Inflationary Effects of Oil Price Fluctuations in the United States and Canada

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 09, 2011

Keywords: Oil Price, Commodity Currencies, Vector Autoregressive Process, International Macroeconomics, Economics

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Abstract

The goal of this thesis is to investigate the inflationary effects of shocks in oil prices with a specific interest in commodity currency markets. The model includes a comparison between the United States and Canada. The individual effects of exchange rate, Consumer Price Index, Gross Domestic Product and oil price are observed. The study employs a structural vector autoregressive process (SVAR) that returns impulse response functions and variance decomposition analysis using a Sims choleski decomposition. The model is used to provide a comparison between the two countries and investigates possible explanations for differences such as exchange rate pass through. A preview into the findings indicates a significant difference in inflationary response between the two countries with incomplete findings for a possible explanation for this result.

Acknowledgments

I would like to thank God for His blessings and guidance. I am also grateful to many loving family members, especially my mother Janet Vick, who provided me with the wisdom, guidance, support, and love that has allowed me to overcome many challenges. I would like to thank my advisor Dr. Hyeongwoo Kim, my committee, and all of the professors in the Economics department; they have made a lasting impact on my life as a student and as a colleague.

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CHAPTER 1

INTRODUCTION

Inflation is a persistent part of everyday life. It affects all countries, all economies and since it is essentially a price it affects all decisions and economic actions. It can be created by macroeconomic changes like money supply changes, or on a micro level such as increases in inputs of production. It affects any temporal transaction and is the determinant for interest rates. An expectation of future inflation influences decisions in methods of investing. For example, demand for gold and gold price will increase when future inflation is expected. Accurately forecasting inflation can be the marginal difference between success and failure when making economic decisions. Knowing the impact inflation has on the economy as well as the individual or firm, it is not a surprise that it is a topic frequently researched. The purpose of this paper is not to accurately forecast inflation as there is already much literature and theories on the subject. Rather, this paper will focus primarily on looking into differences between inflation changes in the United States and Canada.

A commodity currency country is a country who is a large exporter of commodity goods. As a result of the large exports the exchange rates of the country are correlated with commodity prices. This occurs in many developing countries, but occurs in some developed countries. The most well known developed commodity currency countries are Australia, New Zealand and Canada. Commodities are also usually inputs in production. If this is the case then an increase in a commodity price will increase CPI and inflation. However, it has been observed that in a commodity currency country the CPI will increase, but not nearly as much as other countries. A

brief look at this and a preview of the model can be seen in the case of New Zealand, Canada and the United States responses in exchange rate and CPI to an increase in commodity prices (Figures 1 & 2). It is apparent that for the commodity currency countries CPI does not have as much of a positive response as the United States, and exchange rate has a positive response to increases in commodity prices.

Oil price is a hot topic that is constantly being discussed especially in recent years. Oil price is a major input in production in most countries, especially developed countries. This being the case it is expected that as oil price increases inflation will increase steadily in all countries. Oil price can be considered a commodity good and behaves similarly to other commodity goods. After seeing how commodity currency countries respond when approached with commodity price increases the same effects may occur with oil price. I predict that inflation will behave differently between Canada and the United States when presented with an oil price increase, and Canada will act similar to its response to an increase in commodity prices. International trade can benefit greatly from knowing any differences in two similar countries when presented with the same shock. This information would benefit policy makers, individuals and firms that trade on open markets. It may even have some profitable application to exchanging currencies between a commodity currency country and another country.

The purpose of this paper is to compare responses of a commodity currency country and a country that behaves differently. The United States and Canada are chosen as the two countries. It is expected that the inflationary response of Canada will be less than that of the United States as is seen with the commodity currency index example. If this result is attained then this paper will also explore possible causes for this difference between the two countries. An early hypothesis of this is that an upward shock in oil prices will make the Canadian dollar

stronger. This will in turn have two effects on the CPI of Canada. The first is an obvious relationship treating oil as an input to production of many goods. This will drive consumer prices of all goods upwards. The second effect comes from the concept of pass through due to the stronger Canadian dollar. The stronger dollar will have a negative effect on exports. Knowing that the simple GDP equation is:

$$(1)\ Y = C + I + G + NX$$

We can infer that a decrease in exports will create a decrease in GDP creating a recessionary effect that may cause a deflationary effect. This is an idea that will be tested using several different impulse response functions and variance decompositions.

This thesis will test this theory based on a four variable vector autoregressive model using Canada as an example of a commodity currency, and using the United States as a control example of a country whose exchange rates do not behave as a commodity currency. This paper will include a literature review that includes considerations on exchange rate pass through, commodity currencies, and some examples of similar models. The model will be presented, the data will be discussed, followed by results and findings and ending with a conclusion chapter.

CHAPTER 2

LITERATURE REVIEW

Although there is no evident previous work with this same exact form there are some similar models regarding exchange rate pass through in other countries. Some of these examples were observed including Leigh and Rossi's interpretation of Turkey, Parsley's research on South Africa, Chowdhury and Siddique's research for Bangladesh and others. Also papers were examined looking into possible misspecifications of this paper's model in an attempt to better direct future models and research. These were regarding monetary policy and floating exchange rates and will be discussed in a future chapter. Two papers became the most influential for the purpose of this paper and will be discussed fully in this section.

Jonathan McCarthy researches exchange rate pass through using a similar model in his publication "Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies" (2000). This paper uses a VAR model to look at the impact of import prices and exchange rates on PPI and CPI. Although Canada is not included as one of the countries the list includes: United States, Japan, Germany, France, United Kingdom, Belgium, Netherlands, Sweden, and Switzerland. What can be learned from this example is how non-commodity currencies have been shown to behave using VAR techniques using choleski decompositions to return impulse response functions and variance decompositions. The variables include CPI, PPI, oil price as a supply shock, output gap as demand shocks and other methods including distribution chain of pricing to more accurately identify the VAR model. He uses quarterly data after the Bretton Woods beginning in 1976 with 4 lags. His method of creating

stationarity is to de-trend the log of the variables creating a trend stationary process capable of running the SVAR. The forecast sample for the impulse response functions and variance decompositions is 2 years. He finds that "impulse response functions indicate that exchange rate shocks have modest effects on domestic inflation in most countries ... while import shocks appear to have a larger effect." (McCarthy 2000). Also he includes that the variance decompositions indicate that exchange rate and import prices are "relatively modest." There also is a concern with large countries versus small countries. A large country's effects in currency depreciation will be counteracted by a decline in the world price. A small country will have no effect on world prices. This implies that pass through should be greater in smaller economies (McCarthy 2000). This provokes the concern of whether to consider Canada a large country or small country when considering its implication. Chen & Rogoff in a different paper that will be discussed later in this chapter will have some insight on this. As results to his model he finds that in all countries the initial impact of exchange rate appreciation is negative. He finds very modest disinflationary effects from pass through in all countries except the United States. After conducting his analysis he asserts that pass through is not a good indicator of the decline in inflation in the 1990's. This effect most likely came from other factors such as monetary policy and active central banks having more success controlling inflation. McCarthy's paper gives an example of some research using VAR's that test for pass through using impulse response functions and variance decomposition analysis. The paper also provides some basic information on how many countries behave regarding pass-through.

"Commodity Currencies" by Yu-chin Chen and Kenneth Rogoff (2002) investigates specifically countries that are considered to be commodity currencies. The 3 countries chosen are Australia, New Zealand, and Canada. The movements between exchange rates and commodity

prices in New Zealand and Australia are very highly correlated. Canada suggests a "long-run cointegrating relation between commodity prices and the real exchange rate, with relatively weak co-movement in the shorter run." (Chen & Rogoff 2002) This may be due to the de facto moving band regime that Canada operated under in their sample period. This is a loose band around the US dollar that Canada used to somewhat peg their exchange rate. This is discussed in Reinhart and Rogoff's paper (Reinhart & Rogoff 2002). The sample is after the Bretton Woods period for Canada which was 1970, and after 1983 for Australia and 1985 for New Zealand when they began using floating exchange rates. This is to ensure that the data is using a floating exchange rate that had been implemented for a sufficient amount of time. The paper argues that all three countries are "on the whole, price takers in world markets for the vast majority of their commodity exports." (Chen & Rogoff 2002). This allows one to treat Canada as a price taker avoiding the complications that McCarthy had brought up regarding large and small countries affecting world prices. The paper compares the commodity prices to the exchange rates of the currencies using real exchange rates adjusting nominal exchange rates by the relative CPI's. Australia and New Zealand can be treated as trend-stationary, but there is an issue with Canada that suggests it may not survive de-trending. Since this paper's model involves de-trending logged variables this may prove to be a problem. The results are that New Zealand and Australia are related using ordinary least squares (OLS) and dynamic ordinary least squares (DOLS). Canada is only significant using the DOLS method implying only a long-run cointegrating effect as mentioned before. The authors report this finding as a possible effect of the de facto band or that Canada may not be classified as a "true commodity economy" since commodities do not make up the majority of its export base. The paper concludes with findings that "world prices of commodity exports, measured in real US dollars, do appear to have a strong and stable influence

on the real exchange rates of New Zealand and Australia. For Canada, the relationship is somewhat less robust, especially to de-trending" (Chen & Rogoff 2002).

This paper gives very strong insight into how Canada may behave as a commodity currency. The authors do support the idea that Canada deserves to be included as a commodity currency and behaves like a commodity currency more than other countries, but there are some issues with Canada that bring up other possible factors that influence the Canadian exchange rate. It also gives us a textbook example of a commodity currency in New Zealand. This will be important in this paper since New Zealand is used as an example of a country that behaves like a commodity currency.

CHAPTER 3

THE MODEL

The purpose of this paper is to observe differing inflationary effects between commodity currency countries and non-commodity currency countries when confronted with an oil price increase. The United States and Canada are picked as the countries that fit this description. These countries are picked because they trade often and freely as members of NAFTA, and they are similar in social and political regimes. Assuming the expected result is found concerning CPI in both countries this paper will also explore possible explanations for this behavior. One way to explain these results is to attempt to extract the effects of one variable and define its effect on one other variable. This can be achieved using several methods such as principal component analysis or impulse response functions. This paper will use a Structural Vector Autoregressive (SVAR) model and will derive impulse response functions and variance decomposition analysis through a choleski decomposition and specific ordering using Sim's 1980 method. This method was chosen due to its simplicity and because the data used can be interpreted economically and ordered ensuring orthogonality between variables that will be discussed later in this chapter. A brief discussion of the SVAR model can be found in the illustrations section (Illustration 1).

The SVAR model with the Sim's choleski decomposition is used as the structure for the impulse responses that are attained to attempt to explain the shock that oil price will have on CPI, exchange rate, and how a shock in the exchange rate may have an effect on GDP and if that effect is transferred directly into CPI. By breaking the problem down into its original shocks and effects the model hopes to put the pieces back together to make some economic sense out of the

results. To achieve these ends the model uses the SVAR with 4 endogenous variables: oilprice, real effective exchange rate, consumer price index, and real GDP. The model uses 4 lags and a forecast period of 5 years. The oilprice (OP) is in US dollars and is deflated by the United States CPI. The real effective exchange rate (REER) is an index. The consumer price index (CPI) is in home country's currency, and the real gross domestic product (RGDP) is in home currency. More information on the data values and where they are found is presented in the data section following this section. Since there are assumptions that must be made I chose to keep the model as simple as possible to avoid any human error in the less tangible decision of ordering. The model appears as:

$$(2)\ \mathbf{y}_t = \mathbf{B}_1\mathbf{y}_{t-1} + \mathbf{B}_2\mathbf{y}_{t-2} + \ldots + \mathbf{B}_p\mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t$$

where $\mathbf{y}_t$ is a vector with the terms ordered as follows:

$$(3)\ \mathbf{y}_t\text{: } [OP_t, REER_t, CPI_t, RGDP_t]$$

I chose this ordering since oilprice has effects on all three variables on its own and RGDP depends upon the first 3 variables more than they depend on its own movements. Especially when considering Canada or other high export countries I assume that the exchange rate will have a larger effect on CPI when it moves than it would have on itself when CPI makes similar moves.

The data is required to be stationary to forecast accurate variance decompositions and impulse response functions. I used logs of the variables and removed the trend. This technique is similar to the one used in McCarthy's paper (McCarthy 2000) and it is commonly used with trend-stationary level data. The issue of Canada not being trend-stationary indicated by Chen & Rogoff (2002) requires special care. A stationarity test returning inverse roots indicates that all of the inverse roots fall inside the unit circle for both Canada (Figure 3) and the United States

(Figure 4).This indicates that the model is jointly stationary and thus can be used in a SVAR process. The data meets the sufficient requirements to use a SVAR and the ordering matches conventional wisdom on the subject. The following section will further discuss the sample size and other specifics of the data.

CHAPTER 4

THE DATA

All data collected for the United States and Canada is quarterly and comes from the IMF International Financial Statistics (IFS) database CD-Rom found at the Auburn University Library. The oil price is the Western Texas Intermediate Oil priced in dollars per barrel. The Real Effective Exchange Rate (REER) is an index based on relative consumer prices. The CPI is the consumer price index of all cities over 30,000 in the home currency. The GDP is seasonally adjusted nominal GDP in billions of dollars of home currency. The GDP deflator is in 2005 terms. The sample size is from 1980:I to 2010:III. The 123 sample model includes the 4 variables listed in the model: OP, REER, CPI, and RGDP. The values for REER and CPI are already in the correct form, but OP and RGDP needed manipulation. All the variables and the calculations required are listed in the tables section (Table 1).

The data in the following figures and the above model use abbreviations. Here I will provide a list of all abbreviations used in the model and data:

A. Variable Legend

CPI - Consumer Price Index in home country's currency (cities over 30,000)

C$ - Canadian Dollars

GDP - Seasonally adjusted nominal GDP in home country's currency

GDP DEF - Deflator used in the calculation from nominal to Real GDP in 2005 dollars

IRF - Impulse Response Function

REER - Real Effective Exchange Rate relative to Consumer Prices

REERCP - Same as REER … indicates that the REER is relative to Consumer Prices

RGDP - Real Gross Domestic Product

oilprice - Western Texas Intermediate in US dollars per barrel

OP - oilprice given in US dollars and deflated by US CPI

US$ - United States Dollars

VAR - Vector Autoregressive process

CHAPTER 5

RESULTS

The vector autoregressive process is effective in returning impulse response functions and variance decompositions. The impulse response functions can be plotted to show how different variables respond to each other given a standard shock. This is useful when attempting to determine how endogenous variables move together. Since the focal purpose of this paper is to observe movements in oil prices and CPI, this is a good place to start explaining variables. Variance decompositions are derived using the choleski decomposition on the variance covariance matrix and can be obtained quite easily with VAR models. The variance decompositions show how much of a contribution variables have on each other at each period. This is very useful when combined with impulse response functions because where the IRF's give a sense of direction the variance decompositions give a sense of force.

Since the responses can be found on every variable's effect on each other it is clear to see that with a 4 variable VAR sixteen responses can be obtained. For this paper I have selected 6 responses that attempt to describe the important movements in RGDP, CPI, and REER when presented with oil price shocks. As the focal point of the paper, the response of CPI to a shock in oil price is presented first. This is the most important response when looking at the direct impact of oil price to inflation. As an attempt to break down and explain this response five other responses are also calculated and presented. The response of REER to a shock in oil price is presented to show the effect oil price fluctuations have on strength of currency in international

markets. The response of CPI to a shock in REER attempts to find some closer relationship between inflation and exchange rate fluctuations. RGDP is an indicator of a country's current status of growth and may affect CPI. The last three responses attempt to capture any influence of oil response on RGDP.

