas up. There is little response from exports as one would expect as domestic incomes are rising, and any effect from rising US GDP is held constant. Further, there is a lasting impact on short-term interest rates from a positive impulse to Canadian GDP. A 1% increase in Canadian GDP is associated with a peak increase in the short-term interest rate by 6% one quarter out—when the economy booms, domestic short-term interest rates are higher. This impact persists for the next year and a half, all else equal.

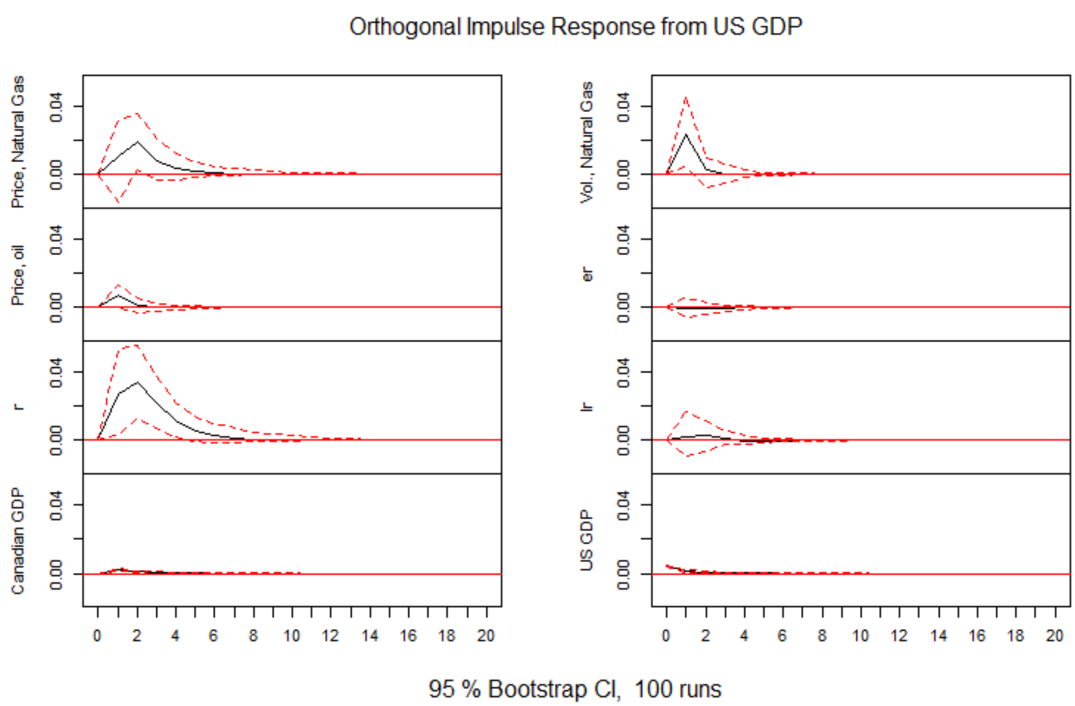

Figure 5: Impulse Response from a Shock to US GDP

A 0.5% increase in real US GDP has very similar effects to the increase in real Canadian GDP. The price of natural gas increases by 2% two quarters out and persists for just over one year. The short-term interest rate in Canada also increases by just under 4% two quarters out. This makes sense as historically when the US economy has boomed, so has the Canadian economy, and short-term investments are made more lucrative. The most notable difference in the impulse to real US

GDP in contrast to the real Canadian GDP impulse, is the increase in volume of exports. The 0.5% increase in real US GDP increases total Canadian exports of natural gas by over 2%. This is consistent with the logic that, as US incomes rise, there will be greater demand for natural gas products from Canada. To discern the true impact of US GDP on the Canadian natural gas market, however, one would have to collect data on Canadian exports exclusively to the US.

5. DISCUSSION AND CONCLUSIONS

I found that as prices of oil rise, the demand for natural gas rises and pushes the price upwards. As US incomes rise, the demand for natural gas rises, consistent with trade relations between the US and Canada. The price of natural gas exports having little impact on Canadian GDP is contrary to what was expected. I interpret this as evidence that the industry is not large enough critically to impact the Canadian economy; however, as this market grows, it will become an integral Canadian export and shift our reliance from oil markets.

This analysis shows how closely tied natural gas is to Canadian trade relations with the US. Canada is still heavily reliant on the US as an importer of Canadian goods and services. There is, however, reason to believe that with the addition of new export facilities, we will have the capacity to expand our exports to the US as well as other countries. The new export facilities are geared towards exporting to Asia, however. Future research in this area should explore a cointegration GVAR modelling approach to consider the impacts of natural gas trade in other countries. This approach would incorporate the impact of recessions and trade relations above and beyond what is explored in this analysis. The basic VAR model is simply not enough to uncover the impacts on trade from natural gas markets given the globalization in trade relations.

6. REFERENCES:

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In Petrov, B. N. and Csaki, F. (eds.), 2nd. *International Symposium on Information Theory*. Akademia Kiado, Budapest, 267-281.

Canada Energy Regulator (2017). Canada's role in the global LNG market – energy market assessment. https://www.cer-rec.gc.ca/nrg/sttstc/ntrlgs/rprt/2017lngmrkt/cndslnglndscp-eng.html

Canada Energy Regulator (2020). Natural gas exports – historical summary – volumes and prices. https://apps.cer-rec.gc.ca/CommodityStatistics/Statistics.aspx?language=english

Federal Reserve Economic Data (2020). Long-Term Government Bond Yields: 10-year: Main, (Including Benchmark), for Canada https://fred.stlouisfed.org/series/IRLTLT01CAM156N

Giles, D. (2013, July 24). Information Criteria Unveiled [Blog post]. Retrieved from https://davegiles.blogspot.com/2013/07/information-criteria-unveiled.html

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics*, 54(1-3), 159-178.

Luetkepohl, H. (2011). Vector autoregressive models. *EUI Working Paper ECO2011/30*. https://cadmus.eui.eu/bitstream/handle/1814/19354/ECO_2011_30.pdf

Mohaddes, K. and Raissi, M. (2016). GVAR toolbox 2.0. https://sites.google.com/site/gvarmodelling/data

Natural Resources Canada (2017). Canada is creating a competitive environment for LNG. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/Canadian%20LNGe.pdf

Natural Resources Canada (2019). Canadian LNG projects. https://www.nrcan.gc.ca/energy/energy-sources-distribution/natural-gas/liquefied-natural-gas/5679

Pfaff, B. (2018). vars: VAR Modelling. R package version 1.5-3. https://cran.r-project.org/web/packages/vars/index.html

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica*, 48(1), 1-48. https://www.jstor.org/stable/1912017%0A?seq=48#metadata_info_tab_contents

Statistics Canada (2020). Table 36-10-0104-01 gross domestic product, expenditure-based, Canada, quarterly (x 1,000,000). Table 36-10-0104-01. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610010401