# AN ANALYSIS OF THE RELATIONSHIP BETWEEN CANADIAN MANUFACTURING AND THE EXCHANGE RATE

**by**

**Megan MacDonald**

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## Abstract

This paper examines the relationship between Canadian manufacturing and the exchange rate, including the historical relationship and changes which have occurred in the last two decades. Statistical analysis seeks to discover whether or not the manufacturing sector should be expected to increase in terms of total value of output given the recent depreciation of the Canadian dollar which followed the oil price shock in 2014. Ordinary Least Squares regression results were significant when using manufacturing as the dependent variable and the exchange rate, import merchandise, and export merchandise as dependent variables. This implies that the exchange rate does hold some explanatory power for manufacturing over the entire sample period. That said, there is strong evidence of a structural break in the data for manufacturing at some point during the Great Recession, using the exchange rate as the break variable. As a result, it is unlikely that the depreciation of the dollar can be expected to be beneficial to the Canadian manufacturing sector in the post-2009 period.

**Keywords:** Canadian manufacturing, exchange rates, imports, exports

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All errors and omissions are my own.

Cha Gheill!

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# 1 Introduction

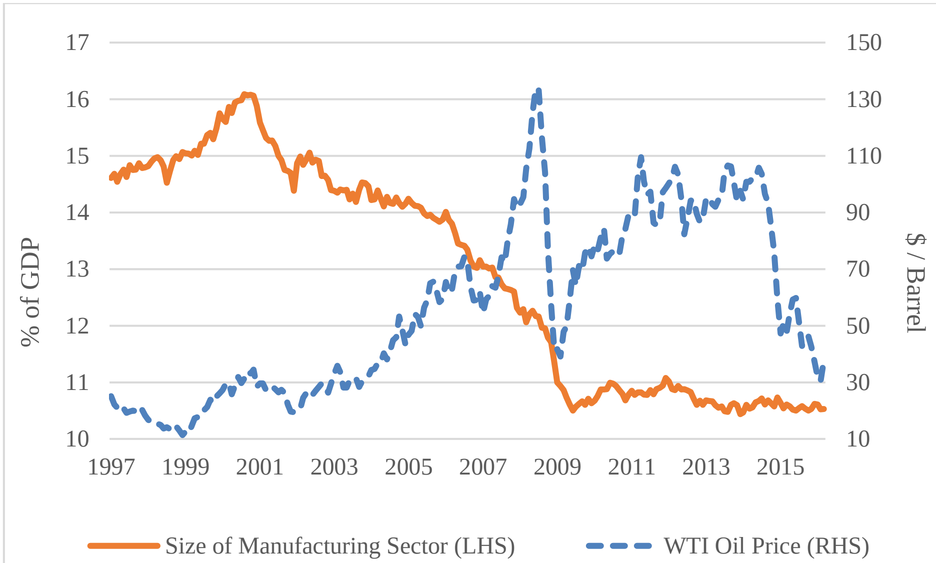
In late 2014, Canada and the rest of the world experienced a major negative oil price shock, which left Canada (as an oil producing country) vulnerable to recession. Though the shock was originally expected to be short lived, it appears possible that crude oil prices will remain low for the foreseeable future. In an effort to shield the country from this shock, the Bank of Canada surprised the markets by lowering the overnight rate, which was received with much scrutiny due to the potential exposure of the already over-priced housing market and the negative impact it would have on the exchange rate. The central bank countered this criticism by arguing that the lower Canadian dollar would help the manufacturing sector by allowing for relatively less expensive exports (Bank of Canada, 2015). However, the benefit to manufacturing has not yet been reflected in the data.

This project examines the relationship between Canadian manufacturing and the exchange rate, along with other potentially important variables. Understanding the relationship between these variables is fundamental to evaluating how the manufacturing sector has changed over the last few decades. Economists have argued that a low Canadian dollar will support the Canadian manufacturing sector, but in the wake of the oil price crash, the size of the manufacturing sector has remained constant. Can we expect this to change based on the relationship observed in the data? Or has something in the sector fundamentally changed since the early 2000s? Through Ordinary Least Squares (OLS), Vector Autoregression (VAR), and Structural Break analysis, this project hopes to shed light on the state of Canada's economic health in a low oil price world.

In this essay I find that the manufacturing sector has experienced a structural break, and that as a result the sector no longer holds the historically strong relationship with the Canadian-U.S. exchange rate. OLS regression results using manufacturing as the dependent variable and the exchange rate, import merchandise, and export merchandise as dependent variables were significant. This implies that over the entire sample period that the exchange rate does hold some explanatory power for manufacturing. That said, there is strong evidence of a structural break in the data for manufacturing at some point during the Great Recession, using the exchange rate as the break variable. As a result, it is unlikely that the depreciation of the dollar can be passed off as beneficial to the Canadian manufacturing sector in the post-2009 period.

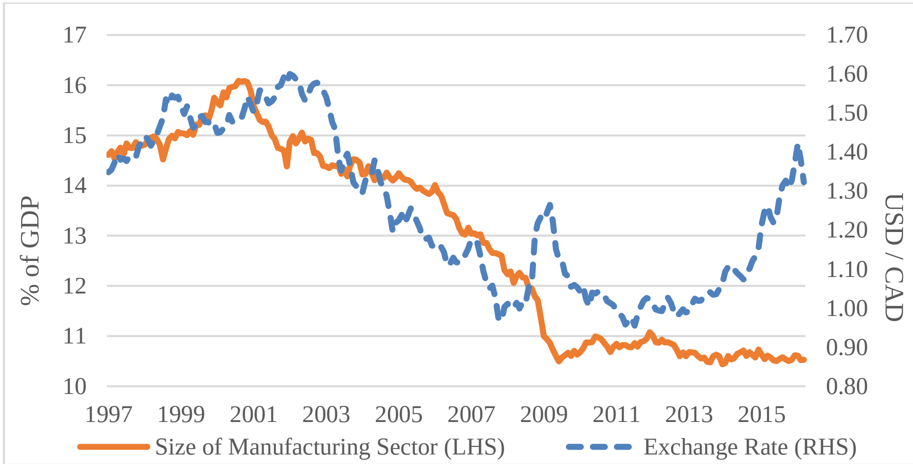
Crude oil price is closely connected to Canadian GDP. In the early 2000s, crude oil prices soared and so did the development of oil sands in Alberta. Meanwhile, in what might be considered a Canadian version of Dutch disease, the manufacturing sector shrunk from approximately 15% of GDP to around 10%, as shown in figure 1 on the following page. Dutch disease is a term for the apparent causal relationship between the increase in the economic development of a specific sector (for example natural resources) and a decline in other sectors (like manufacturing). The origin of the phrase is the Dutch economic crisis of the 1960s, following the discovery of North Sea natural gas (Kiev, 2014). Dutch exports increased rapidly and the economy became highly concentrated in that one sector. While this can be beneficial due to comparative advantage, it became an issue when commodity prices fluctuated. Commodity-rich countries, such as Canada, tend to struggle unless their economy diversifies, and the hope was that, with lower oil prices, the manufacturing sector will pick up the slack in the economy. However, this has not occurred.

**Figure 1: The relationship between Canadian manufacturing and crude oil prices**



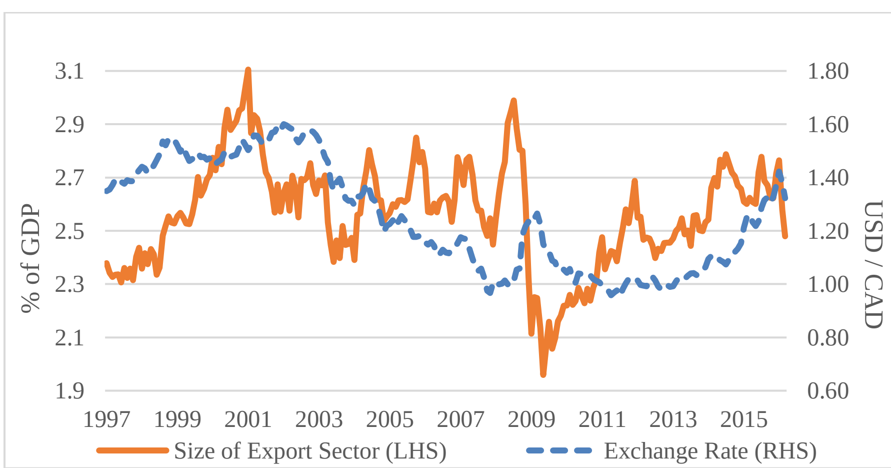

The Canadian manufacturing sector competes both domestically and across North America. As such, U.S. prices play a role in the determination of manufacturing prices (Baldwin & MacDonald, 2012). Increased integration between the two countries has also contributed to an increased influence of American markets on the Canadian economy. Traditionally a strong U.S. dollar has come along with a strong manufacturing sector, as shown in figure 2. However, since 2011, the Canadian dollar has fallen without the increase in the manufacturing sector. One cannot help but wonder whether or not low exchange rates can help the manufacturing sector.