The response of RGDP to a shock in oil price looks at the broad effect that oil price fluctuations have on RGDP. The response of RGDP to a REER shock observes RGDP's responses to exchange rate fluctuations. This is included to observe if the strengths of currencies change exports enough to affect RGDP. The last response is the response of CPI to a shock in RGDP. This finishes the exploration by attempting to determine any inflationary changes that occur due to changes in RGDP. All impulses are standard positive shocks. As a result of this some of the analysis may seem inverted when there is an expected negative shock. This will be pointed out and approached carefully when encountered. Graphical manipulations may also be provided to account for negative responses.

This chapter will include in depth analysis of these six impulse responses for Canada and the United States. The impulse response functions are graphed and included in the Figures section of this paper. The variance decompositions are in table form in the Tables section. The shaded columns of the variance decompositions indicate the variables that are observed with impulse responses. The chapter will be organized in four sections. The first will be detailed individual analysis of each impulse response graph and variance decompositions for the United States. The second section will behave the same except for Canada, and the third section will provide the two countries graphed together and will discuss differences between the two countries. The last section will highlight important points and findings and will conclude the results chapter.

A. United States

The first response that is analyzed is the response of CPI to a shock in oil price (Figure 5). The response begins with a sizable positive shock that is persistent and significantly positive for the first 6 quarters. After this point, the responses begin to steadily decrease back towards zero and eventually end up slightly negative in point estimate after the 10th quarter, but with no statistical significance. This indicates that there is a definite positive shock for the first 6 quarters followed by a reversion back to zero. This appears to be an expected result. We can gather more information from this effect by analyzing the variance decompositions.

Some more information can be attained by looking at the variance decomposition of CPI (Table 3). Firstly we observe that the value of CPI decomposes very quickly. In the 5 year period it is nearly entirely explained, and much of this is consumed by the second year. The piece of the table concerning oil price effect on CPI is found in the 2nd column from the left labeled l_OP. It is easy to see that oil price has a strong effect on CPI especially in the earlier quarters. By the 5th quarter 55% of CPI is explained by oil price. It eventually declines and gives way to exchange rate and GDP effects.

These results are consistent with each other and are very close to what is expected with a country like the United States. The CPI significantly increases as a result of an oil price shock, most likely due to an increase in an input in production driving up costs to firms and consumers. The shock eventually wears off after a few years as companies readjust their production functions and as exchange rate and GDP change other factors in the economy.

The second impulse response function that is focused on is the response of REER to an oil price shock (Figure 6). This shock stays negative in point estimates throughout the entire 5

year period, but is only significantly negative in the first 2 quarters. The initial movement is a strong negative shock in exchange rate to an oil price shock. This lasts for 2 quarters and, as mentioned above, is significantly negative at the 90% confidence level. After this there is a strong movement back to just below zero. It remains at this level mildly fluctuating for the remainder of the period tested, and is insignificant in sign.

The variance decompositions of the REER (Table 2) give support to the impulse response functions. Firstly we observe that throughout the 5 year period REER retains much of its explaining power. This indicates that the variables picked do not have a considerable effect on the real effective exchange rate. In the case of the United States this is an expected result. Under the shaded column labeled l_OP we can observe the oil price effects on REER for the United States. In the first few periods there is a small but relatively noticeable impact on REER. In fact it is the most impact of any variable at any other time period on REER. This is consistent with our impulse response functions.

Both the impulse response function and the variance decompositions seem to indicate similar results. In the first few quarters exchange rate decreases as a result to an oil price increase. After this, the response is not significant or focused for the rest of the period. As seen in the variance decompositions the exchange rate is hardly influenced by the other variables in this model. As a concluding result it appears that the exchange rate moves downward and the currency becomes weaker as oil price goes up in early quarters. This is expected and reasonable given the importing relationship the United States has with oil. Concerning the variance decompositions the result is noted, but not considered to have a very strong effect.

The third response analyzed is the response of CPI to a REER shock (Figure 7). The response begins around zero and ends with a fairly negative response that begins a descent after

approximately a year. The first 5 quarters are insignificant to a sign change as are the last 5 quarters, but quarters 6 through 15 are significantly negative at the 90% confidence level. This implies that after a positive shock in exchange rate there is little or no change to CPI in the first year, but about midway through the second year until the 4th year there is a significant negative shock to REER.

The variance decompositions of CPI (Table 3) will give a better indication of the strength of this response. The shaded column labeled l_REER shows the explanation power that the exchange rate has on CPI. As we observed before, oil price has the dominant effect for the first year or two leaving very little effect from REER. By the third year oil price and the exchange rate is responsible for a near equal amount of CPI movement. This result indicates that by the end of the second year and into the fourth year there is a significantly negative impact on CPI when encountering an exchange rate shock.

The impulse response functions and variance decompositions are in agreement. It is observable that by the third year there is a negative effect on CPI as a result of an increase in REER. It is important when looking at many impulse response graphs together to remember that all responses are drawn to a positive shock. For the United States we recall that the first 2 periods after an oil price shock there is a negative response in exchange rate. The graphs that we just analyzed involved a positive shock to REER, or a stronger dollar. Given the information we have obtained we can attempt to further explain the original graph by using its parts if we are careful. This being said, it can be observed that around the 3rd year after an oil shock CPI should increase due to a chain of events:

(4) OP ↑, REER ↓, CPI ↑

Oil price goes up, therefore initially REER goes down, 2 and a half years after this downward shock of REER, CPI should increase slightly. If we revisit the impulse response function of CPI to a shock in Oil Price (Figure 5) we find a slight leveling out of CPI where it had previously been decreasing around this period. These results are not very clear and involve many problems before one can make the jump to causation. The first major issue with this finding is that when we were discussing oil price's effect on REER it was significant, but did not have a lot of explaining power when looking at the variance decompositions. It is difficult to draw any major conclusions from this result, but it deserves to be mentioned.

The fourth impulse response function observed is the response of RGDP to an oil price shock (Figure 8). The responses begin near zero and begin to have a negative response around the end of the first year. By the middle of the second year the response is significantly negative, and the responses continue to fall until the 9th quarter where it begins to slowly climb. The 5th to the 12th quarter are significantly negative at the 90% confidence level. The impulse response functions seem to imply a negative response in RGDP to a shock in oil price from the middle of the second to the end of the third year.

The variance decompositions of RGDP (Table 4) also indicate this type of movement. First we notice that RGDP is unaffected by all variables until the end of the third year. Even by the end of the period it is not explained fully, but it is noticeably explained by oil price and REER. The shaded column labeled l_OP provides information on oil price's ability to explain RGDP movements. Oil price gives very little explanation until the 7th quarter. From this point it begins to rapidly increase until quarter 13 where it levels out. These results back up the claims made by the impulse response functions. Oil price has little effect until the end of the second year and increases and remains a powerful variable for the rest of the period.

The impulse response function and variance decompositions reinforce each other to make a case that as oil price increases RGDP will decline in the United States significantly between the end of the second year and the beginning of the third year. This response is expected and reasonable. Oil price increases could drive the U.S economy into recessions, and it has been shown to do so. Although oil price seems to have the most effect on RGDP we also recognize that exchange rate carried some weight, especially in later models.

The fifth impulse response function observed is the response of RGDP to a shock in REER (Figure 9). These responses begin slightly negative and near zero for the first year and then increase positively for the remainder of the period. This would seem to imply a positive shock between the exchange rate and RGDP. The problem that immediately occurs in this model is that none of the responses are significant in sign. The point estimates increase a noticeable amount, but it is difficult to make any strong claims due to the large confidence bands. Perhaps the variance decompositions can give some more insight.

As observed before, the variance decompositions for RGDP (Table 4) indicate that few variables influence RGDP until the end of the second year when oil price begins to have sizable explaining power. The row labeled l_REER can give us some further insight specific to the exchange rate power over RGDP. Like oil price there is very little power early in the period. Around the middle of the third year a noticeable amount of explanatory power begins rising steadily until the end of the period. The impulse responses and variance decompositions imply a possible positive relationship between exchange rate and RGDP in later quarters.

When attempting to make conclusions about this result it must be noted that none of the responses are significant in sign at the 90% confidence interval, and that the explanatory power is not dominant at any point. For the sake of recording the results, we will do an analysis of the

effects anyway. Again remembering that when oil price goes up REER initially goes down we can draw the chain of events:

(5) OP ↑, REER ↓, RGDP ↓

It is also noted in the earlier response that as oil price goes up RGDP goes down. Looking at the point estimates of the responses we see that the two move together to affect RGDP in the same downward pull. Given the timing of the responses the results may be correlated, but also could move together due to REER's immediate response to the oil price shock weakening the U.S dollar. This would make imports seem more expensive and exports cheaper to other countries in this early period. As a country that focuses on imports, this could theoretically be a cause for a recession. That being said, the results do not seem very likely, and the insignificant responses combined with weak explaining power reinforces this result as unlikely. It is a good exercise to look at these effects since it is hypothesized that a similar effect may be significant for an export heavy Canada.

The last impulse response function connects the chain of parts back to the original finding. It observes the response of CPI to a RGDP shock (Figure 10). The responses are immediately positive with a good deal of persistence. The first 2 responses are not significant at the 90% confidence level, but the remaining 18 are significantly positive. For the first year and a half the CPI increases until it begins sloping off and remaining positive for the remainder of the period. This response is consistent and significant.

The explanatory power of this result can be observed using the variance decompositions of CPI (Table 3) once again. In the column labeled l_RGDP we find that after the first year there is a noticeable increase in explanatory power until the end of the second year. After this the power remains roughly the same throughout the period. These findings reinforce the positive

findings in the impulse response function. After the second year there is an increase in CPI as a result of an increase in RGDP.

These results are expected for the United States. As RGDP moves up we expect inflation due to an expansionary effect on the economy, and as it moves down we expect a recessionary effect on the economy and decreased inflation. Piecing all of the graphs together we can once again create a possible chain of events such that:

(6) OP ↑, REER ↓, RGDP ↓, CPI ↓

This chain of events for the United States is contrary to the positive effect we actually see on CPI from an oil price shock. The insignificance of many of the results above make this result dubious. The results are noted; however, as containing some importance for discussion.

In conclusion, the results of an oil price shock on CPI in the United States have multiple paths. One is the obvious price of input path which deduces that oil price is a price of an input to most products somewhere in production or transportation. The second is the positive effect that REER directly has on CPI found in equation (4) above. The last effect is the response of RGDP bringing the CPI back down after a couple of years. Looking at this last method it is observed that REER may have an opposite effect on CPI through the equation (6). Looking at these opposing effects we consider an exchange rate pass through effect. This indicates that oil price influences the strength of the dollar which will change trade and eventually pass through into consumer prices.

As observed in the initial response in CPI (Figure 5) price it is clear to see that in response to an oil price shock CPI immediately takes off and then eventually by the end of the second year returns to normal. First the price of input path followed by the RGDP path that brings it back down. It is then observed that a decrease in RGDP will bring the CPI back down

after several years. A problem occurs with the late conflicting results that REER may have on CPI. This could be a cause for a longer inflationary response. Given the fact that the exchange rate effect on RGDP is insignificant this result will not be considered as a source of interpretation for the United States. Sorting through these differences it is possible to see that for the United States the CPI increases rapidly for over a year due to oil being used as an input in production. The CPI will later decrease due to an eventual RGDP decrease three years later slowly bringing inflation back down. The REER effect on CPI is conflicting in some ways and not considered to have strong significant effects on CPI.

Given these findings we discover an expected relationship between oil price and the United States. Exchange rate pass through occurs positively affecting CPI in the United States, but has very little impact on immediate responses to inflation. The leading cause of the immediate inflationary response to positive movements in oil price in the United States is the direct effect that oil price has on CPI as observed in the impulse response functions and variance decompositions. RGDP responses in later years fall, bringing inflation down as a result of the recessionary effects. Knowing this information, many inferences may be made about the United States and her behavior to oil and international markets. A full synopsis of these behaviors will be interpreted later in section C alongside a comparison with Canada.

B. Canada

The analysis of Canada will occur in the same format as the United States analysis of the six responses. The first impulse response observed is the response of CPI to an oil price shock (Figure 11). There is a small increase in CPI for the first year and a half followed by a decrease in CPI. Only the first two responses are significant at the 90% confidence level. Given the

significance levels of the responses it is clear that the CPI response is initially positive and then decreases and becomes possibly negative by the second year.

A look into the variance decompositions of CPI (Table 6) may help with determining the strength of this movement. On first observation we notice that CPI is not nearly as explained as in the United States, especially in earlier quarters. Eventually, by the last couple years CPI is explained mainly due to later changes in RGDP. The oil price explanation is the shaded column labeled l_OP. We note a small but consistent effect on CPI from oil price. This result is not overpowering, but enough to give the impulse response function credibility.

The response of CPI to oil price is initially positive and looks as expected. The explanation power is smaller than expected, but relative to the other variables is significant, especially early. The fact that CPI is not explained very thoroughly when looking at the variance decompositions may imply that there is a variable in the Canadian model that is not being represented. The response is similar to the United States in movement, but is not as positive in magnitude and seems to decrease earlier. Also the explanation power coming from oil price is not nearly as strong. It is already apparent that there will be some differences between the two countries.

The second response for Canada that is analyzed is the REER response to a shock in oil price (Figure 12). This response is initially positive for a little over a year and then decreases and persists just below zero in point estimates. None of the points are significant in sign at the 90% confidence level; however, the first one is just barely insignificant. Given the closeness of the significance I will treat the REER response as a positive one. In the Canadian model there is much less significance in sign, but for the sake of interpretation I will make some assumptions regarding point estimates after pointing out their insignificance. This response is expected for

Canada since it is such a large exporter of oil. As a result, the Canadian dollar should move with the oil price, and appears to behave like a commodity currency.

The variance decompositions of REER (Table 5) may give some more information to this response. The first thing observable is that the Canadian REER is not explained thoroughly in the first 3 years, but does get some explanation from the CPI in later periods. This is a strange result not seen in the United States model, and may indicate some sort of inflation targeting policy by the government or other missing variable in the model. This is an interesting point, but not the primary investigation of this model at this time. Oil price's explanation power is in the column labeled l_OP. Overall throughout the period there is very little explanation power coming from oil price, but like the United States the most comes from the first few periods. This makes sense as the exchange rate response is usually a fast and brief response to a shock.

Overall, the effect that oil price has on exchange rate fluctuation is less than previously expected. However, it does move in an expected fashion and may become a stronger factor as it impacts other variables. The insignificance of sign in the response makes it difficult to produce definite results, but the shape and movements are enough to imply that there is most likely a positive response to an oil shock. In comparison to the United States the response is similar but opposite in sign to what is observed. This result is expected due to the difference in trade structure relating to exports of oil. Given this information it is now possible to explore the effects this movement of exchange rate will have on the other variables.

The third impulse response investigated is the response of CPI to a shock in REER (Figure 13). The responses are consistently positive in point estimate for much of the period. There is an early fluctuation in the first year and reaches its most positive point by the 5th quarter. After this point it slowly decreases until reaching zero by the end of the period. The 5th

and 6th quarters are significantly positive at the 90% confidence level, and it is worth noting that the first quarter's positive response as well as the 7th and 8th quarters are close to significant. This being said, it appears that the response is likely positive for the first 2 years and still likely to be positive until the end of the fourth year. This is an opposite but similar result to the United States which behaves the same way since the REER sign is different as well.

The variance decompositions of CPI (Table 6) can give us more insight into how much can be explained from this result. The variance decomposition of exchange rate's effect on CPI can be found in the column labeled l_REERCP. in the first year there is very little significance after the first quarter, but the effect increases until the end of the third year and then levels out. Around this time period the exchange rate shock surpasses even the oil shock on CPI in explaining power. The numbers are not very large, but relative to some of the other variables it is a sufficient amount.

Based on the results found in the impulse response as well as the variance decompositions there is a positive response in CPI to a positive exchange rate shock. This most likely occurs initially and then resumes in the second year and continues with a good deal of persistence. This response is similar to the United States result and may also have a very small impact on CPI; however, the result is not very large and may not have a very large influence on the overall movement of CPI.

