Effects of Fiscal Policy Shocks in an Open Economy

Evidence from Canada

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Abstract

What is the impact of fiscal policy shocks on key macroeconomic variables in Canada? This question triggered renewed interest in the aftermath of the 2008–09 Great Recession. Indeed, as in many advanced economies, fiscal policy in Canada following the recession started with an expansionary phase to boost domestic demand. It progressed to an adjustment phase to reduce public debt and ensure long-term fiscal sustainability and sustained growth. This paper analyzes the effects of fiscal policy shocks on the Canadian economy, building on the sign-restrictions-VAR approach. Unlike previous studies, this paper explicitly accounts for spillovers from the U.S., Canada’s main trading partner, and for oil price fluctuations. The findings show that the size and sign of the spending and tax revenue multipliers depend on whether the analysis controls for the exogenous factors. The tax-cut multiplier varies between 0.2 and 0.5, while the spending multiplier ranges between 0.2 and 1.1; the spending multiplier tends to be larger than the tax-cut multiplier over the past two decades.
Effects of Fiscal Policy Shocks in an Open Economy: Evidence from Canada

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1 Introduction

The aftermath of the 2008-09 Great Recession triggered renewed interest on the impact of fiscal policy changes on the economy. In response to the global recession, countries typically implemented a two-phase approach to fiscal policy. First, the sudden economic collapse led fiscal authorities in many advanced economies, including Canada, to introduce stimulus packages to revive their economies. Following the stimulus, fiscal authorities shifted gears, adopting adjustment plans to reduce public debt and ensure long-term fiscal sustainability and sustained growth.

Stimulus measures in Canada, introduced through Canada’s Economic Action Plan, were projected at 3.2 percent of GDP in the 2009 federal budget while the ARRA was estimated at 7 percent of GDP. As a result, the federal net debt-to-GDP ratio was expected to increase from 28.6 percent in the 2008-09 fiscal year to 32.1 percent by 2010-11. As the economy started to recover, the Canadian government introduced adjustment plans to tackle high deficits and increased public debt. The federal expenditures-to-GDP ratio, which rose from about 13 percent before the crisis to 16 percent in 2009-10, declined to 14 percent in 2011 and was projected in the 2012 budget to return to the pre-crisis level by 2014-15. The 2012 budget also projected that adjustment measures would bring the federal net debt-to-GDP ratio back to the pre-crisis level by 2014-15, while the consolidated net debt-to-GDP ratio (including federal, provincial and local administrations) was projected to fall to 36.3 percent of GDP (IMF Fiscal Monitor, April 2013). Therefore, examining the size of the fiscal multiplier is important to informing the effectiveness of such policy measures in reviving or not economic activity.

While extensive analysis has been conducted on the U.S. economy, only a few studies (Perotti (2004), Corsetti and Müller (2006), Ravn et al. (2007) and Monacelli and Perotti (2010)) have investigated the impact of fiscal policy changes in Canada. One challenge when studying the effects of fiscal policy changes is to disentangle the automatic fiscal stabilizers to business cycle fluctuations from changes attributed to discretionary policy decisions. This is even more important in a small open economy such as Canada, which is subject to foreign shocks that affect key macroeconomic variables as well as fiscal variables. To identify exogenous changes in fiscal policy, it is important to control for the effects of foreign shocks. Canada is highly integrated with the U.S. through trade and financial links. The U.S. accounts for about 75 percent of total Canadian exports, and American ownership of Canadian assets was valued at more than 50 percent of Canadian GDP in 2009. Any demand shock affecting the U.S. may have a spillover effect on the Canadian economy.

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1The total net debt, according to the IMF’s Fiscal Monitor, rose from 22.4 percent of GDP in 2008 to 34.6 in 2012, and is projected to start falling in 2016 from 36.3 percent. Meanwhile, the total gross debt rose from 71.3 percent of GDP in 2008 to 85.6 percent in 2012, and was projected to fall in 2014 to 84.6 percent of GDP, reaching 78.2 percent in 2018.

2The term small open economy here refers not to the size of the Canadian economy, but to its exposure to foreign shocks mainly from the US, its main trading partner while the reverse does not hold.

3According to Statistics Canada.
economy due to the importance of U.S.-Canada trade. The induced changes in exports may affect corporate tax revenues and GDP. As a net oil exporter, Canada is susceptible to changes in the world oil price. The Canadian economy produces about 4.1 percent of the world’s crude oil and petroleum products. Any increase in oil prices may induce a rise in nominal oil exports, and subsequently result in an increase in tax revenue through corporate income taxes. Consequently, the observed change in Canadian fiscal variables and their possible effects on the economy should not be attributed solely to domestic fiscal policy changes.

The existing literature (e.g. Perotti (2004), Corsetti and Müller (2006), Ravn et al. (2007), Monacelli and Perotti (2010) and Owyang et al. (2013)) does not explicitly take into account spillovers from the U.S. economy and the effects of oil prices. Thus, this paper contributes to the literature by examining the impact of government spending and net tax revenue shocks on key Canadian macroeconomic variables, conditional on U.S. economic developments and fluctuations in the world oil price.

I use a VAR model with block exogeneity: a Canadian block including key macroeconomic and fiscal variables, and a U.S. block including U.S. real GDP to capture economic activity in the U.S. and the real oil price. I allow the Canadian block to depend on the U.S. block, which is assumed to be exogenous to the Canadian economy. As a small oil producer with a minor contribution to the global economy, I assume that changes in the Canadian economy do not affect international oil prices and U.S. GDP. However, I allow for an interdependency between U.S. GDP and oil prices. Indeed, as the main driver of the global activity, changes to U.S. oil demand may affect international oil prices, and vice-versa. International oil prices may also be affected by the supply of U.S. oil with the exploitation of shale oil.

The time period of this paper is 1970:Q1-2010:Q4. Structural shocks are identified using the Mountford and Uhlig (2009) sign restrictions approach. I identify a generic business cycle shock and two fiscal shocks: a government spending shock and a net tax revenue shock, each orthogonal to the business cycle shock.

A number of exercises are performed to test the robustness of the results. After examining the impulse response functions (IRFs) for the identified shocks, I assess GDP multipliers associated with net taxes and spending increases with different specifications of the model — with and without the exogeneous bloc — . Then, I split the sample at the fourth quarter of 1990 to test the stability of fiscal multipliers before and after 1990. Indeed, the Bank of Canada introduced an inflation-targeting regime in the first quarter of 1991. Also, the

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4 According to Energy Canada in 2013, Canada produces about 2.5 million barrels of oil per day and consumes about 1.85 million barrels per day, and imports about 930,000 barrels per day and exports about 1.63 million barrels per day.