**Figure 2: The relationship between Canadian manufacturing and the exchange rate**



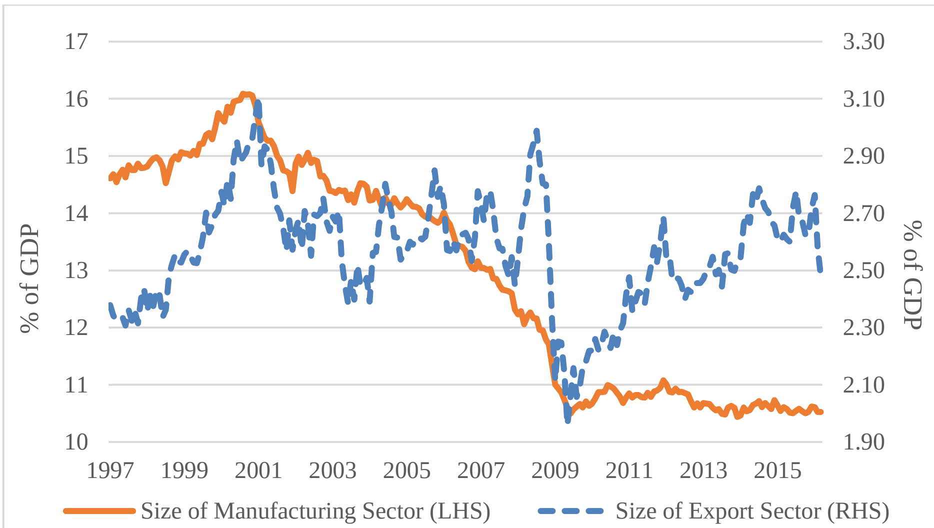

While the historical relationship between manufacturing and the exchange rate appears to have changed since the Great Recession, the story is not complete without looking into what has happened in the export sector during this period. Though the export sector is much more volatile, the size of the sector, defined as merchandise exports as a percentage of GDP, roughly follows the exchange rate. This is as expected, since exchange is defined as USD/CAD, as the dollar falls the exchange rate increases and in turn exports are relatively less expensive so demand increases.

**Figure 3: The size of the export sector roughly follows the exchange rate**



Given the fact that the exchange rate and total exports follow closely, it is intuitive that comparing exports with the manufacturing sector tells a similar story. After a decrease during the financial crisis, merchandise exports have increased again to sit around pre-crisis levels, while the size of the manufacturing sector remains low.

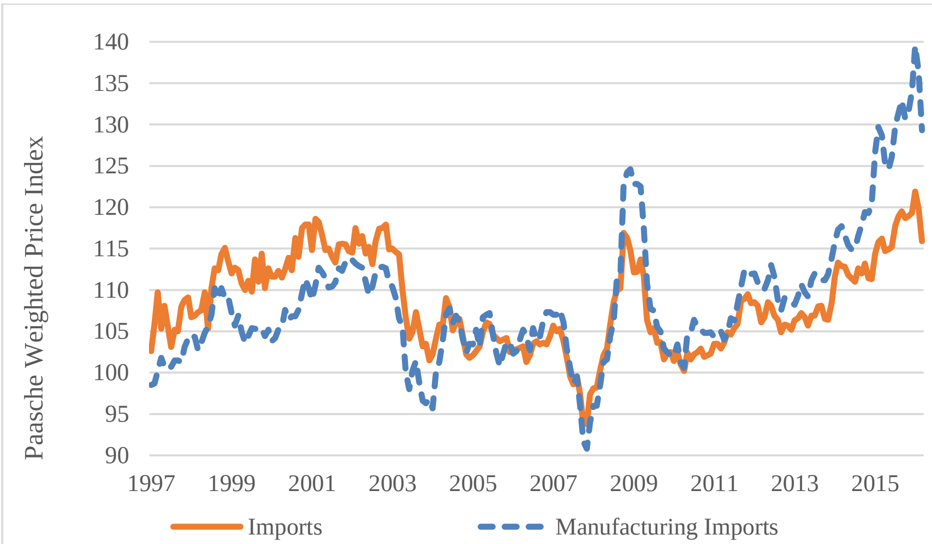
**Figure 4: The comparative sizes of manufacturing and exports in Canada**




Evidence for the research hypothesis could be found by looking at how the manufacturing share of exports has changed over time, and whether this share has increased with a low dollar in spite of the lack of an increase in the sector as a whole. Unfortunately this data is not readily available, and generating it falls beyond the scope of this research. In order to get an idea of what has happened to manufacturing trade the import and export price indices are examined.

The weighted price indices for total imports[1] as well as manufacturing imports tend to move together, though the two appear to have separated beginning in 2013. If manufacturing import prices tend to be lower than imports in general, one would expect this to facilitate growth in the sector, but as shown below, this has not occurred.

**Figure 5: Canadian import price Index**

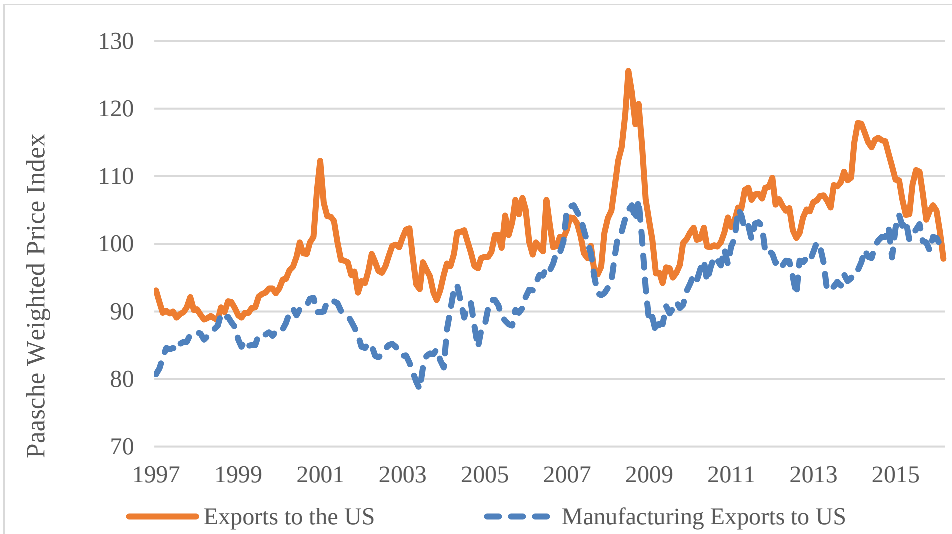



This project is looking specifically at the relationship between the Canadian manufacturing sector and the USD/CAD exchange rate, so the figure above compares the price index for all exports to the U.S. with the price index for manufacturing exports. While these indices tend to move together, there are a few notable exceptions around 2003, 2009 and 2014 where the two series diverge for a short period. In addition, manufacturing export prices tend to be lower for the majority of the series, which could

[1] Data do not exist on the manufacturing share of exports and their collection is outside the scope of this project, so the price index is used to gain insight into this portion of the industry.

offer an explanation for why the lower import prices have not materialized as growth to the sector.

**Figure 6: Canadian export price index for exports to the U.S.**




There are a number of possible reasons that the relationship between a low exchange rate and a prosperous manufacturing sector could be outdated. One reason is that the composition of manufacturing inputs could have changed. With a more integrated global supply chain, it is possible that a larger proportion of inputs come from imports, negating the benefit of lower export prices. However, increased integration could also imply that supply chains could have moved from a vertical framework to horizontal framework. Having the same multinational company responsible for both intermediate and final goods may decrease the importance of exchange rate fluctuations (Bailliu, Dong, & Murray, 2010). Another concern is that changes in the exchange rate are first transmitted to import prices, followed by an adjustment in domestic consumer prices. That is, given a strong downward movement in the exchange rate, the gain in manufacturing through exports would be diluted due to decreased domestic demand. The last possibility is that this inverse relationship still exists and that it is simply taking longer to take effect given the uncertainty surrounding oil prices.