The fourth response observed is the response of RGDP to an oil price shock (Figure 14). The initial shape of this graph is troublesome since it changes sign three times throughout the 5 year period. RGDP appears to initially increase a small amount for the first year, and then it decreases rapidly until the end of the second year and remains negative while slowly rising back to zero by the end of the fifth year. There is no 90% significance in sign at any point, but the first

quarter is extremely close. The result is unclear by observation. Perhaps the variance decomposition can assist in explaining this movement.

The variance decompositions for RGDP (Table 7) indicate that the RGDP is explained to some degree in the model but mostly by CPI. This result is unexpected and not seen in the United States model. Oil price's explaining power is shown in the column labeled l_OP. It appears that there is very little effect on RGDP as a result of oil price. The numbers get larger at the end of the second year and stay level from then on but are still small.

Given the impulse responses and variance decompositions it would appear that we can make a modest claim for a small increase in RGDP in the first quarter. After that there is stronger, but still weak, evidence that RGDP decreases as a result of a positive oil price shock. The CPI response to RGDP is unusually strong and occurs similar to the impact it had on REER. This is an interesting point to discuss at a later time and something to consider when examining the next response.

The fifth impulse response function is the response of RGDP to a shock in REER (Figure 15). Looking again at point estimates it seems to move similarly to the RGDP response to a shock in oil price except much longer and smoother in its movements. This is not unexpected since we have seen a positive relationship between REER and oil price. None of the points are clearly significant in sign, but the 14th and 15th quarter are very close to 90% significance. The response appears to increase initially until the end of the second year and then slowly decrease for the rest of the period. This result again implies another variable moving RGDP other than oil price or exchange rate as in the hypothesis.

The variance decomposition for RGDP (Table 7) once again shows results implying strong explanation by CPI. The exchange rate explanation power can be found in the column

labeled l_REERCP and like oil price does not carry much weight until very late in the period. As seen by the significance in the impulse response function after the 15th quarter there is some decent explaining power from exchange rate, but not enough to make much noise especially compared to the CPI's power.

Observing the response of RGDP to an exchange rate shock gives very little definite evidence to support any strong movement or relationship between the two variables. It is similar to the response of RGDP to oil price and does not indicate results as expected by the hypothesis of exchange rate pass through as a leading factor in Canadian inflation. Also the investigation evokes curiosity into the direct effects of CPI on RGDP responses. This new finding indicates that there may be an unaccounted variable that moves the inflation other than oil price or exchange rate.

The last impulse response function studied is the response of CPI to a RGDP shock (Figure 16). There is an initial decrease for a year followed by a rapid increase. The decrease looks different from the United States, but is not entirely unexpected for Canada. After a year and a half the response moves strongly upwards and behaves very similarly to the United States. The 4th quarter is significant in sign and is the only negative response that is significant. The 8th quarter through the end of the period are all significant at the 90% confidence level and positive. The first year may have an instant downward shock on CPI when combining this response to the previous response, but as a result of something besides the hypothesis that RGDP decreases as a result of a net export decrease. It is possible that an inelasticity in oil price could imply that an increase in price would bring more revenue than is lost in a decrease in exports. Although the initial response is different, the remainder of the period behaves like the United States. If RGDP

goes up there would be expected inflation in the economy especially after a year from the initial response.

The variance decompositions for CPI (Table 6) again may prove to add some explanation to the impulse response functions. RGDP's explanation power on CPI can be found in the column labeled l_RGDP. RGDP does very little to explain CPI in the first few years, but after the second year it becomes the dominant force in explaining CPI movements. This is expected and allows for better interpretation of the response functions.

Due to the small power of the variance decompositions the effects of CPI to an increase in RGDP will be treated as predominantly positive and having the major effect after the second year. The early dip in CPI may have some explanation to the previous reponse's shape. The increasing RGDP in the first year from a REER shock may bring the CPI down in early years. This would support the claim concerning the relationship with REER and RGDP affecting CPI initially, but not support the hypothesis that RGDP decreases initially. Due to insignificance in the last few responses no definite solutions can be drawn. The early shape of the graph is noted and care is taken in recognizing any possible significance it carries, but the only significant responses are the strong positive responses in later periods that are similar to the United States.

After analyzing the six prepared responses for Canada the results were not as robust as expected and new findings may require future research. The oil price's effect on Canada is similar to the United States in movement, but has a much lower positive effect. This result was originally thought to be the result of exchange rate pass through as hypothesized in the introduction, but after looking at the impulse response functions and variance decompositions there may be another variable that is not accounted in this model. The CPI is affected first by the oil price where oil behaves as an input in production. This seems to be true regardless of country;

however, oil price had a lower impact on CPI in Canada than in the United States. The second effect on CPI comes directly from REER. This is found to be a small but positive effect on CPI. This is not a very large or significant result, and it is consistent to the United States model. The last effect that was hypothesized is the effect that oil has on RGDP alone and through REER. The results are interesting concerning this hypothesis and are noted, but given the insignificance and weak variance decompositions it is not considered a decisive claim.

Through the failure of this hypothesis a new possibility is revealed. The results lead to an alternative unaccounted variable that is muting the CPI responses in Canada. This is observed originally in the variance decompositions. For both REER and RGDP the CPI has a considerable effect on REER and RGDP respectively. Another reason to believe something is missing in explaining CPI is that much of the variance decomposition for CPI is retained. A brief discussion of this new finding is presented with two new impulse response functions. The response of REER to a CPI shock (Figure 17), and the response of RGDP to a CPI shock (Figure 18). These two graphs indicate that according to the model it is the CPI shock itself that sparks the REER to continue increasing and RGDP to decrease muting the CPI. Now this may seem cyclical, (and it is) but the purpose is not to show that CPI affects CPI. The purpose is to further indicate the possibility of some variable missing in this model that is being interpreted in the CPI. This may be something like the de facto band that is discussed in the literature review or an inflation targeting monetary policy, or any other missing variable.

In conclusion, it can be interpreted that oil price movements have less of an inflationary effect on Canada than in the United States. What is not clear is the exact reasoning for this result. The original hypothesis of exchange rate changes decreasing exports, RGDP, and causing a recession looks grim, but is not conclusive in this model. It may be prudent to begin searching

for missing variables that could be causing this muted effect on CPI. As a further follow up on the model as well as an attempt to discover the variable muting CPI the remainder of this chapter will be a step by step direct comparison in impulse response functions between Canada and the United States.

C. United States vs. Canada

Closely analyzing Canada and the United States is effective in showing detailed information of the responses in the two countries. This is satisfactory when trying to explain inflationary movements on an individual country, but this paper extends into a comparison as well. The remainder of this chapter will again observe the six impulse response functions, but with Canadian and United States responses on the same graph. This method will call attention to key similarities and difference in movements and put the values of the responses in perspective to one common axis. Since the variance decompositions and confidence intervals have already been discussed they will not be included in the figures, but will be discussed in the analysis. The ordering will be the same as before and the discussions will be brief and focused only on comparisons.

The first impulse response observed is the response of CPI to an oil price shock (Figure 19). The graph shows the large difference in CPI shocks for Canada as well as the United States. The two move very similarly in the first two years, but Canada's shock is consistently lower. By the third year the two responses meet just below zero and then maintain a similar difference between the two. The stronger late downward push on the United States is likely a result of the stronger late downward RGDP effect observed in the United States model around this time. Canada's RGDP response was less definite or significant. The initial responses being so far apart

seem to be the only thing separating these responses to behaving similarly. This finding is the focal point of this paper, but also makes an attempt to explain why the two are different. It was first hypothesized that exchange rate pass through may be case. The pass through into prices is not observed in the model directly from the REER in Canada or through the RGDP. It appears that CPI may not be fully explained in this model and further techniques or variables must be applied.

The second impulse response observed is the response of REER to an oil price shock (Figure 20). For this response the two countries behave in complete opposite ways. Canada starts with a strong positive shock for the first two quarters and eventually falls becoming negative. United States starts with a strong negative shock for the first two quarters and moves toward zero and eventually positive. The two behave differently based on the way their currency moves with oil prices. The United States is an importer of many goods including oil and is not considered a commodity currency. Therefore, this shock as an importer should be negative, meaning the US dollar should weaken due to a shock in oil price. Canada is a large exporter of oil and considered a commodity currency. This implies that due to their massive export base their exchange rate moves with the prices in the goods they export. This would explain the positive movement. This is expected and was the original reasoning behind the hypothesis concerning a lower inflation effect on oil price.

The third response is the CPI response to a REER shock (Figure 21). After the first year the two countries move again in different directions. Noting that the REER shocks move in opposite directions (Figure 22) implies that the CPI actually moves in the same direction. In the United States there is a strong positive impact on CPI after the first year. In Canada there does not seem to be as much significant positive movement. This observation of pass through could

indicate some of the difference in magnitude of inflation between the two countries. It appears that pass through occurs positively and more completely in the United States than in Canada. This is an interesting result to look at, but does not explain the difference between the initial shocks.

The fourth response is the RGDP response to an oil price shock (Figure 23). The two countries move in the same direction, but the United States has a stronger negative effect than Canada. This seems to indicate that after a year in both countries there is a disinflationary effect bringing the CPI back down. This is observed in the original graph. The fact that the United States has a stronger effect does not seem that odd since it also had a stronger positive shock. This may indicate a general movement when CPI increases for a year to have a recessionary effect bring inflation back down.

The fifth response is the response of RGDP to a REER shock (Figure 24). These graphs look initially very different. Remembering that the REER shock is opposite for the countries the shocks can be viewed as negative (Figure 25). Looking at the new graph it can be seen that the United States has a stronger negative RGDP shock as a response to REER. Canada actually has a positive effect in RGDP. These results are not significant and the variance decompositions are not very strong, but it appears to discredit the hypothesis that the decrease in RGDP due to exchange rate fluctuations is the cause for different Canadian inflation response to oil prices. This cannot be fully considered until the last response is observed.

The last response that compares the United States and Canada is the response of CPI to a RGDP shock (Figure 26). This result finishes the chain of reactions and helps make more sense out of the findings in the previous result, but it does this in a confusing way. Firstly the United States moves as expected with a positive and steady increase in CPI when presented with RGDP

growth. This is agreeable to intuition that the expansionary movements in RGDP will increase inflation. Canada moves originally negatively for the first five quarters and then rapidly becomes positive and by the beginning of the third year has a greater and faster increasing positive shock than the United States throughout the rest of the period. This differing response may have something to do with some other variable concerning Canada's monetary movements. After recognizing this finding, the previous response seems more valid. The original positive shocks in RGDP may actually have a negative effect on CPI initially. The late positive CPI effects become muted by the decreasing RGDP. This also will make the response of RGDP to a REER shock more like the United States with a more negative response in later periods to CPI. The sign insignificance still makes the claim weak, but this new piece indicates that there may be an effect on CPI through exchange rate's effect on RGDP just not as a result of an initial RGDP decrease. The later responses are significant, but take many years to have any impact. These responses may explain why the CPI ends lower after 4 or 5 years in Canada when compared to the United States, but is not a likely indicator of the initial difference between the two countries behaviors in oil price shocks.

There is an obvious difference between the United States and Canada when observing inflationary movements following oil price shocks. Canada initially starts off with a lower inflation shock than the United States and then moves similarly, yet consistently below the United States movements. The hypothesis that exchange rates decrease RGDP in Canada is not decisive. In fact, the responses indicate possible positive movements in RGDP. The CPI response to RGDP; however, may still indicate a decrease in CPI, but not as a result of the hypothesis that RGDP decreases initially. Inflation in the United States is described fully in this model. Canada is not explained in entirety and the variance decompositions imply that there may be some

variable affecting CPI not included in this model. This variable will be discussed in the conclusion and possible explanations will be tested in a future model.

CHAPTER 6

CONCLUSION

The model has produced a considerable amount of information for further analysis of the impacts of inflation in Canada and the United States as a response to an oil price shock. It also makes some inferences into commodity countries as a whole. The new information has also presented several problems concerning the model and hypothesis. These failures inspire new thoughts and hypotheses and new models. Overall the two countries behaved as expected to oil price changes affecting CPI. Since this is the focal point of the paper, I consider the results in this paper to be successful in its original purpose.

The model did fail to find a valid explanation to the differences in inflation between the two countries. This is in part due to the robustness of the model, omitted variables, or in the country itself as indicated by Chen and Rogoff concerning Canada's integration as a true commodity currency (Chen & Rogoff 2002). These flaws will be addressed individually in this chapter along with possible solutions to the problems for future models.

The explanation power and results for the United States are consistent and powerful. The model does a satisfactory job of analyzing the United States and its responses to an oil price shock. The variance decompositions of most of the variables are fairly exhausted by the end of the five year period and the impulse responses are somewhat significant where important. The results fit economic intuition and observation. Overall the model was successful in explaining the inflationary effects of oil price in the United States.

The model's success for the United States however, is not as apparent in Canada. There simply is not enough explanatory power for the Canadian economy with the four variables. One possibility is the robustness of the model being weakened as a result of a small sample size (Engel 2000). As a response to this possibility, a future model could add more data possibly as far back as 1971 after the Bretton Woods conference instituted the floating exchange rate. This still is a small sample and would suffer due to size distortion. This is a good idea for robustness, but probably will not be the vital solution. The United States has the same data period in this model and largely outperformed Canada.

As observed earlier the de-facto band that pegged the exchange rate of Canada loosely to the United States may need to be accounted in a model. Perhaps by locating any cointegration between the United States and Canada as compared to other similar countries could help identify the influences presented by the band. If these could be isolated and removed the model may be more robust and explain the relationships more effectively.

Another possible missing variable pertains to strict inflation targeting policies instituted in Canada since 1991 (Devereux 2000). Monetary policy differences between the United States and Canada is not included in the model. Countries with strong monetary policies lessen the pressure of exchange rate changes to consumer prices (Bailliu & Fujii 2004). Monetary policy and inflation targeting may be a variable that is accounted in a future model. Perhaps with the inclusion of an interest rate or federal funds rate as seen in An Liang's model (Liang 2006).

In conclusion, the results returned for both countries are expected and thorough in purpose. The model could use revision to better identify Canada's responses. It is clear that there is a strong inflationary difference between the United States and Canada. The cause of this difference is not as clear. The pass through hypothesis regarding exchange rates and real gross

domestic product is not decisive in this model, but not entirely thrown out in concept. It appears there are also omitted variables in the model that need to be addressed in future research.

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Illustration 1: Structural Vector Process Description and Impulse Response Function Methodology[1]

The SVAR model is based off a vector autoregressive process (VAR) with some assumptions added to resolve the issue of mutually correlated noise terms in the error term.

Begin considering the VAR model:

$$(1)\ \mathbf{y}_t = \mathbf{B}_1\mathbf{y}_{t-1} + \mathbf{B}_2\mathbf{y}_{t-2} + \ldots + \mathbf{B}_p\mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t$$

where $\mathbf{y}_t$ and $\boldsymbol{\varepsilon}_t$ are k x 1 vectors and the **B**'s are k x k matrices.