5 This sample period is chosen because Canada employed a fixed exchange rate regime before 1970 and a flexible exchange rate after 1970. Given that government spending multiplier tend to vary according to the exchange rate regime (see Ilzetzki et al. (2013)), I prefer to limit the study on the flexible exchange rate regime period.

6 The methodology section details how these shocks are identified.
early 1990s was a time of rapid globalization, with greater trade — with the introduction of the North American Free Trade Agreement — and capital mobility. These changes could have affected how the fiscal policy shocks propagate through the Canadian economy. Finally, I discuss the results in relation with the existing literature, and conclude by comparing net tax multipliers and spending multipliers to draw some policy conclusions.

The results show that output, consumption and investment decline in response to a net tax revenue shock. Output and private consumption increase following a government spending shock, while private investment falls. Net exports decline in response to both spending and net tax increases (with a short delay for the decline in response to a net increase in taxes) as a consequence of a real exchange rate appreciation. The size and the sign of both spending and tax revenue multipliers are sensitive to the extent to which exogenous factors are controlled for. A comparison of tax-cut and spending multipliers suggests that tax-cut multipliers vary between 0.21 and 0.51. Meanwhile, spending multipliers range between 0.21 and 1.10. Spending multipliers tend to be larger than tax-cut multipliers, particularly after 1990.

The remainder of the paper is organized as follows: section 2 briefly reviews other identification strategies, develops the empirical methodology and describes the data; section 3 reports and analyzes the results; and section 4 concludes.

2 Methodology and data

As outlined by Leeper et al. (2013), a difficulty when using a VAR model to study fiscal policy is the model’s potential non-invertibility, as changes in fiscal policy can be anticipated in advance.\(^7\) One way to address this issue is to incorporate forecasts of fiscal variables in the VAR, as has been done in recent papers by Auerbach and Gorodnichenko (2012) and Born et al. (2012). Unfortunately, these forecasts have only been available since 1985, and in a semi-annual frequency, rather than quarterly. Therefore, I have assumed as in existing studies (for example Mountford and Uhlig (2009), Ilzetzki et al. (2013)) that the VAR model is invertible.

Before describing the methodology and the data used in the paper, here is a brief review of some common alternative approaches to identifying fiscal policy shocks.

2.1 Alternative approaches for identification of fiscal policy shocks

The narrative approach of Ramey and Shapiro (1998) and Romer and Romer (2010) is a major innovation in identifying fiscal policy shocks. Ramey and Shapiro (1998) identify\(^7\) Leeper et al. (2013) argue that conventional method can lead the econometrician to label as 'tax shocks' objects that are linear combinations of all the exogenous disturbances at various leads and lags. [...] Fiscal foresight poses a formidable challenge because [...] it generates an equilibrium with a non fundamental representation, [...] in which the equilibrium time series contains a moving average component that is not invertible in current and past observables.
an exogenous government spending shock using a news variable that captures episodes that led to large military buildups in the U.S.. More recently, Owyang et al. (2013) use the same approach to estimate spending multipliers contingent on the state of the economy in Canada and in the U.S.. However, this approach is limited by the number of observations of the news variable for countries such as Canada, which rarely participate in large military operations. Romer and Romer (2010) use narrative records, such as Congressional reports and presidential speeches, to identify the main motivations for all major post-war tax policy changes in the U.S.. Although this approach is more appropriate for identifying exogenous changes in tax revenue, its implementation remains in practice more cumbersome.

Another common technique is the recursive approach. It consists of imposing the condition that government spending or tax revenue is not responsive to business cycle fluctuations for at least one quarter (this approach is used by Blanchard and Perotti (2002), Perotti (2004), Monacelli and Perotti (2010), Auerbach and Gorodnichenko (2012)). The logic behind this assumption is that fiscal variables need more than one quarter to adjust in response to unexpected changes in GDP. However, this assumption is often criticized because it imposes a systematic non response of fiscal variables to a business cycle shock.

2.2 The sign restrictions method

I extend the methodology employed by Mountford and Uhlig (2009) in the case of a small open economy by assuming a block exogeneity in the VAR model. Sign restrictions are imposed on the IRFs of a set of variables to identify structural shocks. The advantage of this approach is that it does not assume a lack of contemporaneous effects of unexpected changes in GDP on fiscal variables. This strategy is also used to identify exogenous technology shocks (see, for example, Dedola and Neri (2007), Enders et al. (2011)) and monetary policy shocks (see Uhlig (2005), Mallick and Rafiq (2008)).

2.2.1 The sign restrictions assumptions

Table 1 summarizes the minimal assumptions imposed to identify structural shocks. Following Mountford and Uhlig (2009), a generic business cycle shock is defined as a shock that increases Canadian GDP, private consumption, private investment and net tax revenues for four quarters following the shock. Once the business cycle is identified, each fiscal policy shock is identified as following: a net tax revenue shock is a shock that increases only the net tax revenue for four quarters following the shock and is orthogonal to the business cycle shock, while a government spending shock is a shock that only increases government spending for four quarters following the shock and is orthogonal to the business cycle shock. Since I assume that Canada is a small open economy, U.S. GDP and oil prices do not respond to the shocks that hit the Canadian economy. The signs of

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8These episodes correspond to the Korean war, the Vietnam war, the Carter-Reagan fiscal expansion and, more recently, the aftermath of the Sept. 11, 2001 terrorist attacks (see Ramey (2011)).
## Table 1: Identifying sign restrictions assumptions

<table>
<thead>
<tr>
<th></th>
<th>Generic business-cycle shock</th>
<th>Government spending shock</th>
<th>Net tax revenue shock</th>
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<tbody>
<tr>
<td>Government spending</td>
<td></td>
<td></td>
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<tr>
<td>Net tax revenue</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Private consumption</td>
<td>+</td>
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<tr>
<td>Private investment</td>
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<tr>
<td>GDP</td>
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<tr>
<td>Net-exports-to-GDP ratio</td>
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<tr>
<td>GDP deflator</td>
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<tr>
<td>3-month T-bill rate</td>
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<tr>
<td>REER</td>
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<tr>
<td>U.S. GDP</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Oil prices</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: The sign "+" means that the variable responds positively for 4 quarters following the shock; the "0" means that the impulse responses of the variable are restricted to zero in perpetuity after the shock.