The motivation of this project is to examine the relationship between Canadian manufacturing and the exchange rate, along with other potentially important variables such as crude oil prices, merchandise imports and exports, and manufacturing sector employment data. The empirical portion statistically examines the relationship between manufacturing and exchange rates using OLS, VAR, and structural break tests.

The remainder of the paper is organized as follows. Section 2 presents current literature available on Canadian manufacturing and its correlation to exchange rates. Sections 3 and 4 present the data and statistical methods used for analysis. The results are presented in section 5, followed by conclusions and opportunities for future work in section 6.

# 2 Literature Review

## *2.1 An overview and brief history of the manufacturing sector in Canada*

Canada was a commodity based economy of fish, timber, and fur long before the manufacturing sector developed, in contrast to their southern neighbors whose economy was founded based on agriculture (Balakrishnan, Eliasson, & Sweet, 2007). The development of the manufacturing sector began in the $17^{th}$ and $18^{th}$ centuries, beginning with Canada's vast natural resources which led naturally to primary industries. Manufacturing development followed European settlement from east to west, and by the $19^{th}$ century the manufacturing industry had become a significant part of the Canadian economy.

Canada is geographically large with a small population, concentrated in distinct areas, giving national firms unique challenges, both culturally and in terms of transportation (Balakrishnan, Eliasson, & Sweet, 2007). It was only with the development of the railway system and foreign investment, particularly from the U.S. that the sector was able to expand. The industry began with simple items in small volumes due to the small market and geographical challenges in the vastly unpopulated country. Items were typically hand crafted by artisans, with simple supply chains. By 1809 iron products were the largest component of the sector, but the quality of the ore, charcoal for power generation rather than coal, and lack of transportation resources meant that competition with British producers was nearly impossible.

In the $20^{th}$ century mass production became popular, and manufacturing made up about 20% of Canada's Gross National Product (Balakrishnan, Eliasson, & Sweet, 2007), though the export component was not large and most manufacturing was done for domestic consumption. Major industries in this time included logging and flour milling, along with newer sectors such as meat packaging, representing a shift towards consumer goods. As Canada developed further westward, manufacturing moved towards Ontario from Montreal and the Atlantic. Foreign investment aided the development of mining and pulp and paper mills, with papermaking being Canada’s leading industry by the 1920s. Mass manufacturing was given another boost during the Great War, through military equipment and food exports during the rebuilding period. During the Great Depression the government encouraged diversification of the economy, and the Second World War helped boost manufacturing once again. Growth in the sector continued until the entry of low cost manufacturing from developing nations threatened the industry.

Today, most of Canadian manufacturing is centered in Ontario and Quebec (Balakrishnan, Eliasson, & Sweet, 2007), along with over 50% of the country’s population. This area is ideal as it shares a border with the U.S. Midwest manufacturing hub, facilitating international trade. Many trade agreements have come from this configuration, first with the Auto Pact in 1965, the Canada-United States Free Trade Agreement in 1987, and finally North American Free Trade Agreement (NAFTA) in 1994. These agreements allowed Canadian automobile manufacturing to boom, using parts imported from Detroit in the U.S. and assembling them in Windsor, which saved companies money by operating in Canada, in part due to subsidized Health Care. However, there are no fully Canadian automobile manufacturers; they are all are a subsidiary of a company from another country. That said, these agreements, among others also hindered the competitiveness of Canadian mass manufacturing in international markets. As a result, in the 21st century, Canada has returned to specialized manufacturing, such as aircraft and technology.

Using current calculations, manufacturing makes up nearly 11% of GDP (Government of Canada, 2015). The majority of this contribution comes from the high-skill, high-tech sector which directly provides 1.7 million people in mostly full time, well paying positions, in addition to the indirect and induced effects. The high-tech sector is also the largest R&D investor in the country, investing 6.8 billion in 2014. Though not a huge part of total GDP, the manufacturing sector made up 61% of merchandise exports in 2014, and to this day is highly impacted by free trade agreements. In 2014 the top three manufacturing sectors by sales were transportation equipment, food processing, and petroleum and coal products.

Canada ensures the success of the manufacturing sector in a number of ways, in part through keeping business taxes. KPMG reported that total tax cost in Canada for businesses is the lowest in the G7, almost half of that in many parts of the U.S. (Government of Canada, 2015). This low tax rate extends to manufacturing investment and new business investment. They have also worked to open new markets through free trade agreements, by promoting training for high skilled jobs such as the Canada Job Grant and apprenticeship supports, and by supporting new innovation.

Though the manufacturing sector remains important to Canada's economy, it has suffered some setbacks in the last ten years. Some evidence shows that the decline in manufacturing occurred due to long-term structural changes to the economy which were independent of the increase to the natural resource sector and the appreciation of the dollar (Krzepkowski & Mintz, 2013). It is possible that the decline in manufacturing over the last few decades is not due to Dutch disease at all. Jobs in manufacturing have been decreasing since the 1940s, which is well before the oil sector picked up, indicating that manufacturing labour intensity may have decreased over time. This could also be due to the use of off shore labour. Lost manufacturing jobs tend to be low-skill, so there is a push to encourage growth in higher skill (and higher paying) sectors. If there is no encouragement for growth, this could explain why the sector has not recovered, supported by the fact that capital investment to manufacturing has also been low.

The role of Dutch disease to explain the decline in manufacturing may be overblown, so perhaps we should not expect the reverse relationship to be true when oil declines. Employment in manufacturing has decreased in most OECD countries over the last generation, with many countries seeing an even more pronounced decrease than Canada (Krzepkowski & Mintz, 2013). This decline is not limited to countries with a large resource sector who may have been prone to Dutch disease. As with most OECD countries, in Canada, Ontario has seen a shift from manufacturing to finance and high tech, without a negative impact on growth overall. If Dutch disease is not the cause of decreased manufacturing, rather a shift to the structure of the economy, it is unlikely that a falling dollar will result in the return of jobs to the manufacturing sector. These potential changes to the manufacturing sector in Canada are discussed further in section 2.4 of the literature review.

## *2.2 The Canadian dollar as a commodity based currency*

Canada was one of the first major countries to adopt a floating exchange rate in 1950, but in 1962 it again fixed its currency to the U.S. dollar (Baldwin & Yan, 2011). Following a period where the Canadian dollar was fixed to the U.S. dollar in the 1960s Canada returned to a floating exchange rate which it has kept ever since, giving the country one of the longest experiences with a floating rate regime including a number of cycles between appreciation and depreciation with the U.S. dollar. The Canadian dollar appreciated when it was first allowed to float, followed by depreciation from the mid-1970s to mid-1980s and another appreciation in the late 1980s. This cycle was followed by a decade long depreciation until 2002 where it entered a period of steady appreciation. The high value of the Canadian dollar against the U.S. dollar remained until 2014 when world oil prices crashed along with the Canadian dollar, and it has yet to recover.

The relationship between the exchange rate and manufacturing is not easily analyzed. Looking at only monthly or quarterly frequencies, there is little correlation between oil prices and the Canadian/U.S. exchange rate (Ferraro, Rogoff, & Rossi, 2011). By contrast, daily frequencies for both series are highly correlated, using both current and lagged oil price shocks. Given these correlations, it is found that the predictive value of oil price shocks is highly significant for the daily nominal exchange rate. Since less frequent data does not have the same predictive power, it implies that the correlation is transitory and the oil price shocks to currency tend to be short lived. These results are consistent with other commodity exporting countries such as Chile, South Africa, and Norway.

In a small open economy that exports oil, such as Canada, the exchange rate should reflect changes in oil prices. Recent studies indicate that there is predictive power using exchange rates to predict commodity prices but in and out-of-sample, but that forecasting the reverse has weak power at the quarterly frequency (Ferraro, Rogoff, & Rossi, 2011). This is relevant since the argument used in this paper is that the oil shock led to the depreciation of the dollar. Some literature indicates that nominal exchange rates are not predictable, but this is proven false for commodity based economies in the very short run.