This is a simple AR(P) process that using ordinary least squares (OLS) we can derive the B's and form the variance-covariance matrix:

$$(2)\ \boldsymbol{\Sigma} = E\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t'$$

The problem that arises from this when impulse response functions are the goal is that $\boldsymbol{\Sigma}$ is a positive semi-definite matrix with non-zero off-diagonal numbers. These mutually correlated noise terms will become problematic when making sense of impulse response functions so the model is transformed into a SVAR with the form:

$$(3)\ \mathbf{A}_0\mathbf{y}_t = \mathbf{A}_1\mathbf{y}_{t-1} + \mathbf{A}_1\mathbf{y}_{t-1} + \mathbf{\ldots} + \mathbf{A}_1\mathbf{y}_{t-1} + \mathbf{u}_t$$

where $\mathbf{A}_0$ is a k x k matrix that explains the noise between the endogenous variables in the model. This form allows us to remove the correlation between the variables from our new error term we denote $\mathbf{u}_t$. Removing this allows us to safely assume that:

$$(3)\ E\mathbf{u}_t\mathbf{u}_t' = \mathrm{I}$$

By premultiplying $\mathbf{A}_0^{-1}$ to both sides we can make the SVAR look similar to the original VAR

$$(4)\ \mathbf{y}_t = \mathbf{A}_0^{-1}\mathbf{B}_1\mathbf{y}_{t-1} + \mathbf{A}_0^{-1}\mathbf{B}_2\mathbf{y}_{t-2} + \ldots + \mathbf{A}_0^{-1}\mathbf{B}_p\mathbf{y}_{t-p} + \mathbf{A}_0^{-1}\mathbf{u}_t$$

[1] Derived with the help of Hyeongwoo Kim's Spring 2010 Lecture notes and John Cochrane's Time Series for Macroeconomics and Finance Book.

In this form the $\mathbf{A}_0^{-1}$ is in front of the variables so that the new **B**'s include it as well as the new error term becomes:

$$(5)\quad \boldsymbol{\varepsilon}_t = \mathbf{A}_0^{-1}\mathbf{u}_t$$

using this new error term the variance-covariance matrix becomes:

$$(6)\ \boldsymbol{\Sigma} = E\mathbf{A}_0^{-1}\mathbf{u}_t\,\mathbf{u}_t'\,\mathbf{A}_0^{-1,}$$

because of (3) it becomes:

$$(7)\ \boldsymbol{\Sigma} = E\mathbf{A}_0^{-1}\mathbf{A}_0^{-1,}$$

This will solve the problem that the VAR faces if there is a way to identify the $\mathbf{A}_0$ matrix. The Sim's choleski decomposition method is theoretically effective in dealing with this if you apply some assumptions. The Choleski decomposition will give a lower triangular matrix which has zeros for all values above the diagonal. This method will lose some of the variables explaining power unless you order the variables in a specific order so that these zero values represent what we assume to be near zero values anyways. We do this using some economic intuition and ordering the variables in a way that the second variable ordered has no effect on the first variable. As we continue with more variables the third variable should have no effect on the second variable or the first variable and so forth. This method of ordering allows the lower triangular choleski matrix P to be an accurate portrayal of the data. The Choleski decomposition of a positive semi-definite matrix is unique so that when applied to our variance-covariance matrix it will return:

$$(8)\ \boldsymbol{\Sigma} = \mathbf{PP}'$$

This becomes clear that $\mathbf{A}_0$ can now be defined as:

$$(9)\ \mathrm{A}_0 = \mathbf{P}^{-1}$$

Since we have now successfully indentified $\mathbf{A}_0$ and our B's and $\mathbf{\Sigma}$ can be found through OLS we can recursively substitute our VAR process and forecast our VAR and generate impulse response functions. The VAR appears as follows:

$$(10)\ \mathbf{y}_{t+j} = \mathbf{B}_1^{j+1}\mathbf{y}_{t-1} + \mathbf{P}\mathbf{u}_{t+j} + \mathbf{B}_1\mathbf{P}\mathbf{u}_{t+j-1} + \ldots + \mathbf{B}_1^{j}\mathbf{P}\mathbf{u}_t$$

Therefore the impulse response of $\mathbf{y}_{t+j}$ is:

$$(11)\ \boldsymbol{\psi}_j = \mathbf{B}_1^{j}\mathbf{P}$$

To obtain the cumulative responses as the model for this paper the impulse responses are summed up to create the function used:

$$(12)\ \boldsymbol{\psi}_j = \Sigma^{j}_{k=0}\,\mathbf{B}_1^{k}\mathbf{P}\ ,\ j = 0,1,\ \ldots$$

Table 1: Data with Manipulation

FINISHED DATA	SAMPLE SIZE	DATA USED	CALCULATION
OP (quarterly)	1980:I to 2010:III quarterly	oilprice(in US$) USCPI (in US$)	OP = (oilprice / USCPI)*100
RGDP (quarterly)	1980:I to 2010:III quarterly	GDP (home$) GDP deflator	RGDP = (GDP / GDP DEF)*100
REER (quarterly)	1980:I to 2010:III quarterly	REER (index)	No Calculation Needed
CPI (quarterly)	1980:I to 2010:III quarterly	CPI (home$)	No Calculation Needed

Table 2: United States: Variance Decompositions for REER

Decomposition of variance for REER					
period	l_OP	l_REER	l_USCPI	l_RGDP	std. error
1	7.5308	92.4692	0	0	0.0245
2	8.5062	91.4643	0.0285	0.0011	0.03895
3	6.5234	93.3409	0.0388	0.0969	0.04752
4	4.8624	94.5215	0.1214	0.4947	0.05523
5	3.9088	94.8996	0.1193	1.0723	0.06178
6	3.3417	94.8657	0.1652	1.6275	0.06696
7	2.9602	94.7359	0.2684	2.0354	0.07124
8	2.7266	94.7044	0.3059	2.263	0.07465
9	2.6409	94.6546	0.3597	2.3449	0.07725
10	2.6905	94.5292	0.4517	2.3286	0.07928
11	2.8416	94.3849	0.512	2.2615	0.0809
12	3.0485	94.2229	0.5358	2.1928	0.08215
13	3.2754	94.0183	0.5527	2.1536	0.08314
14	3.4868	93.7912	0.567	2.155	0.08392
15	3.6498	93.5777	0.5738	2.1988	0.08456
16	3.754	93.3906	0.5766	2.2787	0.08506
17	3.8079	93.2288	0.5803	2.383	0.08546
18	3.8239	93.0892	0.5858	2.5011	0.08579
19	3.8163	92.9657	0.5926	2.6254	0.08606
20	3.7988	92.8493	0.6016	2.7503	0.08629

Table 3: United States: Variance Decompositions for CPI

Decomposition of variance for CPI					
period	l_OP	l_REER	l_USCPI	l_RGDP	std. error
1	34.9072	0.0351	65.0577	0	0.00422
2	48.1354	0.0149	51.3056	0.5441	0.00649
3	53.9558	0.9431	41.2361	3.865	0.00734
4	56.4126	1.3913	34.4019	7.7941	0.00805
5	57.5366	1.9579	29.9141	10.5914	0.00884
6	55.7523	4.461	26.6704	13.1162	0.00954
7	52.3585	8.1807	23.906	15.5548	0.01009
8	48.9064	11.7617	21.9503	17.3816	0.01055
9	45.3813	15.6721	20.5523	18.3943	0.01099
10	41.8583	20.0101	19.3235	18.8082	0.01145
11	38.8113	24.0805	18.1872	18.9209	0.01189
12	36.3194	27.5162	17.3141	18.8503	0.01232
13	34.2136	30.4046	16.7144	18.6673	0.01273
14	32.4378	32.8171	16.2566	18.4886	0.01312
15	30.975	34.7301	15.8951	18.3998	0.01347
16	29.7506	36.1774	15.6527	18.4193	0.0138
17	28.6941	37.2551	15.5049	18.5459	0.0141
18	27.7762	38.0404	15.4001	18.7833	0.01437
19	26.9787	38.5782	15.318	19.1251	0.01461
20	26.2782	38.9125	15.2581	19.5512	0.01484

Table 4: United States: Variance Decompositions for RGDP

Decomposition of variance for RGDP					
period	l_OP	l_REER	l_USCPI	l_RGDP	std. error
1	0.2167	1.1294	1.1399	97.5141	0.00534
2	0.3251	0.6717	0.5804	98.4229	0.00829
3	0.5053	0.6651	0.7857	98.0439	0.01128
4	1.8688	0.5642	1.0727	96.4944	0.01357
5	5.0339	1.0466	0.9564	92.9631	0.01549
6	9.7054	2.0182	0.8371	87.4393	0.01713
7	15.0669	3.3562	0.7163	80.8605	0.01865
8	20.286	5.0043	0.6427	74.0669	0.02007
9	24.6673	6.6849	0.6874	67.9605	0.02137
10	28.0341	8.3012	0.7993	62.8654	0.02252
11	30.408	9.8676	0.9562	58.7683	0.02354
12	31.9168	11.3711	1.1512	55.5608	0.02441
13	32.7764	12.7639	1.3488	53.1109	0.02515
14	33.1929	14.0311	1.5208	51.2552	0.02576
15	33.3178	15.1673	1.6657	49.8492	0.02627
16	33.2687	16.156	1.7873	48.7881	0.02669
17	33.1352	16.9858	1.8856	47.9934	0.02705
18	32.9749	17.6603	1.9636	47.4013	0.02734
19	32.8203	18.1903	2.0271	46.9624	0.02758
20	32.6891	18.5895	2.081	46.6404	0.02777

Table 5: Canada: Variance Decompositions for REER

Decomposition of variance for REER					
period	l_OP	l_REERCP	l_CanCPI	l_RGDP	std. error
1	3.6667	96.3333	0	0	0.02116
2	2.9205	96.1897	0.8898	0	0.03506
3	2.1738	97.1224	0.6968	0.0069	0.04298
4	1.6643	97.5781	0.5748	0.1829	0.04967
5	1.3216	97.3664	0.7756	0.5363	0.05604
6	1.1555	97.3104	0.9586	0.5755	0.06106
7	1.1962	97.2826	1.0069	0.5143	0.06487
8	1.1751	97.3492	1.0008	0.4749	0.06801
9	1.1238	97.4442	0.9392	0.4928	0.07067
10	1.0992	97.369	0.9023	0.6295	0.07299
11	1.0875	97.0103	0.983	0.9192	0.07516
12	1.0807	96.3672	1.1863	1.3658	0.07729
13	1.0996	95.4078	1.5242	1.9685	0.07936
14	1.1455	94.1599	2.0041	2.6905	0.08135
15	1.2017	92.7429	2.5833	3.4722	0.08325
16	1.2673	91.2376	3.2187	4.2764	0.08504
17	1.3448	89.6851	3.8906	5.0795	0.08669
18	1.4248	88.1498	4.5733	5.8522	0.0882
19	1.4996	86.6907	5.2391	6.5706	0.08956
20	1.5687	85.3338	5.8747	7.2228	0.09076

Table 6: Canada: Variance Decompositions for CPI

Decomposition of variance for CPI					
period	l_OP	l_REERCP	l_CanCPI	l_RGDP	std. error
1	5.7043	3.3153	90.9804	0	0.004423
2	7.4097	1.6835	90.1076	0.7993	0.006703
3	7.3049	1.3433	88.6146	2.7372	0.007613
4	7.6659	2.1002	85.2619	4.972	0.008346
5	6.8466	4.4086	83.4977	5.2471	0.009079
6	6.3588	5.8868	83.0898	4.6647	0.009645
7	6.4869	6.6853	82.3174	4.5103	0.010056
8	6.3816	7.4878	81.2956	4.8351	0.010366
9	6.395	8.1458	79.6413	5.8179	0.010611
10	6.6506	8.5723	77.0122	7.7649	0.010842
11	6.9087	8.9197	73.5536	10.618	0.011107
12	7.1387	9.1462	69.5487	14.1665	0.011423
13	7.4328	9.1121	65.2939	18.1613	0.011793
14	7.7288	8.8689	61.1754	22.2269	0.012206
15	7.9725	8.5113	57.4313	26.0848	0.012641
16	8.2068	8.0685	54.1009	29.6239	0.013092
17	8.4396	7.5828	51.202	32.7756	0.013548
18	8.6362	7.1158	48.7461	35.5019	0.013992
19	8.7925	6.7072	46.6885	37.8118	0.014414
20	8.9214	6.3823	44.9628	39.7335	0.01481

Table 7: Canada: Variance Decompositions for RGDP

Decomposition of variance for l_RGDP					
period	l_OP	l_REERCP	l_CanCPI	l_RGDP	std. error
1	2.9567	0	15.187	81.8563	0.005566
2	1.3525	0.1068	22.8348	75.7059	0.009963
3	0.7705	0.742	28.5975	69.89	0.013379
4	0.4982	1.6106	34.6379	63.2534	0.016653
5	0.7681	2.2766	37.9063	59.0489	0.0197
6	1.7914	2.4194	38.5607	57.2285	0.022273
7	2.8021	2.2324	38.4151	56.5504	0.024344
8	3.5315	1.9738	38.2944	56.2003	0.025961
9	4.0061	1.8402	38.3095	55.8441	0.027212
10	4.2779	1.9059	38.3718	55.4444	0.028179
11	4.4255	2.1586	38.3819	55.034	0.028921
12	4.5017	2.5829	38.3109	54.6045	0.029493
13	4.5274	3.1566	38.1736	54.1424	0.029932
14	4.5192	3.8458	37.9819	53.6531	0.030267
15	4.4935	4.6206	37.7396	53.1463	0.030526
16	4.4596	5.4547	37.4533	52.6324	0.030733
17	4.4214	6.3197	37.1355	52.1234	0.030906
18	4.3811	7.1897	36.8011	51.6281	0.031059
19	4.3409	8.0411	36.465	51.1529	0.031203
20	4.3027	8.8514	36.1408	50.7051	0.031344

Figure 1: USA, New Zealand, and Canada: CPI response to a Commodity Price Shock[2]