The main macroeconomic variables are agnostic to the fiscal policy shocks. Note that I chose four quarters because a fiscal year corresponds to four quarters.\(^9\)

### 2.2.2 The VAR model and the identification procedure

The VAR model is specified as:

\[
A(L)y_t = \epsilon_t
\]

where \(y_t \) is a \(m \times 1\) vector of observations, \(A(L)\) is an \(m \times m\) lag polynomial matrix, and \(L\) is the lag operator with the non-negative powers. \(\epsilon_t\) is an \(m \times 1\) vector of structural shocks with:

\[
y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}; \quad A(L) = \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ 0 & A_{22}(L) \end{bmatrix} \quad \epsilon_t = \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \quad \text{and} \quad E[\epsilon\epsilon'] = \Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12}' & \Omega_{22} \end{bmatrix}
\]

\(y_{1t}\) is an \(m_1 \times 1\) vector of Canadian economic variables, and \(y_{2t}\) is a \(m_2 \times 1\) vector including U.S. GDP and oil prices, where \(m_1 + m_2 = m; \epsilon_{1t}\) and \(\epsilon_{2t}\) are, respectively, \(m_1 \times 1\) and \(m_2 \times 1\) vectors of structural disturbances. The dimensions of \(A_{11}(L)\), \(A_{12}(L)\) and \(A_{22}(L)\) are \(m_1 \times m_1\), \(m_1 \times m_2\) and \(m_2 \times m_2\) respectively. The restriction \(A_{21}(L) = 0\) follows from the assumption that the Canadian block variable \(y_{1t}\) does not enter into the second block \(y_{2t}\) either contemporaneously, or with lagged values in the structural form (1). The reduced-form version of the structural model (1) can be written as follows:

\[
y_t = \sum_{i=1}^{P} B_i y_{t-i} + u_t
\]

where \(B_i = \begin{bmatrix} B_{11}^i & B_{12}^i \\ 0 & B_{22}^i \end{bmatrix} \); \(u_t = \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \); with \(E[uu'] = \Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12}' & \Omega_{22} \end{bmatrix}\)

\(^9\)Note that, the inclusion of the interest rate in the VAR helps to control for the impact of the monetary policy changes on variables of interest.
Because the right-hand-side variables of the previous reduced form differ across equations due to the block exogeneity, the estimation of each equation using ordinary least squares (OLS) is inefficient. For this reason, I follow the methodology developed by Hamilton (1994),\(^\text{10}\) transforming the model such that OLS remains efficient. The reduced form model is then transformed as follows:

\[
y_{1t} = \sum_{i=1}^{P} B_{11}^i y_{1t-i} + \sum_{i=0}^{P} G_i y_{2t-i} + v_t
\]

with

\[
E[vv'] = H
\]

\[
y_{2t} = \sum_{i=1}^{P} B_{22}^i y_{2t-i} + u_{2t}
\]

with

\[
E[u_2u_2'] = \Omega_{22}
\]

The previous equations are then estimated equation by equation using OLS. Thereafter, the coefficients of original reduced form (2) are recovered using the following relationships:

\[
\hat{\Omega}_{12} = \hat{G}_0 \hat{\Omega}_{22}, \quad \hat{B}_1^i = \hat{G}_i + \hat{G}_0 \hat{B}_2^i, \quad i = 1,..,P \quad \text{and} \quad \hat{\Omega}_{11} = \hat{H} + \hat{G}_0 \hat{\Omega}_{22}'
\]

To identify structural shocks \(\epsilon_t\), it is necessary to find a matrix \(A\) such that \(u_t = A\epsilon_t\) and \(\Omega = AA'\), with

\[
A = \begin{bmatrix} A_{11} & A_{12} \\ 0 & A_{22} \end{bmatrix}
\]

Let \(n\) be the number of structural shocks to be identified. Mountford and Uhlig (2009) show that identification of these shocks is equivalent to identifying an impulse matrix of size \(m \times n\), that is a sub matrix \([a^{(1)},...,a^{(n)}]\) of the matrix \(A\) such that

\[
[a^{(1)},...,a^{(n)}] = \tilde{A}Q
\]

for any \(m \times m\) matrix \(\tilde{A}'\) satisfying the following relationship

\[
\Omega = AA' = \tilde{A} \tilde{A}'
\]

where \(Q = [q^{(1)},...,q^{(n)}]\) is a \(m \times n\) orthonormal matrix, that is \(QQ' = I_m\). The previous authors identify \(\tilde{A}\) as the Cholesky factor of \(\Omega\). However, with the block exogeneity, the procedure is different. The Appendix shows in details how \(\tilde{A}\) is identified.

Once \(\tilde{A}\) is identified, Mountford and Uhlig (2009) show that the IRF to a structural shock \(s = 1,..,n\) (i.e. the IRF to the impulse vector \(a = a^{(s)}\)) is given as the linear combination of the impulse responses obtained under the \(\tilde{A}\) decomposition of \(\Omega\). Consider \(r_{ji}(k)\) as the impulse response of the \(j^{th}\) variable at horizon \(k\) to the \(i^{th}\) shock (that is, the \(i^{th}\) column

\(^{10}\)Pages 309-312.
of $\hat{A}$) under the $\hat{A}$ decomposition of $\Omega$ and the $m \times 1$ dimensional column vector $r_i(k)$ as the vector response $[r_{1i}(k), ..., r_{mi}(k)]'$, the $m \times 1$-dimensional impulse response $r_a(k)$ \textsuperscript{11} at horizon $k$ to the impulse vector $a$ is given by:

$$r_a(k) = \sum_{i=1}^{m} q_i r_i(k)$$

(7)

where $q_i$ is the $i^{th}$ entry of $q$. Identification of the structural shock $s$, that is the impulse vector $a = a^{(s)}$ with sign restriction consists of selecting the right impulse vector $a = a^{(s)}$ that satisfies sign restrictions imposed on the IRFs. The procedure is explained in detail in the Appendix.

2.3 Data description

The VAR-system is composed of two blocks $y_{1t}$ and $y_{2t}$ of quarterly data from the first quarter of 1970 to fourth quarter of 2010. The first block $y_{1t}$ contains Canadian variables: (a) GDP, (b) private consumption, (c) private non-residential investment, (d) government spending, (e) net tax revenue, (f) GDP deflator, (g) REER, (h) net-exports-to-GDP ratio and (i) the 3-month T-bill rate. Variables (a) to (e) are presented in real per-capita terms by dividing each real variable by the labor force.

Except for the net-exports-to-GDP ratio and the 3-month T-bill rate, all the variables are expressed in log form. Private consumption is comprised of non-durable goods and services. Government spending is government purchases (i.e. the sum of current consumption and public investment). Net tax revenue is the sum of personal and corporate income tax revenues, social security contributions and taxes on production and imports, net of transfers to households and private corporations. Real net tax revenue is obtained by dividing the nominal tax revenue by the GDP deflator ($2002 = 100$). The definition of these variables is in line with previous studies, in order to facilitate consistent comparisons.