Past research indicated an inverse relationship between energy prices and the Canadian dollar where an increase in real energy prices led to depreciation of the dollar (Issa, Lafrance, & Murray, 2008). Using structural break tests it was found that this relationship switched signs in the early 1990s so that increased energy prices led to appreciation of the dollar. This shift corresponds with changing energy policy in Canada and changes to trade policy.

A commodity based currency responds highly to changes in global commodity prices, in Canada's case crude oil (Issa, Lafrance, & Murray, 2008). Research in this area became popular in the early 2000s as energy prices increased, along with the value of many currencies which are viewed to be commodity based such as the Canadian and Australian dollars. Growth in this sector transformed Canada from an oil importer in the 1970s to one of the largest exporters in both oil and natural gas. Then, in the early 1990s new policy as well as high world crude oil prices facilitated the development of the Alberta oil sands. Though free trade agreements aided the manufacturing sector, Canadian international trade is still comprised mainly of commodities in net terms. That said, there is debate as to whether or not Canada's currency is actually commodity based, and research suggests that the relationship may have declined during the 1980s and many other sectors, as well as economic performance of the United States remain important to the Canadian economy.

### *2.3 The historical relationship between the exchange rate and manufacturing*

The real exchange rate was not traditionally considered a part of growth models. However, more recent literature focuses on export led growth, where the exchange rate allows for an incentive to transfer resources into the manufacturing sector, resulting in a one-time increase to economic growth (Eighengreen, 2007). This method is effective because the onset of diminishing returns to manufacturing is much slower than other sectors such as agriculture. Globalization makes demand for manufactured goods perfectly elastic since supply could always have perfect substitutes. In addition, the manufacturing sector in quickly growing developing countries tends to be disproportionately large. Some literature suggests that the level of the exchange rate is less important than its volatility, since a volatile (or unpredictable) exchange rate discourages international trade. In spite of this, minimizing volatility does not necessarily help maximize growth, as hedge funds can mitigate the risk.

Since the 1980s the manufacturing sector has become more exposed to imports (Campa & Goldberg, 1995). The impact of the exchange rate depends on the price-over-cost markup in the particular manufacturing industry. Industries with low markup cannot absorb the change in the exchange rate so the effect is seen in investment to the sector. High markup sectors can absorb the exchange rate changes so investments are not impacted as heavily. Traditionally, depreciation of the dollar would be seen as beneficial for manufacturing as exports become less expensive relative to world prices, however, more exposure of a sector to imports, the more depreciation of the dollar results in lower investment.

Changes in the exchange rate can impact both imported goods and those which are domestically produced, and can be heterogeneous across different industries (Kardasz & Stollery, 2001). The exchange rate impacts manufacturing both directly and indirectly. The direct effect is on the price of imported goods and exports, while the indirect effect is on domestic goods which use imported materials as a factor input, impacting the marginal cost (which is the price in perfectly competitive markets). As a result, though both show responses, exports prices respond more to changes in the exchange rate than the prices of goods sold domestically since the indirect effect is only a fraction of the direct effect.

Another possible reason for a change in the impact of the exchange rate of the Canadian manufacturing industry is a change in exchange rate pass-through (ERPT). ERPT refers to the direct effect that the value of a currency has on domestic price of imported goods and services, and on domestic prices in general (Bailliu, Dong, & Murray, 2010). Canadian exchange rate pass-through to import prices tends to be small in the manufacturing sector, in other words there is a small indirect effect. A 10% depreciation of the Canadian dollar results in an increase of import prices of only 2.25, with the price increase on domestically produced goods being even less (Kardasz & Stollery, 2001). The exchange rate pass-through elasticities vary greatly between industries, but tend to be higher in industries with a high degree of substitution between imported and domestic goods. With the high-skilled manufacturing sector in Canada it is likely that elasticities would tend toward the lower end of the spectrum.

The U.S. market is much larger than the Canadian market, and evidence suggests that Canada is a price-taker, often matching the price set by U.S. markets for both imported and domestically manufactured goods (Kardasz & Stollery, 2001). However, the relationship between manufacturing and the exchange rate should be similar in both countries, so a case study done in the United States is examined below. The U.S. dollar greatly appreciated in the 1980s, which in turn decreased the U.S. output of importable commodities, giving an opportunity for new firms to open up new markets (Branson & Love, 1988). In 1985 the U.S. dollar began to depreciate, but it is not certain that changes to the manufacturing industry will be reversible. Between 1970 and 1986, appreciation of the U.S. dollar has significant negative effects on manufacturing, especially that of durable goods including primary metals, fabricated metal, electrical machinery, and transportation equipment.

The impact of the dollar on manufacturing depends on if the specific good is importable or exportable, but not as much on overall imports and exports (Branson & Love, 1988). As would be expected, high employment in manufacturing sectors is correlated with a low national unemployment rate. Industries which experienced job losses during this time included those which were expecting decline as well as those which had forecasted growth, resulting in the expectation that the exchange rate is to blame. Appreciation of the dollar may cause firms to move manufacturing facilities overseas, and they may not return with depreciation of the dollar. Though jobs in manufacturing research, marketing, and administration related to the manufacturing industry are more likely to remain in the U.S., the relationship may change over time as the U.S. economy becomes more open and sensitive to world markets.

With the decrease of the Canadian manufacturing sector in the 1980s and 1990s, Canada saw the closure of many manufacturing facilities. In a sample of solely Canadian manufacturing plants which were active in 1979, 65% had closed by 1996 (Baldwin & Yan, 2011). With only the least productive plants closing, high plant death has the effect of increasing productivity in the manufacturing sector. Newer and smaller plants also tend to be less efficient and therefore have lower survival rates.

Though both the exchange rate and tariffs impact the manufacturing market through international trade, the impact of the exchange rate is not always homogeneous to the impact of tariff reductions on the survival rate of plants (Baldwin & Yan, 2011). As would be expected, exporting plants are more sensitive to changes in the exchange rate than those who do not export, and appreciation of the dollar has a positive impact on exit from the market, especially when productivity is low. This implies that though depreciation of the dollar has not boosted manufacturing that it may protect smaller or less efficient plants from closing. Unfortunately, since these plants are the least productive, it is uncertain whether or not the economy would actually benefit.

### *2.4 How has the manufacturing sector evolved in the last two decades*

As with most industries, technology has allowed manufacturing to evolve over the last two decades. In the period from 2002 to 2012 both total exports and manufacturers' sales have increased, yet exports of Canadian goods manufactured have declined, indicating that there must have been a shift in the industry during that time (Carrière, 2014). Unfortunately, the Monthly Survey of Manufacturing does not contain information on the composition of output, meaning that we know the sales, but not the Canadian value added of manufacturing, as some work may have been done by foreign producers. This means that if parts are bought from another country and sold as a final good, information is only known on the export value of the final product, not the Canadian component.

In 2012, 78% of Canadian manufacturing exports went to the U.S., and while total manufacturing exports decreased, the exports to countries other than the U.S. have increased over the 2002 to 2012 period, meaning that the export destinations of Canadian manufactured goods have changed (Carrière, 2014). While U.S. imports of Canadian goods has recovered somewhat since the Great Recession, their value has yet to return to pre-recession levels, indicating that Canada has transferred some U.S. imports to other countries. That said, the U.S. still imports the majority of Canadian manufactured goods.

It is clear that the countries receiving Canada's exports have shifted, but where is new output going? China has had the largest increase in the share of manufacturing exports, going from 0.9% to 3.5% of total exports over the ten year period (Carrière, 2014). This is to do in part to the fast growth to Chinese GDP in this period and a tripled imports. Export sectors to China showing extraordinary growth over this period are paper manufacturing, wood product manufacturing, and primary metals manufacturing. This is of particular interest because the paper industry in Canada has undergone sharp declines over this period. Russia is historically China's largest source of wood imports, but due to increased export tax China has begun looking to other sources, including Canada. Canadian manufacturing exports also increased to countries in the European Union with an increase from 4.5% to 6.5%. Much of this EU increase came from primary metal products to Great Britain and petroleum and coal products to the Netherlands.

Overall, exports in the manufacturing sector are more diversified than they were in 2002 (Carrière, 2014). Increased diversification goes hand in hand with a decrease in the share of exports going to the U.S., as new products open new demand markets. Transportation equipment is the largest manufacturing sector in sales and exports, though it also showed the greatest decline from 2002-2012. This sector made up 27.1% of manufacturing exports, even after a 7% decline from 2002. Transportation and equipment is in a large part made up of motor vehicle manufacturing and motor vehicle parts manufacturing, with 97% of these exports going to the U.S., this sector is highly correlated to U.S. motor vehicle demand. The variation matches the changes in demand from the post-recession period, but not before.