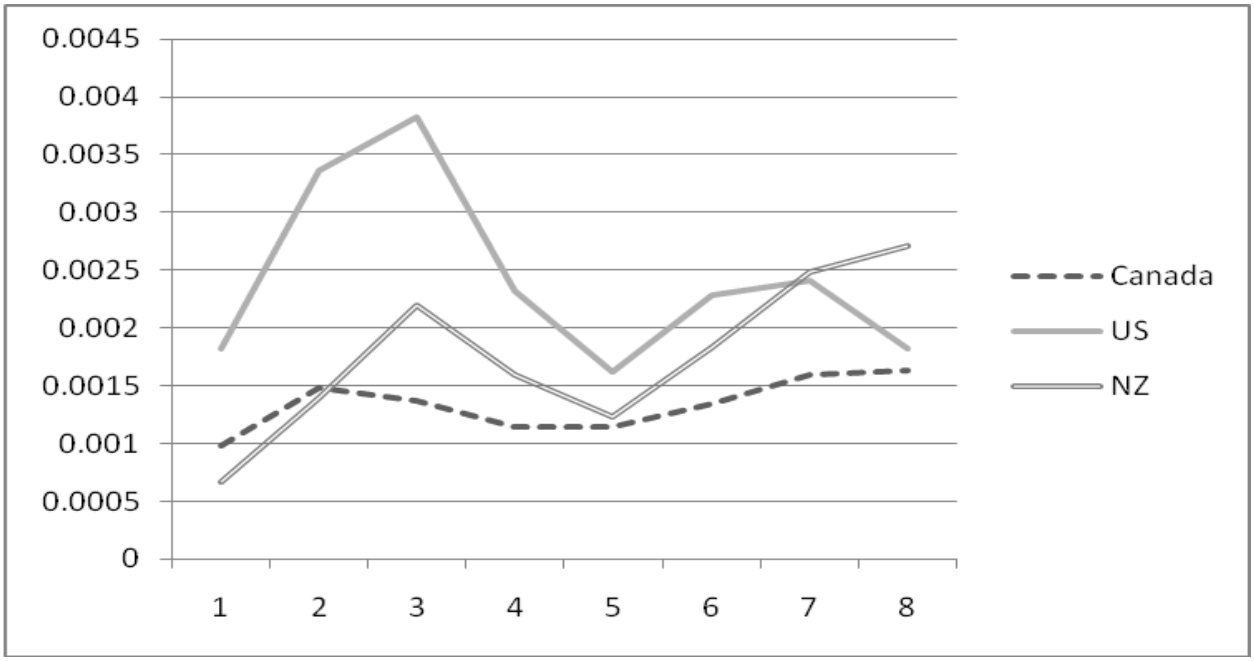
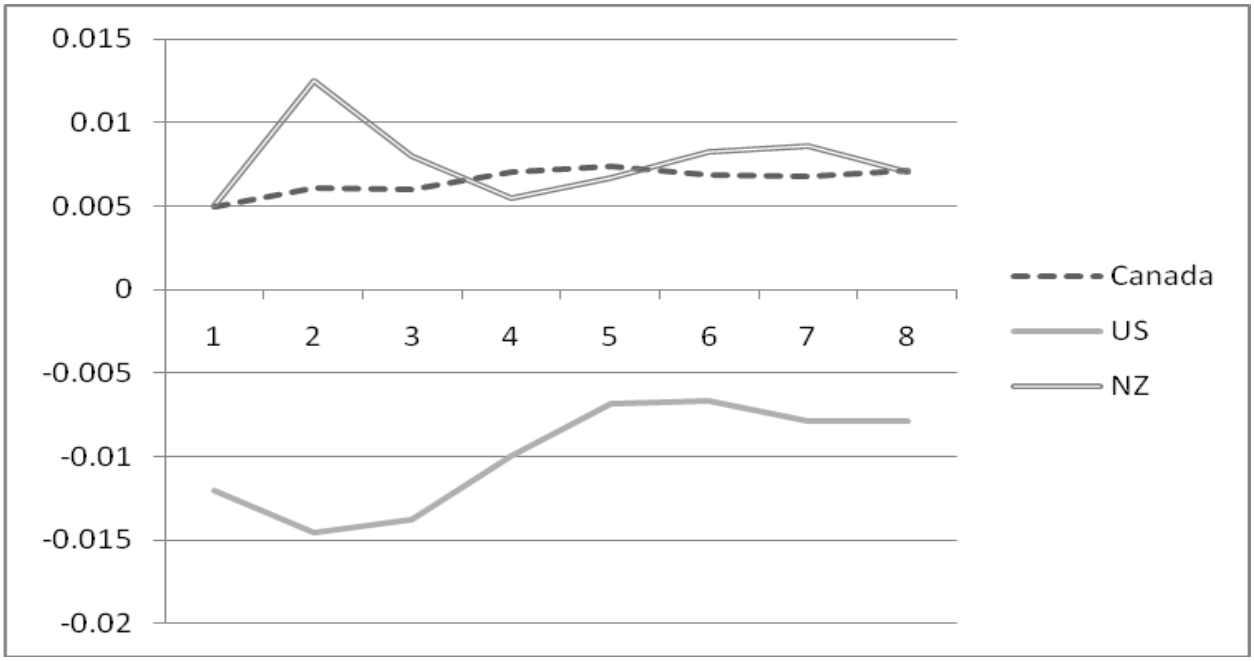


Figure 2: USA, New Zealand, and Canada: REER response to a Commodity Price Shock[40]



[2] These responses are found by running the same 4 variable VAR as used in this paper. The variables are CPI, RGDP, REER, and the non-fuel commodity index during the period: 1987 Q2 - 2010 Q2. The period is 2 years.