Except for the REER, all the variables in the Canadian block are from Statistics Canada’s CANSIM database. The REER, based on relative unit labor costs in the manufacturing sector, is from the Federal Reserve Bank of St. Louis (FRED) database. A rise in the index as shown in Figure A1 (the net-exports-to-GDP ratio declines with an increase of the REER) in the Appendix represents a deterioration in the country’s competitiveness. The second block, $y_{2t}$, includes the logarithm of U.S. real GDP (2005=100) per capita and real oil prices. U.S. GDP is from the U.S. National Income and Product Accounts database. Oil prices are expressed in real terms by dividing the West Texas Intermediate Oil Price (in U.S. current dollars per barrel) taken from the IMF-WEO database by the U.S. GDP deflator($2005 = 100$). I chose the GDP deflator instead of the consumer price

\textsuperscript{11}The $j^{th}$ element $r_{ja}(k)$ of $r_a(k)$, $j = 1, ..., m$ is the impulse response at horizon $k$ of the $j^{th}$ variable to the impulse vector $a$. 

7
index in order to have the same base year as U.S. GDP. Following Ilzetzki et al. (2013), the data used are deviations of non-stationary variables from their linear trend. The results remain unchanged using a quadratic trend.\textsuperscript{12}

3 Results

I estimate a VAR with 2 lags, where the number of lags is chosen using the Bayesian information criterion. I test the exogeneity of $y_{2t}$ with a likelihood ratio test. The results of the test, not shown here, do not reject the null hypothesis of a block exogeneity at the 5-percent level. The following subsection analyzes the IRFs to the identified shocks, assesses GDP multipliers associated with spending and tax increases without and including exogenous variables $y_{2t}$ in the model, studies the impact of fiscal policy shocks over two sub-periods (before and after 1990:Q4), compares the results to existing estimates, and finally compares spending and tax multipliers in order to draw some policy conclusions.

3.1 IRFs to identified shocks

The IRFs to the identified shocks are displayed in the subsequent figures. The shaded areas around the median IRF are the 68 percent confidence regions constructed from 5,000 draws of parameters from the Normal-Wishart distribution. For each draw, the IRFs are computed at each horizon and the 16\textsuperscript{th}, 50\textsuperscript{th} and 84\textsuperscript{th} quantiles are chosen to construct the confidence intervals. The green bands represent the imposed sign restrictions.

3.1.1 Effects of a business cycle shock

Defined as a shock for which Canadian GDP, private consumption, private investment and net tax revenue increase for four quarters following the shock, the IRFs to this shock are shown in Figure 1. The IRFs of these variables remain positive many quarters after the shock. In particular, the response of consumption tends to be highly persistent and behaves in a hump-shaped fashion. This behavior of consumption can be interpreted as a consequence of a higher degree of habit formation. The buoyant response of net tax revenue (net tax revenue increases at higher rate than GDP) can be interpreted as a result of progressive marginal income tax rates. Because government spending here does not incorporate transfers, the response of government purchases is not countercyclical. Instead, as the resources in the economy increase, public investment and current consumption increase too. The decline of the price level is less intuitive, since all components of aggregate demand increase. However, this response could be a result of a countercyclical response of monetary policy (the interest rate increases in response to the shock) to dampen the effect of aggregate demand on the price level. The response of the net-exports-to-GDP

\textsuperscript{12}Although keeping variables in level in the VAR-system would implicitly account for any existing cointegration relationship, variables are detrended because the VAR-system is not stationary with variables in levels.
ratio behaves in the opposite direction of the REER. As the REER increases upon impact, net exports decline and increase when the REER starts to fall.

Figure 1: IRFs to a business cycle shock

Notes: The green areas denote the identified sign restriction assumptions, the blue lines denote the median impulse responses, and the shaded areas denote the 68% confidence region.

3.1.2 Effects of a government spending shock

The IRFs to the government spending shock are displayed in Figure 2. The response of government purchases is positive for four quarters following the shock as imposed by the identifying assumptions. The effect of the shock on GDP is weak upon impact and remains insignificant for many quarters. The response of net tax revenue follows the same pattern as the response of GDP, despite the slight decline upon impact. Private consumption is crowded-in by government spending. While this result is at odds with the standard real business cycle prediction, it is consistent with recent empirical findings regarding the effect of government shock on private consumption. By contrast, private investment is crowded out, as predicted by the standard real business cycle model. The slight increase in the response of the 3-month T-bill rate could explain this result. The government spending shock decreases the competitiveness of the country as the REER appreciates in the aftermath of the shock, subsequently causing a deterioration of the trade balance.
This result in the literature is known as “twin deficits,” that is the coexistence of a trade deficit and budget deficit.

3.1.3 Effects of a net tax revenue shock

The IRFs to a net tax revenue shock are displayed in Figure 3. By construction, the response of net tax revenue is positive for four quarters following the shock. A net tax revenue shock has a negative impact on private activities, as private consumption and private investment fall upon impact. This decline persists for many quarters after the shock. As a result, GDP also declines. Because the impact of a shock on net tax revenue is not persistent, the three variables start to increase as net tax revenue decreases, although the impact remains negative. Government purchases behave procyclically, following the same pattern as the response of GDP. Monetary policy tends to behave countercyclically, where monetary authorities reduce the nominal interest rate to dampen the negative effect of the increase in taxes on the private sector. The co-movement of net exports to GDP with REER in the short run in response to the shock seems less intuitive. While one might expect competitiveness to be reduced due to an appreciation of the REER as the
rise in taxes increases the country’s production costs in the manufacturing sector, the increase of net exports in the first quarters after the shock is unexpected. However, in the long run, net exports fall as the competitiveness of the country declines. The rise of the price level in the short run might be a result of the effect on aggregate supply dominating the effect on aggregate demand.\textsuperscript{13}

Figure 3: IRFs to a net tax revenue shock

Notes: The green areas denote the identified sign restriction assumptions, the blue lines denote the median impulse responses, and the shaded areas denote the 68\% confidence region.