Along with changes to the types of manufacturing exports, between 2002 and 2012 the total manufacturing export intensity decreased from 52.1 to 45.7, meaning that Canada is now exporting a smaller proportion of manufacturing sales (Carrière, 2014). This is intuitive since over this period the Canadian dollar also strengthened and was close to parity with the U.S. dollar. The Canadian dollar has since depreciated, and it is possible that the manufacturing export intensity has increased once again, though this is not clearly reflected in the data. It is also possible that the diversification of manufacturing production has increased manufacturing for domestic demand, and that changes to the Canadian dollar no longer impact manufacturing exports as it has in the past.

Another point of interest is how the manufacturing sectors compare between the U.S. and Canada. The manufacturing trends in both Canada and the U.S. are similar from 1970 onward (Baldwin, Jarmin, & Tang, 2002). In terms of their share of manufacturing employment, small plants increased up until the 1990s, where they have remained relatively constant. In terms of their share of output, small manufacturing companies also increased until the 1990s, but at that point the share of output declined. The labour productivity of small manufacturing plants in Canada has been falling since the 1970s, whether due to a low capital intensity or low efficiency. While small firms were seen to be of increasing importance around this time, this era appears to have ended. In addition, though employment in small firms increased, this does not necessarily signal income growth, as small firms in Canada are found to have lower wages than larger firms with comparable jobs. This difference could indicate structural differences between the industries in both countries.

One final evolution in the manufacturing industry which goes hand in hand with globalization is the degree of external exposure. Significant changes have been observed in the external orientation of the Canadian manufacturing sector, in terms of the export share, import penetration, and the share of imports used as factor inputs (Campa & Goldberg, 1995). The most widely used measure of external orientation is "openness to trade" which is calculated by net trade in the industry relative to domestic consumption in that industry. This definition excludes certain characteristics of external orientation which are of growing importance, such as the increased role of imported inputs in manufacturing. For example, an industry with a low openness to trade could still be sensitive to changes in the exchange rate if a high proportion of factor inputs come from imports.

External orientation of Canadian industries is higher than that of their U.S. counterparts, though both have increased considerably over the last two decades. Canada has seen high increases to exports without the same increase to imported inputs, resulting in quickly increasing external exposure (Campa & Goldberg, 1995). Since the 1970s, Canada has gone from 40% of manufacturing industries having a high external exposure to 80% in 1993. This exposure could indicate that imports are playing a more important role in manufacturing production, which could negate the anticipated boost to manufacturing expected from a depreciation of the Canadian dollar. These various reasons for how the manufacturing sector has changed over the last twenty years support the fact that increased manufacturing has not been realized following a drop in the value of the dollar. The sections which follow attempt to add an empirical analysis to this observation.

# 3 Data

The majority of the data used in this project is generated by Statistics Canada and available from CANSIM (Statistics Canada, No date). In order to maximize the number of observations for statistical purposes, monthly data are used[2]. In some cases quarterly data are available for a longer time horizon, but this is not the case for all variables.

The key variable of interest for this project is Canadian manufacturing. Data is retrieved from the Monthly Survey of Manufacturing (MSM), released on a monthly basis since January 1992. In order to achieve a larger time series, this series has been spliced backwards with the version of the survey with slightly different definitions. This allows for sufficient degrees of freedom for statistical analysis and an examination of the implementation of the Canada-U.S. Free Trade Agreement. The series used for the current data is sales of goods manufactured, seasonally adjusted. This is used as a measure of output of the manufacturing industry. The series is not available prior to 1992. Instead, seasonally adjusted new orders are used as a proxy. Taking the level in period (t+1) and the growth rate from new orders, the series is extended back to January 1981, with 424 observations.

The same splicing procedure is used for combining two MSM series for raw materials inventories. Raw materials inventories are used since high inventory may be indicative of a lower level of manufacturing, or as preparation for higher anticipated future levels of manufacturing. Both could add explanatory power to the model.

[2] Quarterly data are available for some series, but though they extend further back their use would decrease the number of total observations, and monthly data is preferred for timely short-term forecasting.

Data on the output in the manufacturing industry is obtained through the Labour Force Survey (LFS), accessible through CANSIM (Statistics Canada, No date). Total employment in the manufacturing sector is available from Jan 1976 onwards, and actual hours worked in the sector per week are available starting in 1987. This data is not seasonally adjusted.

For the exchange rate variable, the United States - Canadian exchange rate is used, expressed in terms of Canadian Dollars ($\frac{\$USA}{\$Canada}$). This is a monthly series extending back to October 1950, as recorded by the Bank of Canada and available to the public through CANSIM.

Import and exports data are also considered as part of the model. Both imports and exports of merchandise come from the balance of payments seasonally adjusted data. This data comes from the Merchandise Imports and Exports data available from Statistics Canada, which is only available on a monthly basis starting in January 1988, restricting the time series for the full model to 340 observations.

In order to draw comparisons with the historical relationship of oil and the manufacturing industry, oil price data is used from the St. Louis Fed (Federal Reserve Bank of St. Louis, 2016). West Texas Intermediate (WTI) prices are used as this series is available on a monthly frequency from 1986 onwards. Heavy Canadian oil, or Western Canada Select, are generally at a lower price. However, the Canadian series only starts in 2005 and fluctuations will follow the same trend. Thus, we turn to WTI, the other North American standard in this project.

The final dataset ranges from January 1988 to March 2016. Data are all monthly, and seasonal adjustments are used from statistics Canada whenever possible. The remaining series were seasonally adjusted using the X-13 ARIMA process for seasonal filtering in MATLAB. Further information on the specific series used is available in the data appendix.

# 3 Methods

## *4.1 Stationarity of the data*

Most macroeconomic variables will increase following a trend, therefore it is necessary to establish stationarity prior to running a regression model. All variables were found to be stationary after first-differencing with the exception of actual hours worked in the manufacturing sector, which is I(0). This was established by performing the augmented Dickey–Fuller test for all eight variables and confirming the findings with the autocorrelation and partial autocorrelation functions.

The augmented Dickey–Fuller test checks the presence of a unit-root process. The null hypothesis is that the variable contains a unit root, and the alternative is that the variable was generated by a stationary process. The table below shows the results to the Dickey-Fuller tests with trend, with an interpolated D-F 5% critical value of -3.423:

**Table 1: Dickey-Fuller tests for stationarity**

| | Level | | First Difference | |
|---|---|---|---|---|
| **Variable** | **Test Statistic** | **P - value** | **Test Statistic** | **P - value** |
| Manufacturing | -1.792 | 0.7087 | -24.789*** | 0.0000 |
| Exchange Rate | -1.396 | 0.8622 | -15.081*** | 0.0000 |
| Manufacturing Employment | -1.597 | 0.7936 | -13.112*** | 0.0000 |
| Raw Materials | -1.322 | 0.8824 | -22.337*** | 0.0000 |
| Merchandise Imports | -2.973 | 0.1398 | -21.960*** | 0.0000 |
| Merchandise Exports | -2.051 | 0.5733 | -17.906*** | 0.0000 |
| WTI | -1.959 | 0.6238 | -12.479*** | 0.0000 |
| Manufacturing Hours Worked | -18.377*** | 0.0000 | -18.072*** | 0.0000 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | | |

The test concluded that seven variables are generated by a stationary process after first-differencing. They are Canadian manufacturing, United States / Canadian exchange rate, employment in the manufacturing sector, raw materials inventories, imports of merchandise, exports of merchandise, and West Texas Intermediate (WTI) oil prices, which are all statistically significant at 99%. This includes tests with and without trend, drift and constant. The fact that actual hours spent in manufacturing sector is stationary at I(0) is not surprising. The average is 40 per week from 1988 to 2016, with the minimum and maximum being 34.5 and 41.5 suggesting that the variable is independent of time.