Figure 3: VAR inverse roots with the Unit Circle for Canada

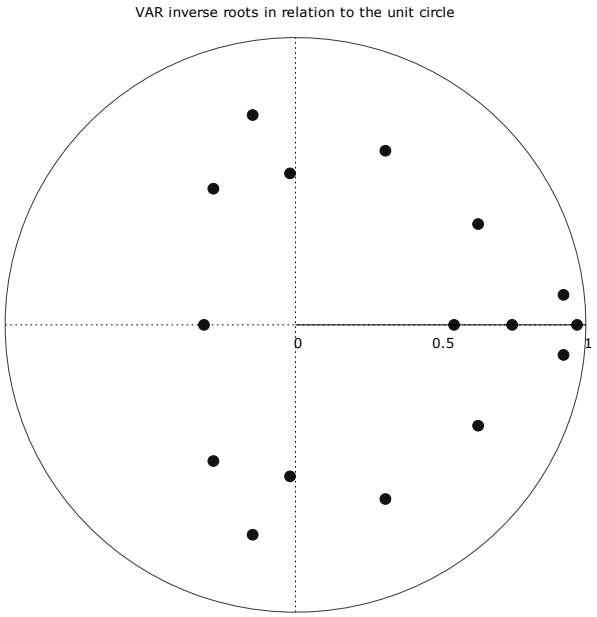


Figure 4: VAR inverse roots with the Unit Circle for the United States

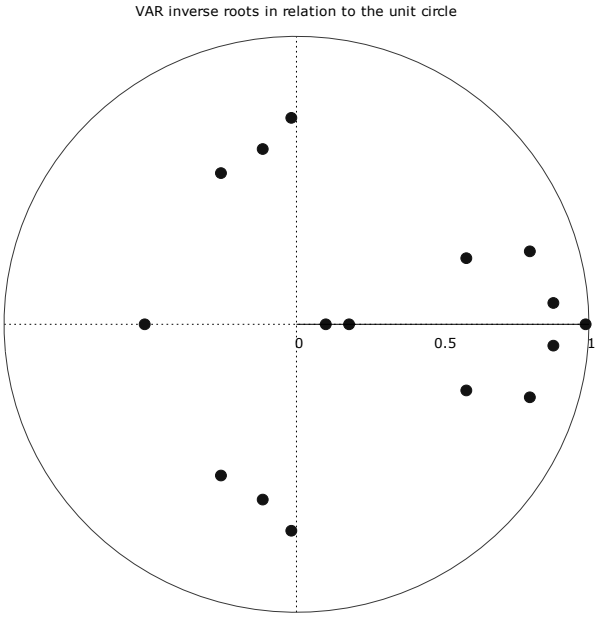


Figure 5: United States: CPI response to a positive Oil Price shock

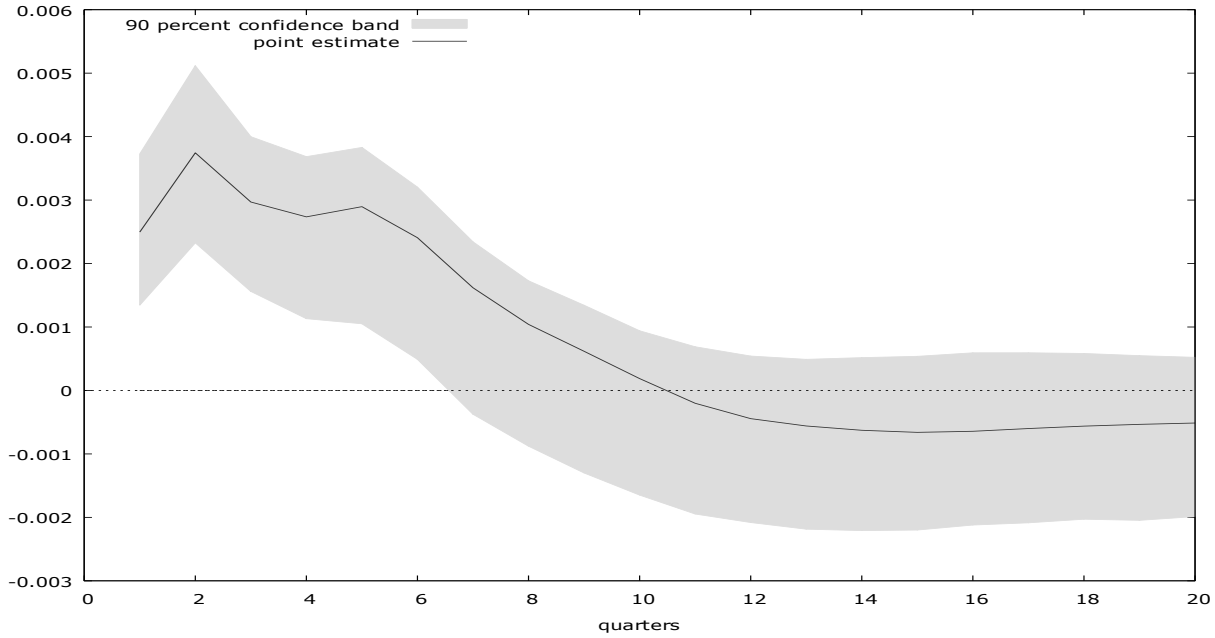


Figure 6: United States: REER response to a positive Oil Price shock

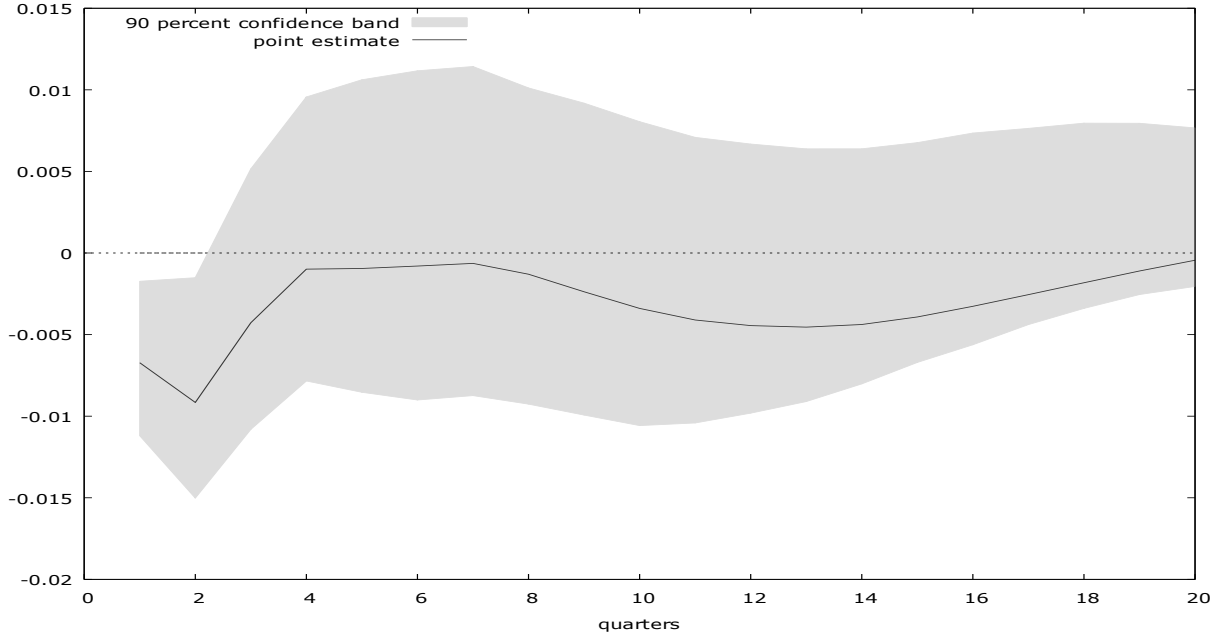


Figure 7: United States: CPI response to a positive REER shock

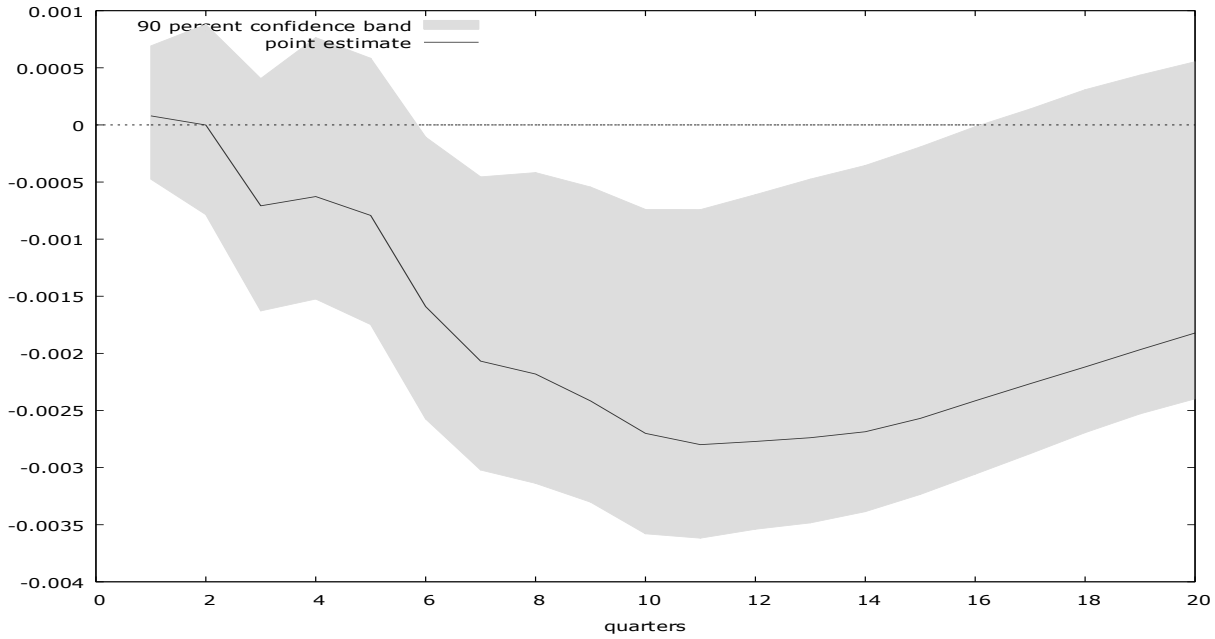


Figure 8: United States: RGDP response to a positive Oil Price shock

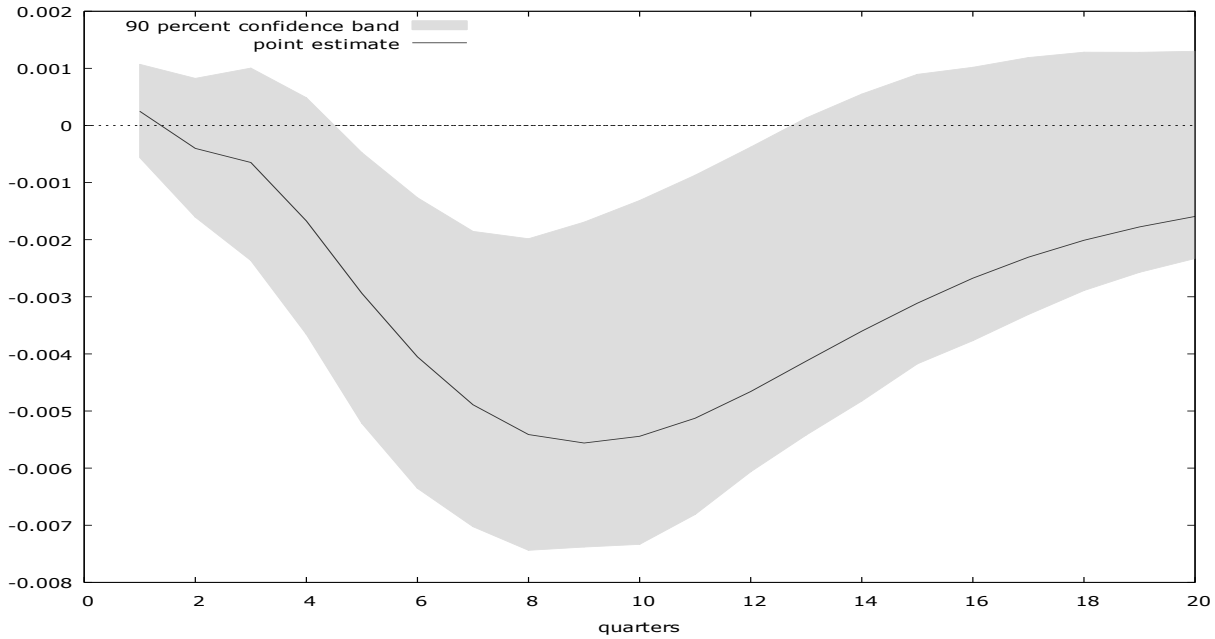


Figure 9: United States: RGDP response to a REER shock

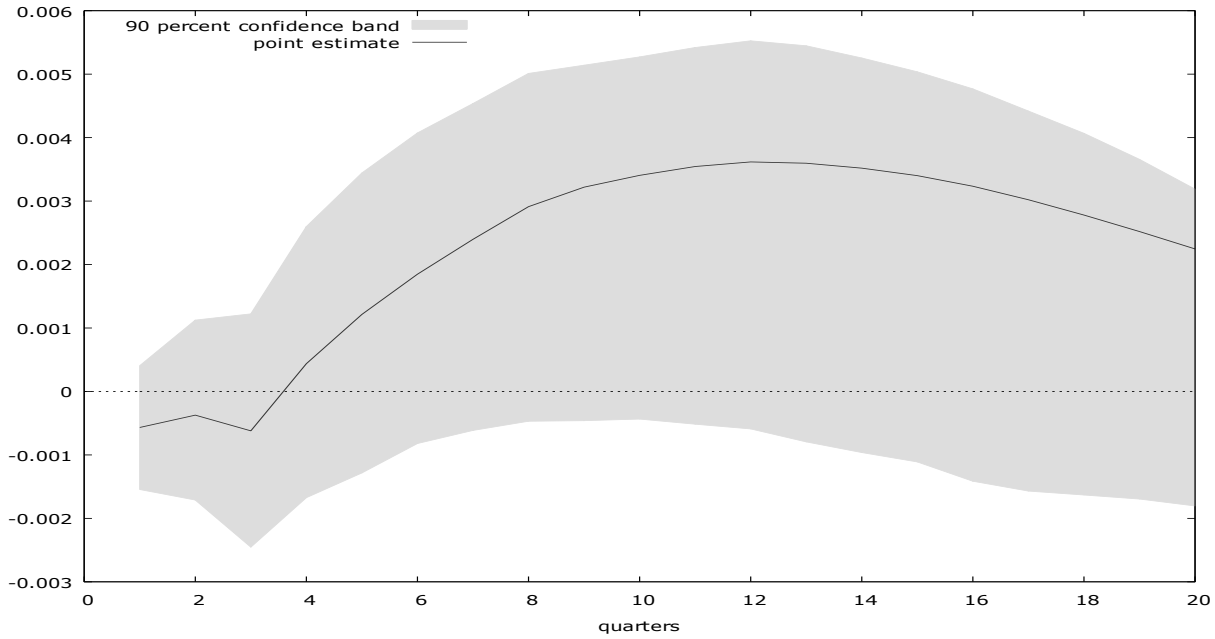


Figure 10: United States: CPI response to a RGDP shock

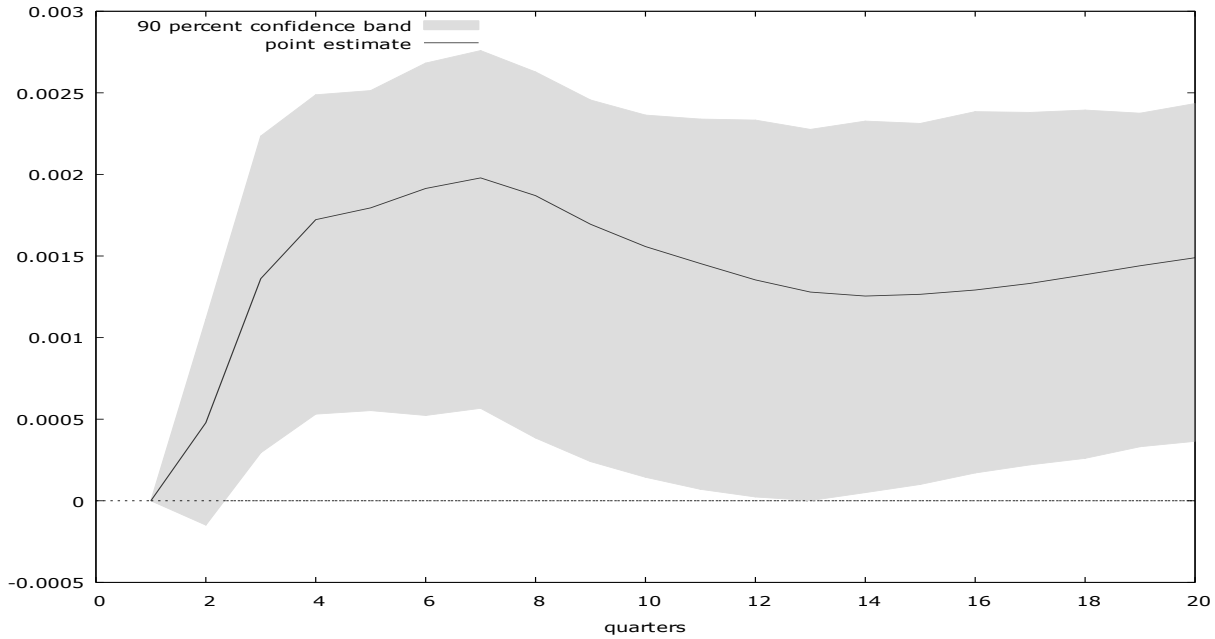


Figure 11: Canada: CPI response to a positive Oil Price shock

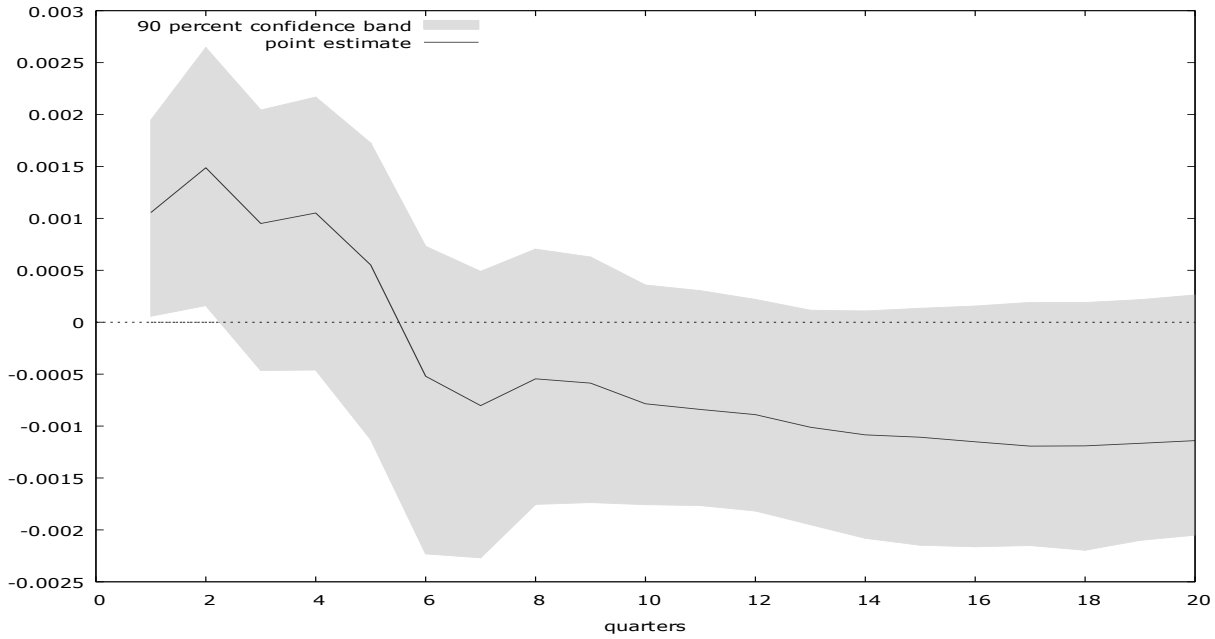