3.2 Measuring the fiscal multipliers

A fiscal multiplier is a measure of the impact on GDP in dollars induced by a change of one dollar in that fiscal variable. I report two measures of the fiscal multiplier: the impact multiplier and the cumulative multiplier. For each fiscal indicator, I also report the maximum response of GDP. The impact multiplier, $M^0_{Y,F}(k)$ measures the change in dollars in GDP at period $k$ induced by a one-dollar change in a fiscal variable in the first period. This is the multiplier typically used in the literature, such as in Blanchard and Perotti (2002). The cumulative multiplier, $CM^0_{Y,F}(k)$ allows to account for the persistence

\textsuperscript{13}The shift of the supply curve to the left as production costs rise with the increase in taxes is larger than the shift of the demand curve to the left.
response of that fiscal variable to the shock (see Auerbach and Gorodnichenko (2012)). It measures the impact in dollars of each shock along the entire path of the responses up to a given period $k$. The indicators are defined as follows:\footnote{It is important to acknowledge that the approach of measuring the fiscal multiplier using IRFs from a VAR is an ad hoc approach not allowing to account for the variation of $F/Y$ over time}

$$M_{Y,F}^0(k) = \frac{r_{Y,F}(k)}{r_{F,F}(0)} \frac{1}{F/Y}$$

(8)

$$CM_{Y,F}(k) = \frac{\sum_{h=0}^{k} r_{Y,F}(h)}{\sum_{h=0}^{k} r_{F,F}(h)} \frac{1}{F/Y}$$

(9)

where $r_{j,F}(k)$ denotes the IRF of variable $j$ to the fiscal shock $F$ at period $k$. Because government purchases and net tax revenue are expressed in logs, the IRFs are scaled by the inverse of the sample average ratio of the fiscal variable over GDP, $F/Y$. For each of the fiscal policy shocks, I calculate the multipliers with and without the inclusion of the exogenous bloc in the model.

### 3.2.1 Case of the government spending multiplier

Table 2 reports the estimated multiplier associated with a one-dollar increase in government purchases within the first quarter. The findings suggest that the sign and statistical significance of the estimated multiplier depend on whether exogenous factors are controlled for. The first panel reports the spending multiplier when the model accounts for exogenous factors. Within the first quarter, the multipliers — impact and cumulative multipliers — are equal to $0.21$. After one year, they remain statistically insignificant.

When the model does not control for exogenous factors, the multiplier within the first quarter is equal to $0.26$ slightly larger than in the previous case. After one year, both multiplier measures become negative. Qualitatively, these results are consistent with the findings of Mountford and Uhlig (2009). In fact, when exogenous factors are not controlled for, the impulse responses of GDP to a government spending shock at all horizons are larger — in absolute value — than the corresponding responses when the model does not account for those factors. As consequence, the implied spending multiplier in absolute value tends to be larger in the former case than in the latter.

### 3.2.2 Case of the tax revenue multiplier

Table 3 reports the estimated multiplier associated with a one-dollar increase in net tax revenue within the first quarter. The size, sign and statistical significance of tax revenue multipliers also depend on whether exogenous factors are controlled for. In the model with block exogeneity, a dollar increase in tax revenue induces a decline of GDP of about $0.32$ within the first quarter. As net tax revenue declines, the impact multiplier becomes non-significant after 2 years while the cumulative multiplier remains negative up to 20 quarters. When exogenous factors are not controlled for, GDP declines by about $0.35$
Table 2: Multiplier associated with spending increases

<table>
<thead>
<tr>
<th>Quarters</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>20</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impact multiplier</td>
<td>0.21*</td>
<td>0.00</td>
<td>-0.11</td>
<td>-0.08</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Govt. spending</td>
<td>1.00*</td>
<td>0.85*</td>
<td>0.64*</td>
<td>0.48*</td>
<td>0.25*</td>
</tr>
<tr>
<td></td>
<td>Net tax revenue</td>
<td>-0.07*</td>
<td>-0.63*</td>
<td>-0.66*</td>
<td>-0.48*</td>
<td>-0.17*</td>
</tr>
<tr>
<td></td>
<td>Cumulative multiplier</td>
<td>0.21*</td>
<td>0.11</td>
<td>0.01</td>
<td>-0.04</td>
<td>-0.03</td>
</tr>
</tbody>
</table>

Model without exogenous factors

|                  | Impact multiplier | 0.26* | -0.50*| -1.02*| -1.19*| -1.03* | 0.26*(1) |
|                  | Govt. spending    | 1.00* | 0.94* | 0.79* | 0.66* | 0.44*  |         |
|                  | Net tax revenue   | 0.02  | -0.93*| -1.39*| -1.47*| -1.22* |         |
|                  | Cumulative multiplier | 0.26* | -0.14*| -0.55*| -0.85*| -1.22* | 0.26*(1) |

Notes: Each panel of this table provides the multiplier associated with a one-dollar increase in government spending in the first quarter. The first and fourth rows represent the impact multiplier and the cumulative multiplier, respectively, for each quarter. The multiplier given here is the median and * denotes that 0 does not belong to the confidence region. The second and third rows represent the response of government spending and net tax revenue. The last column reports the maximum multiplier, and numbers in brackets denote the quarters in which the maximum is observed.

Upon impact. With the decline in tax revenue at a lower rate than in the previous case, the multiplier now gradually becomes positive in the medium term.

Overall, except the first quarter, the negative effects of net taxes on GDP tend be larger when exogenous controls are included in the VAR. These results are in line with the expectations. Indeed, when there is no exogenous control variable in the VAR, a one-dollar increase in tax revenue might come from changes in tax policy, oil prices, and U.S. GDP. Because changes in tax revenue coming from oil prices and U.S. GDP fluctuations do not result from domestic changes to tax rates, they might not have significant effects on GDP. Therefore, the part of the impact coming from changes to tax rates might not be large enough. Controlling for these exogenous changes might therefore increase the negative effects of an increase in net tax revenue on GDP, as this increase results entirely from changes in tax policy.

3.3 Sub-period analysis

To test the stability of the impact of fiscal policy shocks on GDP over time, I split the sample at the 4th quarter of 1990 in order to have two sub-periods with relatively the same size. In addition, the Bank of Canada introduced an inflation-targeting regime in the first quarter of 1991 to stabilize inflation. The early 1990s was also a time of rapid globalization, with greater trade — with the introduction of the North American Free Trade Agreement — and capital mobility. These changes could have affected how the fiscal policy shocks propagate through the Canadian economy. In the following, I study the impact of the government spending and net tax revenue shocks over both sub-periods while controlling for changes in the state of the U.S. economy and world oil prices.
Table 3: Multiplier associated with net tax increases

<table>
<thead>
<tr>
<th>Quarters</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>20</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model with exogenous factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact multiplier</td>
<td>-0.32*</td>
<td>-0.15*</td>
<td>-0.06</td>
<td>-0.01</td>
<td>0.07</td>
<td>-0.32*(1)</td>
</tr>
<tr>
<td>Govt. spending</td>
<td>-0.10*</td>
<td>-0.05*</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Net tax revenue</td>
<td>1.00*</td>
<td>0.46*</td>
<td>0.16*</td>
<td>0.05</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Cumulative multiplier</td>
<td>-0.32*</td>
<td>-0.33*</td>
<td>-0.34*</td>
<td>-0.33*</td>
<td>-0.24*</td>
<td>-0.34*(9)</td>
</tr>
<tr>
<td><strong>Model without exogenous factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact multiplier</td>
<td>-0.35*</td>
<td>-0.10*</td>
<td>0.16*</td>
<td>0.36*</td>
<td>0.59*</td>
<td>-0.35*(1)</td>
</tr>
<tr>
<td>Govt. spending</td>
<td>-0.10*</td>
<td>-0.07*</td>
<td>-0.07</td>
<td>-0.06</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Net tax revenue</td>
<td>1.00*</td>
<td>0.82*</td>
<td>0.65*</td>
<td>0.55*</td>
<td>0.46*</td>
<td></td>
</tr>
<tr>
<td>Cumulative multiplier</td>
<td>-0.35*</td>
<td>-0.25*</td>
<td>-0.09*</td>
<td>0.06*</td>
<td>0.36*</td>
<td>-0.35*(1)</td>
</tr>
</tbody>
</table>