### *4.2 AR and OLS analysis of the relationship*

The first statistical techniques used to evaluate the relationship between manufacturing and the exchange rate are simple auto-regressive and ordinary least squares regressions. Various specifications were tested to find which variables are significant, leading to a single, refined OLS model. In testing, the end of the sample is restricted to December 2012 in order to allow for out of sample forecasting. First, an AR model is used to evaluate the impact of past manufacturing values on the current data. Based on the correlogram, only the first lag is significant, so an AR(1) is tested:

**Table 2: First-differenced manufacturing AR(1) results**

| | | | | |
|---|---|---|---|---|
| Number of observations: 383 | | | | |
| Log Likelihood: -5,773.68 | | | | |
| Wald $\chi^2(1)$: 36.02*** | | | | |
| **Variable** | **Coefficient** | **Standard Error** | **z - Statistic** | **Confidence Interval** |
| Manufacturing $_{t-1}$ | -0.1699*** | 0.0283 | -6.00 | [-0.225, -0.114] |
| Sigma | 852,520.4*** | 15,825.2 | 53.87 | [821,503.6, 883,537.2] |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | | |

With a Wald statistic of 36.02 the model as a whole is statistically different from zero at the 1% level, which indicates that manufacturing is partially explained by past values. Though a positive relationship was expected, the coefficient on the first lag is actually negative. This implies that high manufacturing growth last period leads to lower growth this period. Many trend-stationary series show a negative correlation when analyzed in growth rates. This could be a result of the relationship with inventories and the unknown fluctuations in demand. The residuals for the AR(1) were tested for serial correlation using a Portmanteau test for white noise, as shown below:

**Table 3: Portmanteau test for white noise in the AR model**

| | |
|---|---|
| $H_o$: No serial correlation | |
| $H_a$: Serial correlation of unknown form | |
| **Portmanteau Statistic: $\chi^2(12)$** | **P – Value** |
| 15.6172 | 0.2094 |

This test fails to reject the null, indicating that there is no evidence of serial correlation, therefore there is no reason to question the efficiency of the results in the AR(1) model and there is no need to correct for serial correlation.

Given this information, the AR(1) variable for manufacturing is included in the OLS model. The other potentially relevant explanatory variables used for the OLS model are the Canada / U.S. exchange rate, manufacturing hours worked, merchandise imports, merchandise exports, raw materials, and West Texas Intermediate oil prices. A constant is also included in the original model. Based on the stationarity results in the previous section, all variables are first-differenced with the exception of hours worked in the manufacturing sector. The full results to this OLS regression are presented on the following page. With an adjusted R-squared of 0.558 the explanatory power of this model is quite good, however a number of the variables are shown to have insignificant coefficients based on the t-test performed with the regression. In order to determine if these individually insignificant variables are jointly significant an F test is used.

**Table 4: OLS results for first-differenced model with all variables**

| Number of observations: 339 | | | | |
|---|---|---|---|---|
| $R^2$: 0.5684 | | | | |
| Adjusted $R^2$: 0.5580 | | | | |
| **Variable** | **Coefficient** | **Standard Error** | **T – Statistic** | **Confidence Interval** |
| Constant | 12,658.74 | 32,844.42 | 0.39 | [-51,952.11, 77,269.58] |
| Exchange Rate | -4,629,470** | 1,894,312 | -2.44 | [-8,355,920, -903,018.8] |
| Hours Worked | 5,599.13 | 15,160.55 | 0.37 | [-24,224.38, 35,422.64] |
| Employment | 547.56 | 1,077.50 | 0.51 | [-1,572.08, 2,667.17] |
| Merch. Imports | 376.89*** | 55.84 | 6.75 | [267.04, 486.73] |
| Merch. Exports | 511.76*** | 42.37 | 12.08 | [428.40, 595.11] |
| Raw Materials | -0.033 | 0.112 | -0.29 | [-0.254, 0.189] |
| WTI | 11,465.19 | 8679.38 | 1.32 | [-5,608.70, 28,539.07] |
| Manufacturing $_{t-1}$ | -0.172*** | 0.037 | -4.69 | [-0.244, -0.0999] |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | | |

**Table 5: F test for joint significance of insignificant variables**

| $H_o$: Hours Worked = Employment = Raw Materials = 0 | |
|---|---|
| **F – Statistic** | **P - Value** |
| 0.19 | 0.8285 |

This test fails to reject the null that the coefficients for hours worked, employment, and raw materials are jointly equal to zero, confirming that they are insignificant, even when the combined impact is taken into account. For this reason these insignificant variables were dropped from the OLS model. After running this new model, the constant was still insignificantly different from zero, so it was also omitted. This results in a final OLS model with only four explanatory variables: lagged manufacturing, the Canada / U.S. exchange rate, merchandise exports, and merchandise imports[3]:

$$(\mathbf{M_t - M_{t-1}}) = \boldsymbol{\beta_1}(\mathbf{E_t - E_{t-1}}) + \boldsymbol{\beta_2}(\mathbf{X_t - X_{t-1}}) + \boldsymbol{\beta_3}(\mathbf{P_t - P_{t-1}}) + \boldsymbol{\delta}(\mathbf{M_{t-1} - M_{t-2}}) + \boldsymbol{\epsilon_t} \qquad (1)$$

[3] All Greek letters in this paper represent model parameters.

Where, *M: Canadian manufacturing*

*E: Canada / U.S. exchange rate*

*X: Canadian merchandise exports*

*P: Canadian merchandise imports*

The residuals for this model were then tested for signs of heteroskedasticity in the error term using a White test:

**Table 6: White test for heteroskedasticity**

| $H_o$: Homoskedasticity | |
|---|---|
| $H_a$: Unrestricted heteroskedasticity | |
| **$X^2$(14)** | **P - Value** |
| 19.23 | 0.1563 |

The White test fails to reject the null that there is homoskedasticity, therefore there is no need to use robust standard errors in the analysis as there are no signs of heteroskedasticity in the model, of any form. The OLS results to this model are reported in section 5.1.

Finally, the unconditional means of the OLS variables are computed, as a basis for evaluation of the forecasting exercise. The results are shown below:

**Table 7: Unconditional means for the OLS variables**

| Variable | Unconditional Mean | Standard Deviation |
|---|---|---|
| Manufacturing | 90,577.45 | 859,040.1 |
| Exchange Rate | 0.000244 | 0.019271 |
| Merch. Imports | 98.20 | 694.93 |
| Merch. Exports | 89.63 | 940.08 |

## *4.3 Is VAR a better option?*

In addition to the OLS and AR models, which were explored in the previous section, a Vector Autoregression model is developed in order to incorporate more potentially relevant lagged variables into the analysis. VAR is a good option as it does not require specific prior knowledge on the interactions between variables as is required for a structural simultaneous equations model. Manufacturing is the key variable of interest, so it is used first in the equation order, as interest is focused on how other variables impact manufacturing, with less concern on their impact on each other. The paragraphs which follow explain the process followed for variable and lag order selection for the final VAR analysis.

The lag order was chosen based on the results of lag order selection statistics of vector autoregressions of order up to 12 from various criteria. Five criteria for model selections were considered: sequential likelihood-ratio (LR) test, final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC). Two of the criteria, FPE and AIC, recommended three lags, while SBIC suggested one lag and HQIC two lags. LR always chose the last lag no matter how many orders were tested. To reduce the maximum number of lags allowed for the tests, the LR result was rejected. Based on keeping all relevant information, the final VAR model used the lag order of three for further testing, as indicated by FPE and AIC.