Figure 12: Canada: REER response to a positive Oil Price shock

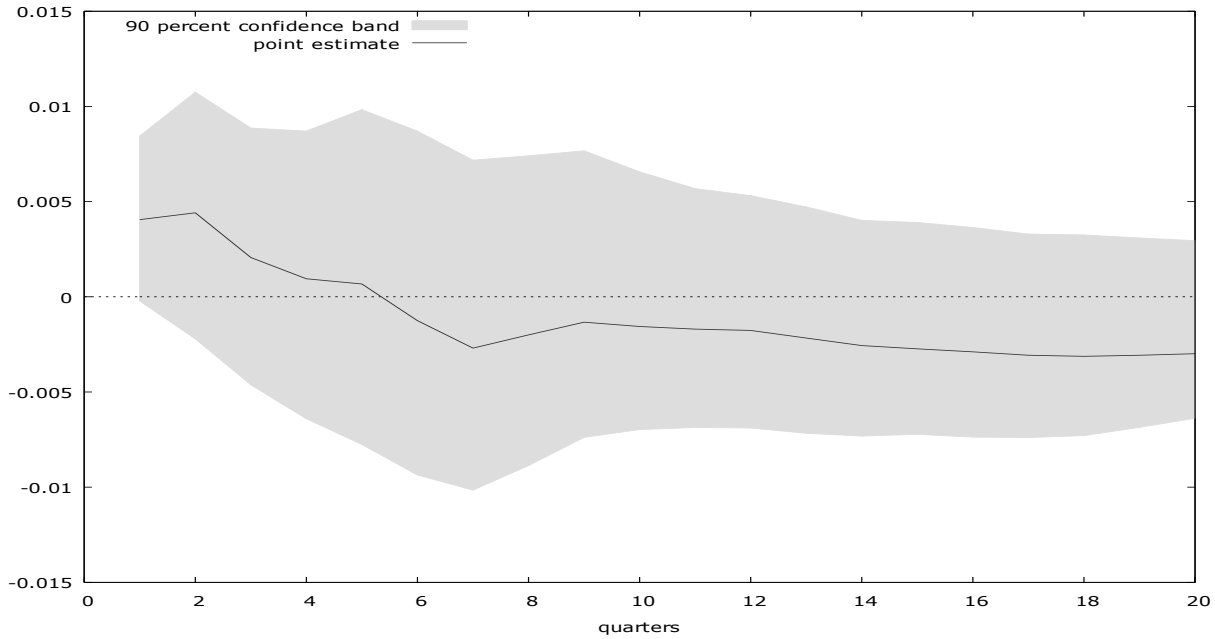


Figure 13: Canada: CPI response to a positive REER shock

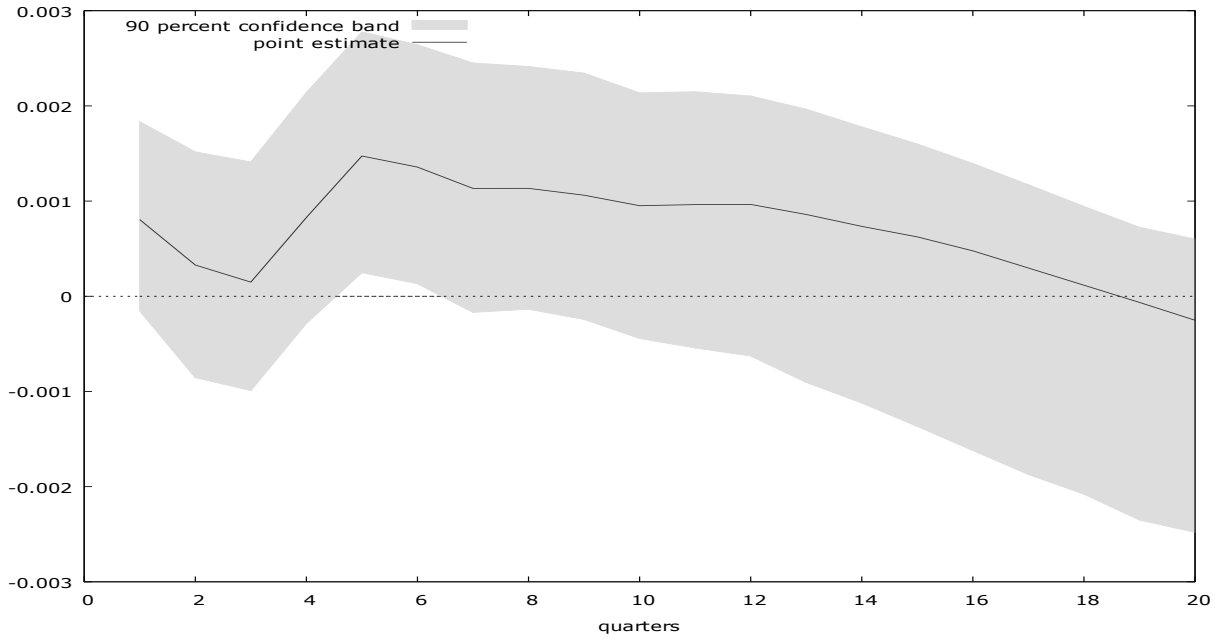


Figure 14: Canada: RGDP response to a positive Oil Price shock

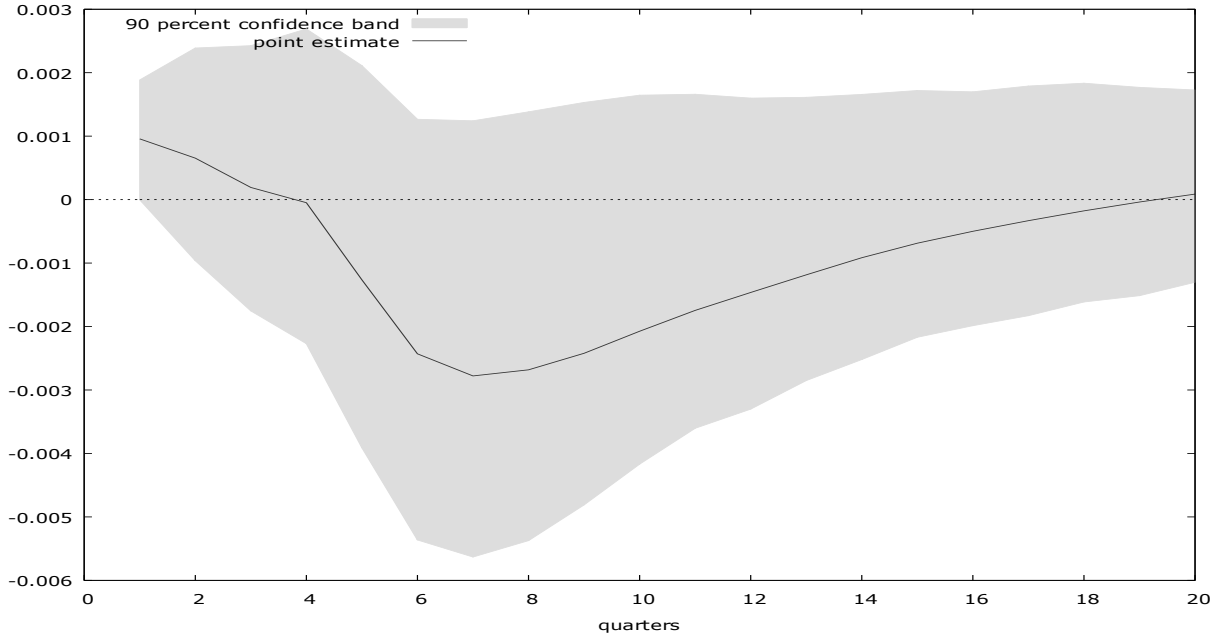


Figure 15: Canada: RGDP response to a positive REER shock

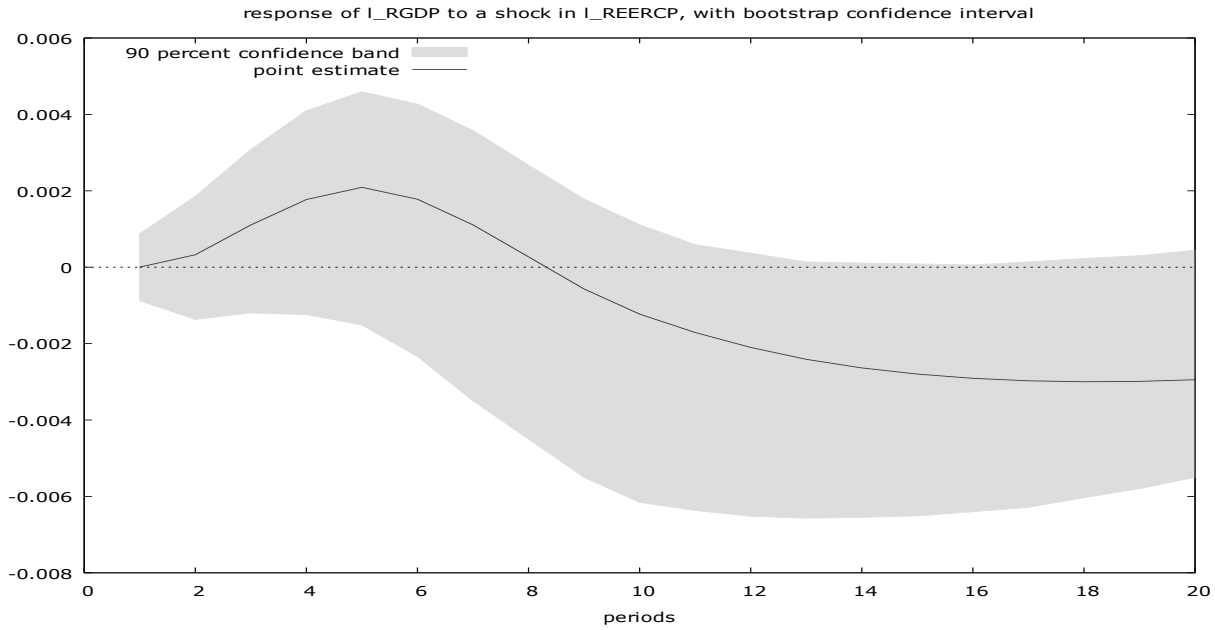


Figure 16: Canada: CPI response to a positive RGDP shock

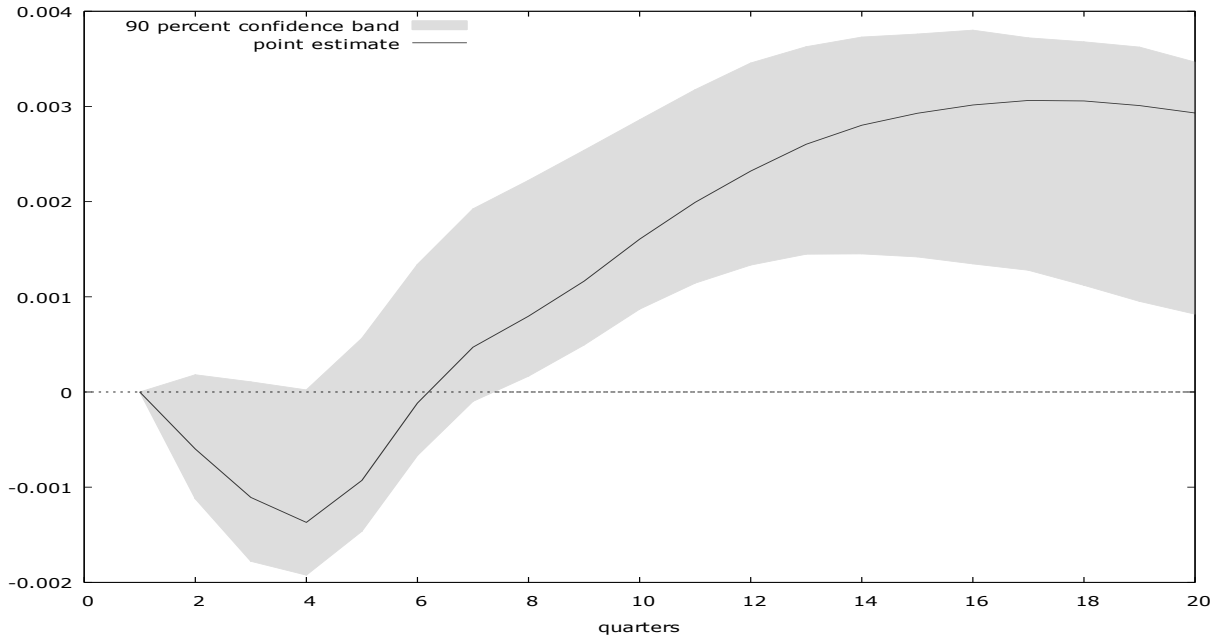


Figure 17: Canada: REER response to a positive CPI shock

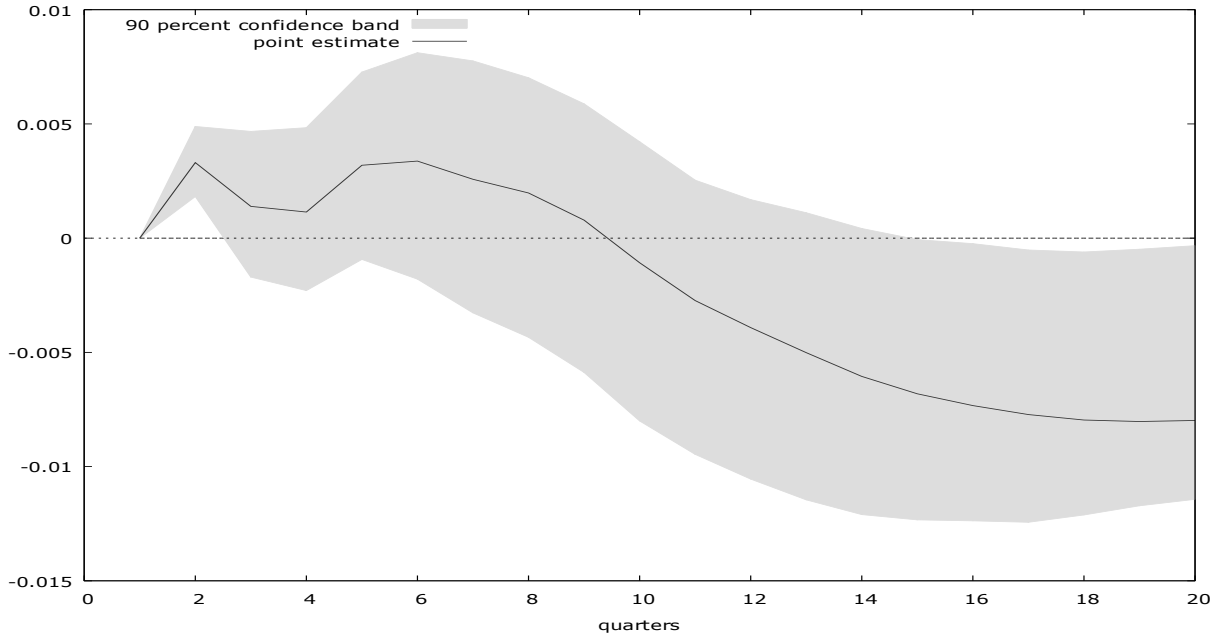


Figure 18: Canada: RGDP response to a positive CPI shock

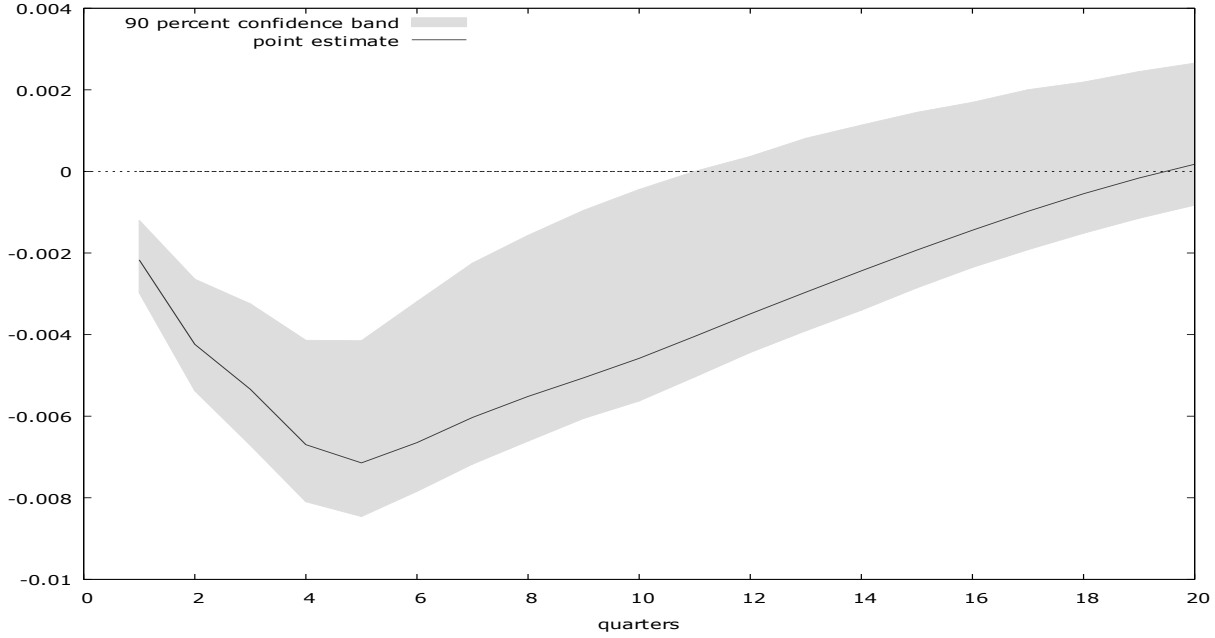


Figure 19: USA vs. Canada: CPI response to a positive Oil Price shock

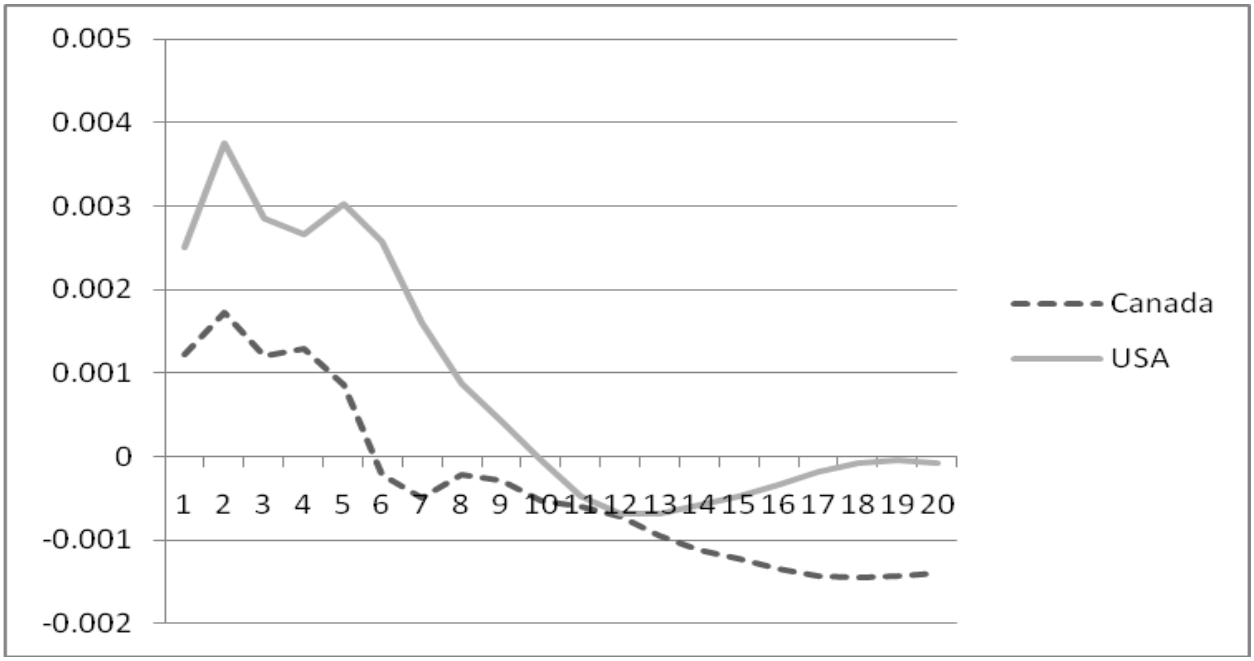


Figure 20: USA vs. Canada: REER response to a positive Oil Price shock

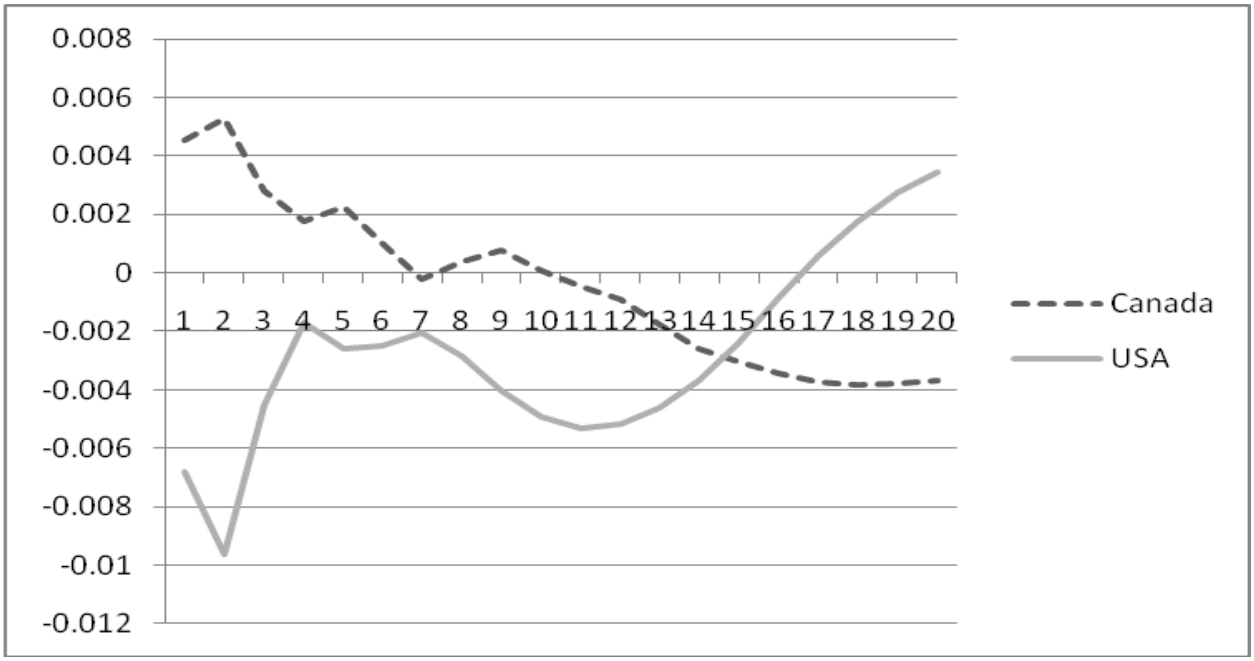


Figure 21: USA vs. Canada: CPI response to a positive REER shock