Notes: Each panel of this table provides the multiplier associated with a one-dollar increase in net tax revenue in the first quarter. The first and fourth rows represent the impact multiplier and the cumulative multiplier, respectively at each quarter. The multiplier given here are the median and * denotes that 0 does not belong to the confidence region. The second and third quarters represent the response of government spending and net tax revenue. The last column reports the maximum multiplier (in absolute value) and numbers in brackets denote the quarter in which the maximum is observed.

3.3.1 Sub-period government spending multiplier

Table 4 reports the multiplier associated with a one-dollar increase in government purchases within the first quarter over both sub-periods. The results suggest that the impact of a government spending shock on GDP tends to be larger in the second sub-period than in the first sub-period. Within the first quarter, GDP increases by $0.4 in the first sub-period, while it increases by $0.70 in the second. The maximum effect for the impact multiplier is achieved upon impact for the first sub-period, while it is achieved with a short delay of two quarters in the second sub-period and equal to $0.92.

For the cumulative multiplier, the maximum effect is equal to $0.66 in the first sub-period, while it is equal to $1.09 in the second. However, both effects are achieved after a long delay. Several quarters after the shock, tax revenue falls faster in the second sub-period than in the first sub-period. The persistent response of government spending coupled with this large drop in tax revenue may contribute to the larger impact of a government spending shock on output in the second sub-period.

The higher spending multiplier post 1990 suggests that, on the one hand, the rapid globalization may have played a little role in reducing the effectiveness of government spending in Canada. On the other hand, the inflation targeting regime associated with more effective capital expenditure could have been determinant. Indeed, after 1990, the Canadian economy was characterized by lower: inflation, interest rate and volatility compared to the period before the inflation targeting. The high confidence of the private sector in such environment may have helped to mitigate the crowding-out effect of government spending. Also, it is possible that public investment which is theoretically associated with higher multiplier than recurrent expenditures was more effective in stimulating the economy in
such a context.

Table 4: Government spending multiplier over both sub-periods

<table>
<thead>
<tr>
<th>Quarters</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>20</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970:Q1-1990:Q4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact multiplier</td>
<td>0.44*</td>
<td>-0.07</td>
<td>0.11</td>
<td>0.17</td>
<td>0.09</td>
<td>0.44*(1)</td>
</tr>
<tr>
<td>Govt. spending</td>
<td>1.00*</td>
<td>0.40*</td>
<td>0.24*</td>
<td>0.18</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Net tax revenue</td>
<td>-0.64*</td>
<td>-1.18*</td>
<td>-0.50*</td>
<td>-0.08</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Cumulative multiplier</td>
<td>0.44*</td>
<td>0.10</td>
<td>0.12</td>
<td>0.23*</td>
<td>0.52</td>
<td>0.66(30)</td>
</tr>
</tbody>
</table>

| 1991:Q1-2010:Q4 |    |    |    |    |    |       |
| Impact multiplier | 0.70* | 0.85* | 0.80* | 0.79* | 0.40* | 0.92*(2) |
| Govt. spending   | 1.00* | 1.08* | 0.89* | 0.59* | 0.26 |       |
| Net tax revenue    | 0.01 | -1.08* | -1.33* | -1.02* | -0.46 |       |
| Cumulative multiplier | 0.70* | 0.80* | 0.82* | 0.91* | 1.08* | 1.09*(24) |

Notes: This table reports spending multiplier and responses of government spending and net tax revenue to a government spending shock over the two sub-periods. The multiplier is the median, and * denotes that 0 does not belong to the confidence region. The last column reports the maximum multiplier and numbers in brackets denote the quarters in which the maximum is observed.

### 3.3.2 Sub-period tax revenue multiplier

The impact of a net tax revenue shock on GDP over the two sub-periods is reported in Table 5. In response to an increase in net tax revenue of $1, GDP declines by $0.38 upon impact during the first sub-period and by $0.21 during the second sub-period. The peak response in the second sub-period is equal to -$0.51, while in the first sub-period, it is equal to the response upon impact.

For the cumulative multiplier, the same patterns are observed. The decline in GDP is larger in the first sub-period than in the second sub-period. The response of net tax revenue may explain this different impact on GDP. After the shock, net tax revenue declines steadily in the second sub-period, while the decline in the first sub-period tends to be faster.

### 3.4 Comparison of the results with existing findings

To my knowledge, most of the papers examining empirical evidence of the impact of fiscal policy shocks in Canada do not explicitly report numerical results. Rather, they report the IRFs on graphs, making any quantitative comparison difficult. Therefore, the quantitative comparison is limited to the Owyang et al. (2013) study.

#### 3.4.1 Comparison with Owyang et al. (2013)

Table 6 reports the cumulative multiplier associated with spending increases in both studies. Owyang et al. (2013) estimate spending multiplier, contingent on the state of the
Table 5: Tax revenue multiplier over both sub-periods

<table>
<thead>
<tr>
<th>Quarters</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>20</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970:Q1-1990:Q4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact multiplier</td>
<td>-0.38*</td>
<td>-0.23*</td>
<td>-0.14</td>
<td>-0.07</td>
<td>0.01</td>
<td>-0.38*(1)</td>
</tr>
<tr>
<td>Govt. spending</td>
<td>-0.19*</td>
<td>-0.08*</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Net tax revenue</td>
<td>1.00*</td>
<td>0.53*</td>
<td>0.16*</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Cumulative multiplier</td>
<td>-0.38*</td>
<td>-0.40*</td>
<td>-0.45*</td>
<td>-0.51*</td>
<td>-0.36</td>
<td>-0.51*(13)</td>
</tr>
</tbody>
</table>

1991:Q1-2010:Q4

| Impact multiplier | -0.21* | -0.02 | -0.10 | -0.12 | -0.03 | -0.21*(1) |
| Govt. spending | -0.20* | -0.18* | -0.10 | -0.02 | 0.04 |  |
| Net tax revenue | 1.00* | 0.36* | 0.18* | 0.06 | -0.04 |  |
| Cumulative multiplier | -0.21* | -0.10 | -0.17 | -0.28* | -0.43* | -0.44*(22) |

Notes: This table reports spending multiplier and responses of government spending and net tax revenues to a government spending shock over the two sub-periods. The multipliers is the median, and * denotes that 0 does not belong to the confidence region. The last column reports the maximum multiplier (in absolute value) and numbers in brackets denote the quarters in which the maximum is observed.

economy (characterized by the unemployment rate). They identify a government spending shock as a news shock using expected change in military spending. The comparison with their linear VAR specification shows that over the first sub-period, the multiplier in this study is below their multiplier, but over the second-period, it is slightly above. It should be noted that in both studies, the multiplier is increasing with the number of periods following the initial increase in spending. Also, in the linear case, spending multiplier in both studies is almost below one, characterizing the theoretical prediction of the size of the spending multiplier in open economies.