Next, the model variables were tested for evidence of Granger causation. Some of the individual variables showed a lack of Granger causation on manufacturing (the endogenous variable of interest), although, collectively, they always have an impact. A time series *X* is said to Granger-cause *Y* (manufacturing) if it can be shown, usually through the Granger causality tests, that those *X* values provide statistically significant information about future values of *Y*. Specifically, it was found that the United States - Canadian exchange rate and the WTI oil prices are always statistically significant but the other variables (Raw materials, Manufacturing hours, Manufacturing Employment, Merchandise imports, and Merchandise exports) were not. The insignificance of these variables persisted, as insignificant variables were dropped in various combinations. Therefore, all variables were dropped except the export variable as leaving one of the variables was shown to add to the model.[4]

**Table 8: Granger causality tests for manufacturing**

| Excluded Variable | F - Statistic | Degrees of Freedom | P – Value |
|---|---|---|---|
| Exchange Rate | 5.1177*** | 2 | 0.0065 |
| Exports | 4.5676** | 2 | 0.0111 |
| WTI | 18.984*** | 2 | 0.0000 |
| All | 11.476*** | 6 | 0.0000 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | |

In addition, none of the third lags in the remaining regression were significant. As such, the model was reduced to a first-difference VAR(2) with three exogenous variables of United States - Canadian exchange rate, Canadian exports, and the WTI oil prices in an effort to keep the model as simple as possible. The model of simultaneous equations is outlined on the following page:

[4] Results did not vary based on which of the originally insignificant variables was kept in the final model, but excluding all five decreased the power of the model.

$$\alpha M_t = \beta_0 + \beta_1 M_{t-1} + \beta_2 M_{t-2} + \epsilon_t \qquad (2)$$
$$\delta E_t = \theta_0 + \theta_1 E_{t-1} + \theta_2 E_{t-2} + \varepsilon_t$$
$$\rho X_t = \varphi_0 + \varphi_1 X_{t-1} + \varphi_2 X_{t-2} + u_t$$
$$\omega W_t = \tau_0 + \tau_1 W_{t-1} + \tau_2 W_{t-2} + \mu_t$$

Where, *M: Canadian manufacturing*

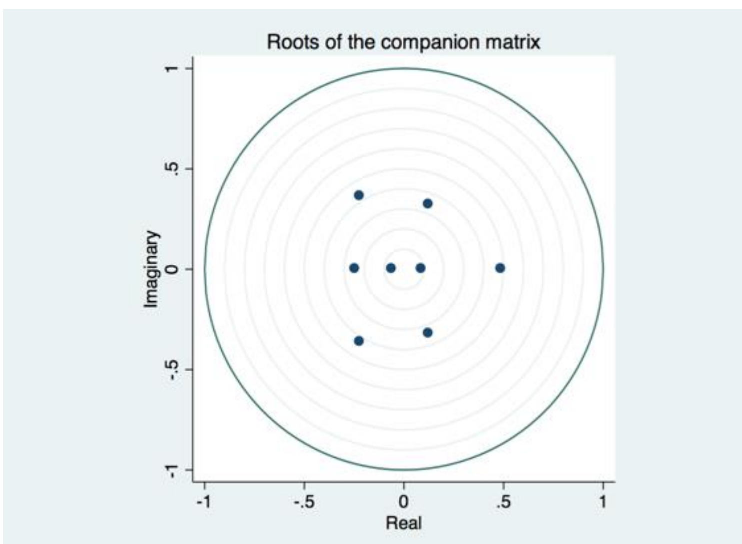
*E: Canada / U.S. exchange rate*

*X: Canadian merchandise exports*

*W: West Texas Intermediate oil prices*

The eigenvalue stability condition was verified after estimating the parameters of the above VAR(2) model. As depicted below, all eigenvalues lie within the unit circle, therefore the estimates satisfy the eigenvalue stability condition.

**Figure 7: Unit root test on the first differenced VAR**



Moreover, we tested if the disturbances in a VAR are normally distributed. Overall, the VAR(2) model passes the skewness test, the kurtosis test, and the Jarque-Bera[5]. Lastly, the first-difference VAR(2) with three variables is robust to small sample degree of freedom correction. Given these tests, the results of the final VAR model can be considered robust, and were followed by an analysis of various shocks using impulse response functions, and a short forecasting exercise, which are all reported in the results section.

### *4.4 Structural breaks in the data*

There are a few possible structural breaks that have been indicated which could impact the trend of manufacturing output in Canada. The most relevant of these breaks are the Free Trade agreement (FTA) in 1988 and later the amendments leading to the North American Free Trade Agreement (NAFTA) in 1994, as well as the financial crisis in 2008 and 2009. Since the majority of the data begins in 1981, where the Auto Pact had been in effect for 15 years, the free trade agreements are less concerning given that the model examines only interactions between Canada and the United States. That said; if behaviour differs around 1988 and 1994 this could be an explanation. The figure below shows the Canadian manufacturing data as well as the dates of the potential break points. Based on this figure the Great Recession in 2008 and 2009 is used as an estimated break date for structural break estimation.

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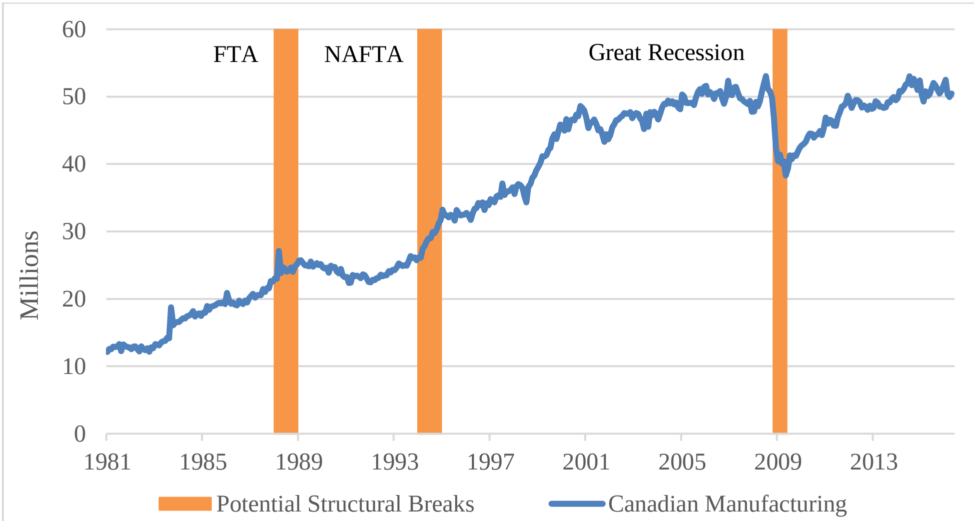
[5] Other than the exchange rate and exports which fail the skewness test, all other variables are individually and collectively significant at 99% level.

**Figure 8: Possible structural breaks in the Canadian manufacturing sector data**




For testing, the final OLS model is used, without de-trending the variables as the trend is required to perform a structural break test. Though all regression variables are included, only the exchange rate is used as a break variable. The structure of the model is outlined below:

$$M_t = \beta_1 E_t + \beta_2 X_t + \beta_3 P_t + \delta M_{t-1} + \epsilon_t \qquad (3)$$

Where, *M: Canadian manufacturing*

*E: Canada / U.S. exchange rate*

*X: Canadian merchandise exports*

*P: Canadian merchandise imports*

There are two key assumptions which must be made prior to executing a structural break test. The first is that the data follow a trend, but are stationary once first differenced, and the second is that there is a cointegrating relationship between the variables (Issa, Lafrance, & Murray, 2008). The first assumption is valid for all variables in the regression model, as discussed in section 4.1 on the stationarity of the variables. In order to test for cointegration among the model variables a Johansen test is used.

**Table 9: Johansen tests for cointegration**

| Number of observations: 338 | | | | | |
|---|---|---|---|---|---|
| Sample: 1988m3 – 2016m4 | | | | | |
| Lags: 2 | | | | | |
| **Maximum Rank** | **Parameters** | **Log Likelihood** | **Eigenvalue** | **Trace Statistic** | **5% Critical Value** |
| 0 | 20 | -9491.9973 | . | 63.5871 | 47.21 |
| 1 | 27 | -9474.4796 | 0.09846 | 28.5516* | 29.68 |
| 2 | 32 | -9462.4689 | 0.06860 | 4.5302 | 15.41 |
| 3 | 35 | -9460.6144 | 0.01091 | 0.8211 | 3.76 |
| 4 | 36 | -9460.2038 | 0.00243 | | |
| *Significant maximum rank | | | | | |

With a 5% critical value of 47.21 which is below the trace statistic at maximum rank 0 we reject the null hypothesis that there is no cointegration in the model. Based on this the trace statistic of 28.5516 being lower than the critical value of 29.68, it is concluded that there is cointegration in the model with a maximum rank of 1. With all model variables being I(1) and an established cointegrating relationship, the structural break test can be completed. The results to all three statistical approaches mentioned above are outlined in the section which follows.