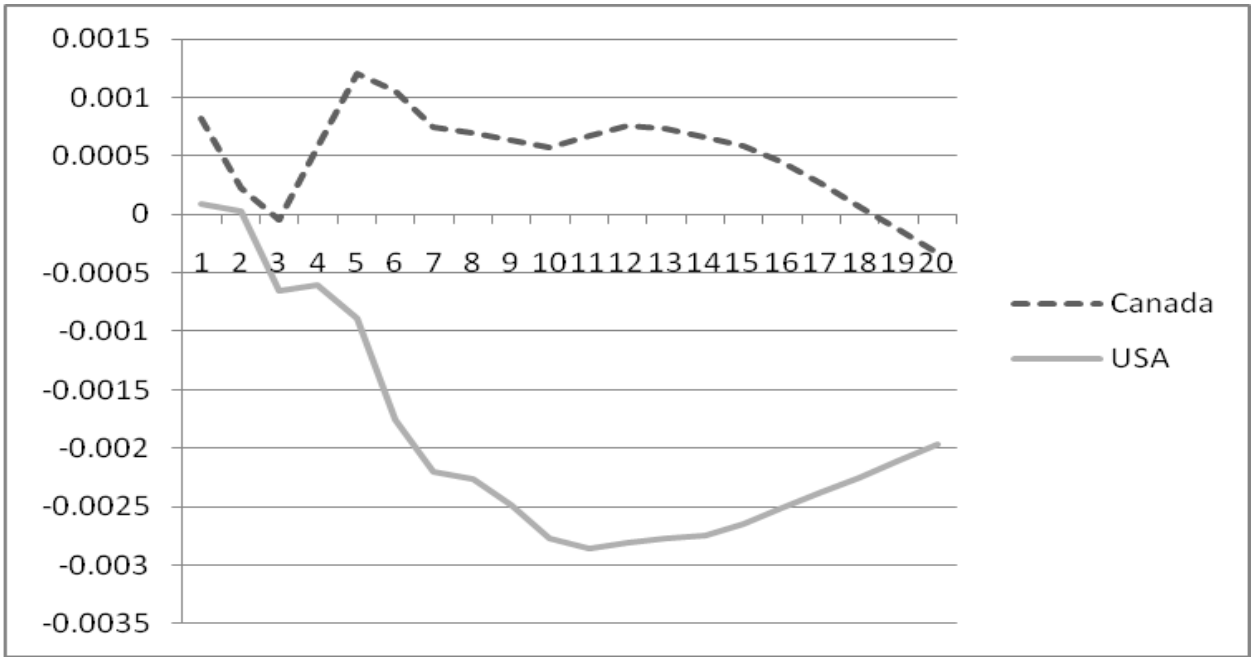
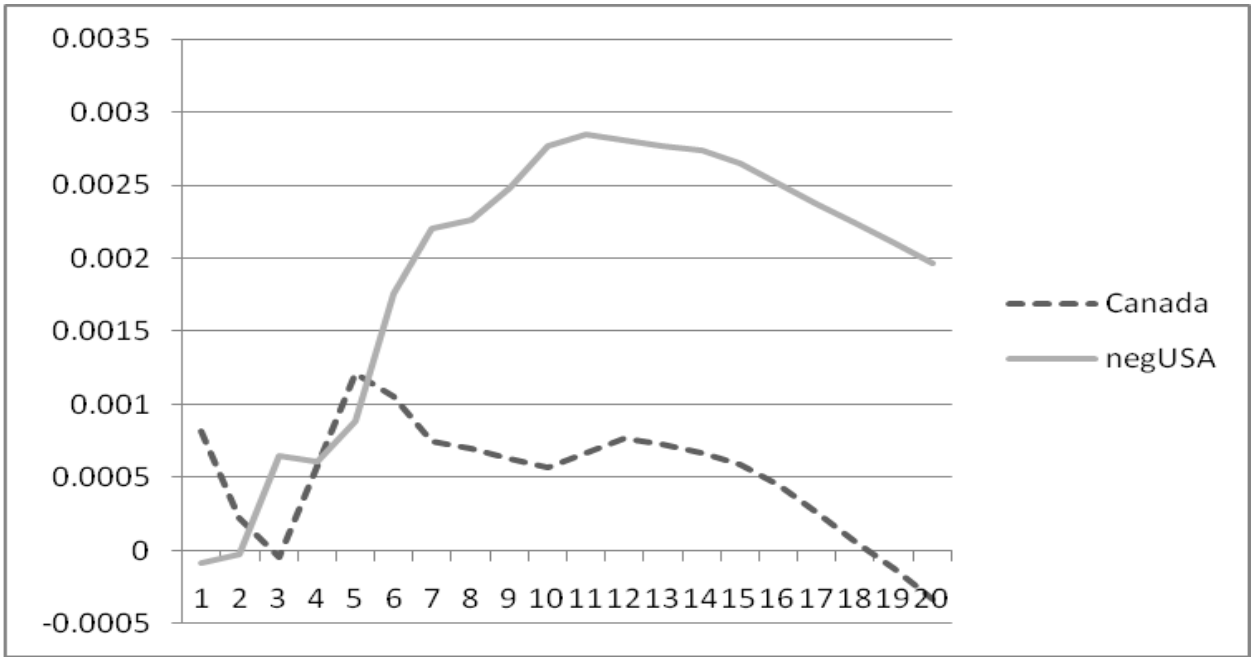


Figure 22: USA vs. Canada: CPI response to its REER shock[3]



[3] The United States values have been multiplied by negative one to show a response to a negative REER shock while maintaining Canada values the same due to its positive REER shock.

Figure 23: USA vs. Canada: RGDP response to a positive Oil Price shock

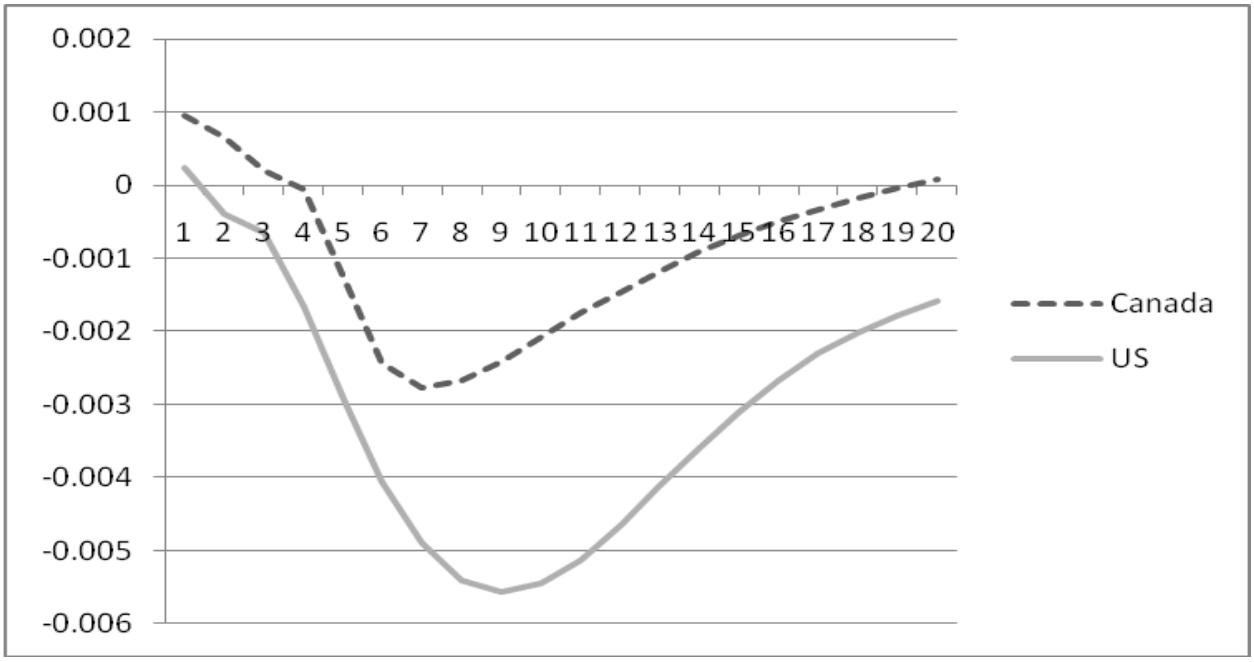


Figure 24: USA vs. Canada: RGDP response to a positive REER shock

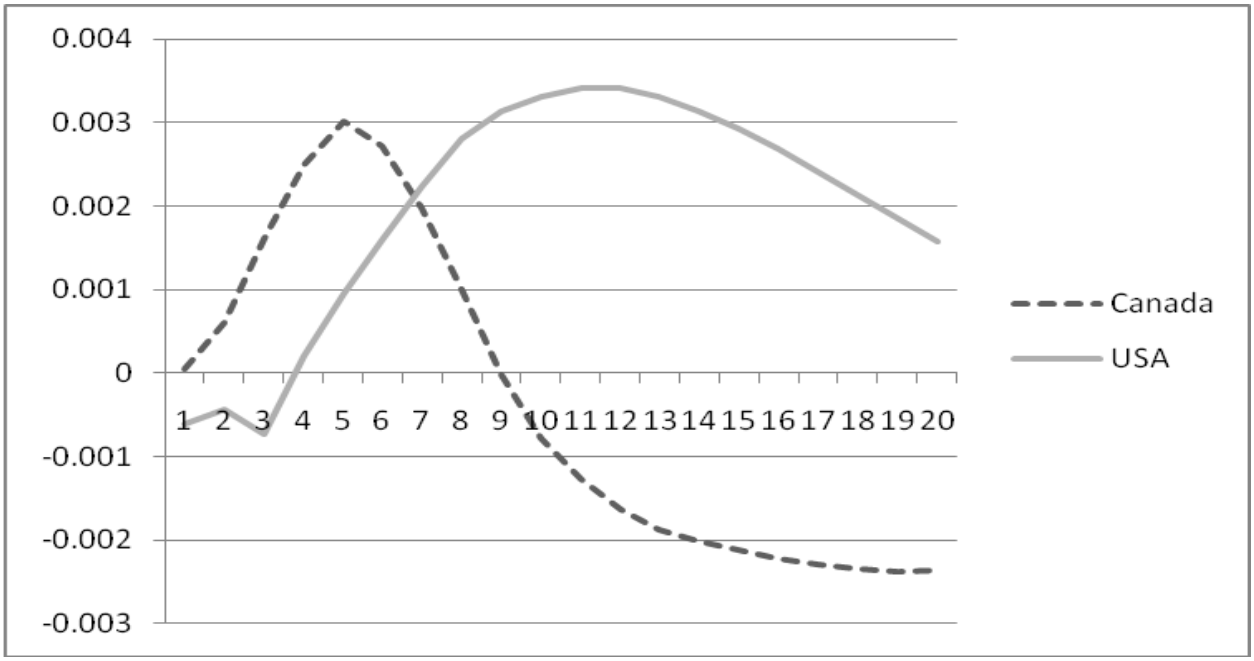


Figure 25: USA vs. Canada: RGDP response to its REER shock[4]

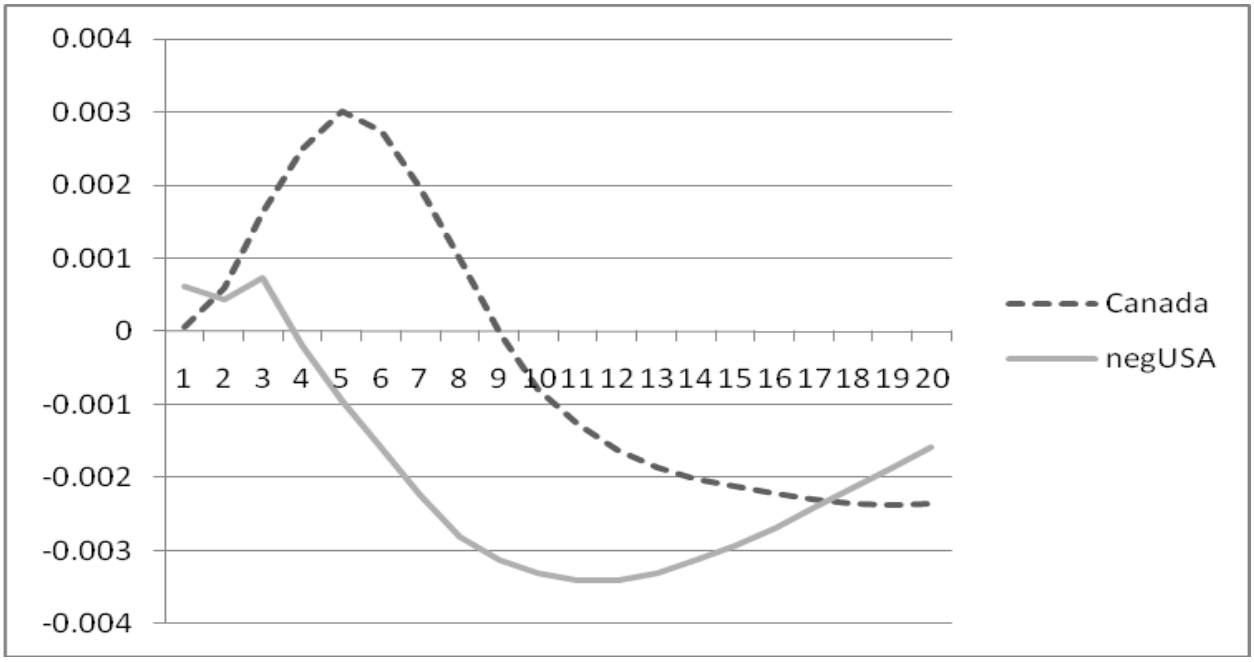
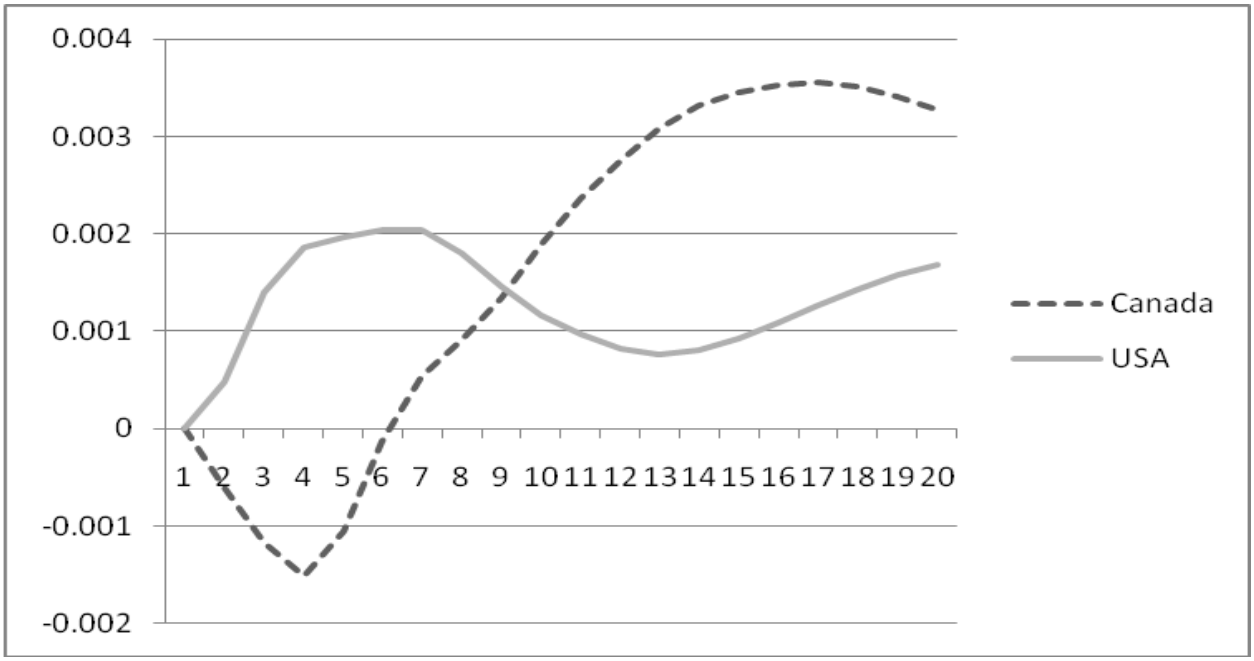


Figure 26: USA vs. Canada: CPI response to a positive RGDP shock



[4] The United States values have been multiplied by negative one to show a response to a negative REER shock while maintaining Canada values the same due to its positive REER shock.