Table 6: Comparison with Owang et al. (2013)

<table>
<thead>
<tr>
<th></th>
<th>2-year integral</th>
<th>4-year integral</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>My results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-sample 1</td>
<td>0.12</td>
<td>0.38</td>
<td>0.44</td>
</tr>
<tr>
<td>Sub-sample 2</td>
<td>0.82</td>
<td>1.01</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Owyang et al. (2013)

<table>
<thead>
<tr>
<th></th>
<th>2-year integral</th>
<th>4-year integral</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear VAR</td>
<td>0.67</td>
<td>0.79</td>
<td>0.57</td>
</tr>
<tr>
<td>High unemployment</td>
<td>1.60</td>
<td>1.16</td>
<td>0.65</td>
</tr>
<tr>
<td>Low unemployment</td>
<td>0.44</td>
<td>0.46</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Notes: This table compares the multiplier associated with spending increases to Owang et al. (2013)’s multipliers. The integral measure is computed as the cumulative multiplier. The peak measure is the ratio of the IRF of GDP and government purchases at their respective peaks scaled by the inverse of the average ratio of G/Y.
3.4.2 Comparison with other studies

With respect to studies of the impact of fiscal policy in Canada, the rise of private consumption in response to a government spending shock is consistent with the findings of Ravn et al. (2007) and Perotti (2004). The decline of private investment in response to a government spending shock is also consistent with Perotti (2004) findings. With respect to the effect of a government spending shock on net exports, results of this study are consistent with the twin deficits suggested by Corsetti and Müller (2006) and Monacelli and Perotti (2010).

With regard to studies on the U.S. economy, the findings of this paper on the effects of both tax and spending increases on consumption and investment are similar to the results of Blanchard and Perotti (2002) and Mountford and Uhlig (2009). Consumption rises in response to a government spending shock while private investment declines; consumption and private investment both decline in response to tax revenue increases. However, as an open economy, the size of the impact of fiscal shocks in this study is lower than the size in the Blanchard and Perotti and Mountford and Uhlig papers.

3.5 Policy implications: Spending increases vs. tax cuts

Table 7 reports the cumulative multiplier associated with spending increases and tax cuts over the whole sample and over each sub-period. The results suggest that (i) regardless of the period, the multiplier associated with a cut in net tax revenue varies between $0.21 and $0.51, while that associated with spending increases ranges between $0.21 and $1.09; (ii) taxes tend to have a larger multiplier over the whole sample and during the first sub-period than during the second sub-period, but the difference with the multiplier associated with spending is not large enough (in absolute value); and (iii) over the second sub-period, the spending multiplier tends to be larger than the net tax revenue multiplier.

Table 7: Cumulative multiplier associated with spending increases and cut in tax revenue

<table>
<thead>
<tr>
<th>Quarters after shock</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>20</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole sample</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spending</td>
<td>0.21*</td>
<td>0.11</td>
<td>0.01</td>
<td>-0.04</td>
<td>-0.03</td>
<td>0.21*(1)</td>
</tr>
<tr>
<td>Net taxes</td>
<td>0.32*</td>
<td>0.33*</td>
<td>0.34*</td>
<td>0.33*</td>
<td>0.24*</td>
<td>0.34*(9)</td>
</tr>
<tr>
<td><strong>Sub-period1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spending</td>
<td>0.44*</td>
<td>0.10</td>
<td>0.12</td>
<td>0.23*</td>
<td>0.52</td>
<td>0.66(30)</td>
</tr>
<tr>
<td>Net taxes</td>
<td>0.38*</td>
<td>0.40*</td>
<td>0.45*</td>
<td>0.51*</td>
<td>0.36</td>
<td>0.51*(13)</td>
</tr>
<tr>
<td><strong>Sub-period2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spending</td>
<td>0.70*</td>
<td>0.80*</td>
<td>0.82*</td>
<td>0.91*</td>
<td>1.08*</td>
<td>1.09*(24)</td>
</tr>
<tr>
<td>Net taxes</td>
<td>0.21*</td>
<td>0.10</td>
<td>0.17</td>
<td>0.28*</td>
<td>0.43*</td>
<td>0.44*(22)</td>
</tr>
</tbody>
</table>

Notes: This table compares the cumulative multiplier associated with spending increases and cut in tax revenue. Since the effects are assumed symmetric in the linear VAR model, the multiplier associated with net tax increases has been multiplied by -1 to be interpreted as response to tax revenue cuts.
These results suggest that given the size of the multiplier associated with spending increases over the last two decades, a large fiscal adjustment through spending cuts could be more harmful to the economy than tax-based fiscal adjustment.

4 Conclusion

In this paper, I use quarterly data from 1970 to 2010 to study the impact of government spending and net tax revenue shocks on key Canadian macroeconomic variables, employing sign restrictions as an identification strategy. I explicitly control for spillovers from the U.S. economy and for world oil price fluctuations. In addition, I examine the impact of fiscal shocks over two sub-periods: before and after the fourth quarter of 1990.

This paper has several key findings. The estimated value of both spending and tax multipliers is sensitive to the inclusion of relative oil prices and U.S. GDP in the VAR model. Output, consumption and investment decline as a response to an increase in net taxes. Output and private consumption increase when government purchases increase, whereas private investment falls. Net exports decline in response to both spending and net tax increases (with a short delay for the decline in response to the net tax increase) as a result of real exchange rate appreciation. Tax-cut multipliers vary between $0.20 and $0.50, while spending multipliers range between $0.20 and $1.10. Spending multipliers tend to be particularly larger than tax-cut multipliers over the last two decades.

The composition of government spending is relevant for the size of the multipliers. For example, some theoretical and empirical findings suggest that government investment tends to have larger GDP multipliers. Since these issues are not addressed in this paper, they are left for future research.
References


Appendix

Identification of the $\tilde{A}$ matrix

In order to easily recover the block exogeneity, $\tilde{A}$ is chosen as follows:

$$\tilde{A} = \begin{bmatrix} \tilde{A}_{11} & \tilde{A}_{12} \\ 0 & \tilde{A}_{22} \end{bmatrix}$$

The relation (6) in the paper can then be written as:

$$\Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12}' & \Omega_{22} \end{bmatrix} = \begin{bmatrix} \tilde{A}_{11} \tilde{A}_{11}' + \tilde{A}_{12} \tilde{A}_{12}' & \tilde{A}_{12} \tilde{A}_{22}' \\ \tilde{A}_{22} \tilde{A}_{12}' & \tilde{A}_{22} \tilde{A}_{22}' \end{bmatrix} = \tilde{A} \tilde{A}' \quad (A1)$$

- Because of the block exogeneity, $\tilde{A}_{22}$ is identified solely from the lower-right block of (A1) as the lower triangular Cholesky factor of $\Omega_{22}$, which is estimated directly from the $y_2$ sub-system and independently of $y_1$; see (4).

- Once $\tilde{A}_{22}$ is identified, $\tilde{A}_{12}$ is derived from the upper-right matrix in (A1):

  $$\Omega_{12} = \tilde{A}_{12} \tilde{A}_{22}' \quad (A2)$$

  $$\tilde{A}_{12} = \Omega_{12} \left( \tilde{A}_{22}' \right)^{-1} \quad (A3)$$

- Finally, from the upper-left matrix in relation (A1), $\tilde{A}_{11} \tilde{A}_{11}'$ is derived:

  $$\tilde{A}_{11} \tilde{A}_{11}' = \Omega_{11} - \tilde{A}_{12} \tilde{A}_{12}' \quad (A4)$$

  Since the right-hand side of (A4) is symmetric and positive definite, $\tilde{A}_{11}$ is identified as the lower triangular Cholesky factor of the right-hand side of (A4).

Identification of the impulse vectors

Using the penalty function defined in Mountford and Uhlig (2009), an impulse vector $a$ is identified through the following minimization:

$$a = \text{argmin}_{a \sim A_q} \Psi(a)$$

where

$$\Psi(a) = \sum_{j \in J_+} \sum_{k = k_1}^{k_2} f \left( -\frac{r_{ja}(k)}{s_j} \right) + \sum_{j \in J_-} \sum_{k = k_1}^{k_2} f \left( \frac{r_{ja}(k)}{s_j} \right)$$

$s_j$ is the standard error of variable $j$, $J_+$ and $J_-$ are the subsets of variables $j$ such that $r_{ja}(k) \geq 0, j \in J_+$ and $r_{ja}(k) \leq 0, j \in J_-$, respectively, for some horizon $k = k_1, \ldots, k_2$. The $f$ function, which rewards large impulse responses with the right sign and penalizes
impulse responses with the wrong sign, is given by

$$ f(x) = \begin{cases} 
100x & \text{if } x \geq 0 \\
x & \text{if else} 
\end{cases} $$

Now consider $[a^1, a^2]$, the two impulse vectors that help to identify the business cycle shock and the fiscal policy shock, respectively (i.e. the government spending shock and the net tax revenue shock).

$a^1$ is identified as follows:

$$ a^1 = \arg\min_{a = \tilde{A}q, q_i = 0, i = m_1 + 1, \ldots, m} \Psi(a) $$

with $J_- = \emptyset$, $J_+ = \{\text{Canadian GDP, Private consumption, Private investment, Tax revenue}\}$, $k = 0$ and $\bar{k} = 3$.

Once $a^1$ is identified through the choice of $q^1$, $a^2$ is identified such that:

$$ a^2 = \arg\min_{a = \tilde{A}q, q_i = 0, q_i' = 0, i = m_1 + 1, \ldots, m} \Psi(a) $$

with $J_- = \emptyset$, $J_+ = \{\text{Government spending}\}$ or $J_+ = \{\text{Net tax revenue}\}$, $k = 0$ and $\bar{k} = 3$.

The constraints $q_i = 0$, $i = m_1 + 1, \ldots, m$ allow the variables in the second block $y_2$ to not respond to the shock from the first block.

Sources and definitions of data

Canadian data the from the CANSIM data base:

**Real GDP**: Table 380-0002: row 1

**Real private consumption**: Table 380-0002: Sum of personal expenditures on non-durables (row 5) and services (row 6)

**Real private non-residential investment**: Table 380-0002: Sum of total business GFCF (row 10) and business investment in inventories (row 15) minus residential structures (row 11)

**Real government purchases**: Table 380-0002: Sum of government current expenditure on goods and services (row 7), government GFCF (row 8) and government inventories (row 9)

**Net exports to GDP ratio**: Table 380-0002: is obtained as the ratio of net exports (row 19 minus row 22) over GDP (row 1)

**GDP deflator (2002=100)**: Table 380-0003: row 1

**The labor force**: Table 282-0087: row 2. Quarterly data are obtained by taking the monthly average of each quarter. In the database, data are available from 1976. Data from 1970 to 1975 are obtained through documents available at the Université de Montréal library.
**Nominal tax revenue**: Table 380-0007: Sum of taxes on income (row 2), Social security contributions (row 6) and taxes on productions and imports (row 7)

**Transfers**: Table 380-0007: Sum of transfers to persons (row 15) and transfers to business (row 16)

**Net tax revenue** is the difference between nominal tax revenue and transfers, and real net tax revenue is obtained by dividing the nominal net tax revenue by the GDP deflator.

**The three-month T-bill rate**: Table 176-0043: row 34. Quarterly data are obtained taking the average of the monthly data for each quarter.

**Real per-capita variables** (GDP, consumption, investment, net taxes and government spending) are obtained by dividing data in level $y$ by the labor force.

**The REER** is from the FRED database at http://research.stlouisfed.org/fred2/series/CCRETT02CAQ661N

**U.S. real GDP**: NIPA Series ID: GDPC96

**U.S. labor force participation**: NIPA Series CNP16OV. Quarterly data are obtained by taking the average of monthly data of each quarter.

**U.S. GDP deflator (2005=100)**: NIPA Series GDPDEF. Real per-capita GDP is obtained by dividing real GDP by the labor force.

**Oil prices** (Crude Oil (petroleum), West Texas Intermediate 40 API, Midland Texas, U.S$ per barrel) are from the IMF World Economic Outlook database.

**Figures**

Figure A1: Net-exports-to-GDP ratio in percentage and the REER index

![Net-exports-to-GDP ratio in percentage and the REER index](image)

Notes: The left vertical axis measures net exports to GDP in percentages; the right vertical axis measures the REER index