# 5 Results

## *5.1 OLS Results*

The final OLS results for the sample up to December of 2012 are shown below:

**Table 10: OLS results for refined first-differenced model**

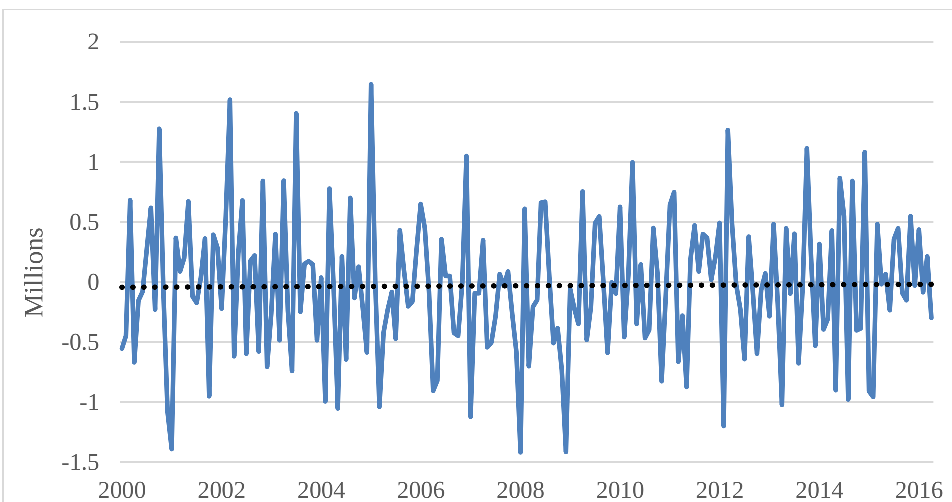
| Number of observations: 339 | | | | |
|---|---|---|---|---|
| $R^2$: 0.5690 | | | | |
| Adjusted $R^2$: 0.5638 | | | | |
| **Variable** | **Coefficient** | **Standard Error** | **T - Statistic** | **Confidence Interval** |
| Exchange Rate | -6,038,699*** | 1,604,061 | -3.76 | [-9,194,000, -2,883,397] |
| Merch. Imports | 379.91*** | 54.66 | 6.95 | [272.40, 487.43] |
| Merch. Exports | 530.25*** | 40.04 | 13.24 | [451.49, 609.01] |
| Manufacturing $_{t-1}$ | -0.171*** | 0.036 | -4.75 | [-0.241, -0.0999] |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | | |

With an R-squared value of 0.569 these variables are shown to have some explanatory power over manufacturing, even when de-trended using first differencing. All coefficients on the refined model are statistically different from zero with a 99% confidence level. That said, it is of interest that both merchandise imports and merchandise exports have a positive impact on manufacturing while the coefficients for the exchange rate and past manufacturing are both negative.

In this paper the exchange rate is defined as the U.S. dollar divided by the Canadian dollar, therefore an increase in the exchange rate indicates depreciation of the Canadian dollar. Due to this definition, the negative relationship between manufacturing and the exchange rate was anticipated, as a lower dollar facilitates manufacturing exports. The negative relationship between the first lag of manufacturing and current manufacturing was also anticipated based on the negative coefficient reported in the AR(1) results. In fact, the AR(1) coefficient of -0.1699 changes very little when added to the OLS model. Though counterintuitive, once de-trended it is possible that spikes in manufacturing are followed by downturns in the next period and vice versa due to fluctuations in demand around the trend value.

Strangely, merchandise imports and merchandise exports both have a positive impact on manufacturing of similar magnitudes (379.90 and 530.25, respectively), where it was anticipated that one would have a positive relationship and the other negative. This would be possible if imports went primarily towards the manufacturing of final goods while exports came from the manufacturing sector. In this case higher imports would facilitate growth to manufacturing as well as higher export demand. However, this hypothesis cannot be confirmed without further data on the sectoral breakdowns of merchandise imports and exports, which is not currently available for Canadian data.

**Figure 9: Plot of the OLS residuals**[6]



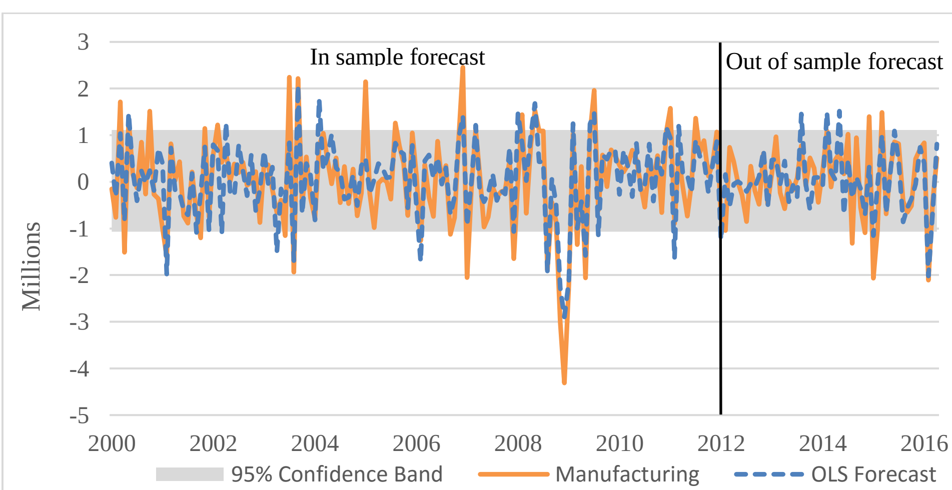

Though the residuals, which are plotted above, appear to be centered around zero without any evidence of serial correlation, there are some concerns with this regression

[6] The black dotted line represents a linear trend line, showing no evidence of heteroscedasticity.

analysis. The first potential problem is with the variation in the magnitudes of the variables. While the exchange rate has low magnitudes and small variances manufacturing is huge, resulting in a large coefficient on the exchange rate and small coefficient on lagged manufacturing. However, this is not unreasonable when considering that manufacturing changes are more likely to be in the millions rather than in one dollar increments. This inconsistency makes the interpretation of the regression more difficult, but should not impact the validity of the results.

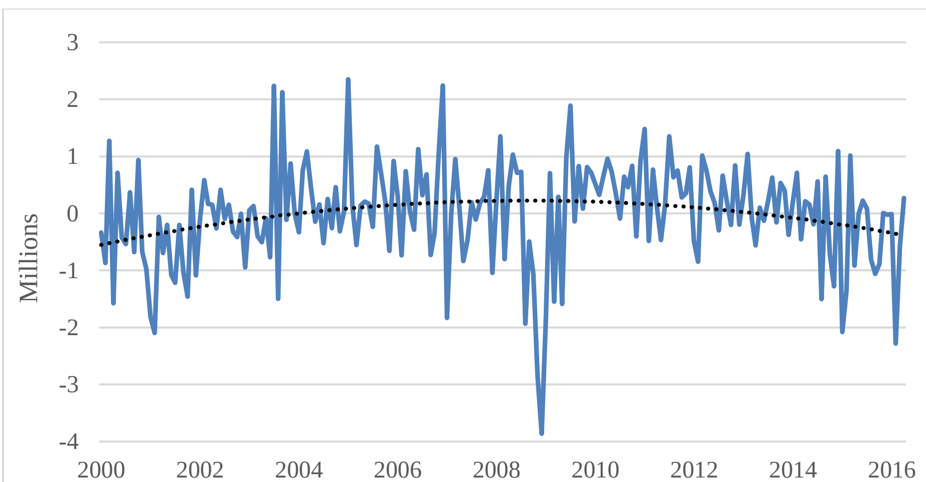
The second issue is with the potential loss of information due to the first differencing of the data. This is of particular concern for the exchange rate series where a prolonged low or high period could have significant impact on investment to manufacturing, without showing up in the de-trended data. One solution would be to achieve stationarity through a different de-trending method such as HP-filtering, but given the limited scope of this project that is saved for future work. In spite of these concerns, there appears to be a degree of explanatory power in the model, so a forecasting exercise is still performed with the results graphed below:

**Figure 10: OLS in and out of sample forecasting exercise**



As would be expected, this forecast performs relatively well in sample, though it fails to pick up the larger deviations in the manufacturing series, centering itself more towards the mean. The out of sample forecast period also performs relatively well, though it misses more of the short term fluctuations, especially around 2014. The errors in the forecast are highlighted below in the graph of the residuals from the OLS forecast of manufacturing. When compared to the residuals from the OLS model the variance is much higher as would be expected with any forecast, but there also seems to be a negative bias, especially towards the beginning and end of the sample, giving the residuals almost a quadratic form. A polynomial trend line of the second order has been shown on the graph to demonstrate this observation. This heteroscedasticity which shows in the forecast indicates that the data may not fit the model as desired.

**Figure 11: Plot of the OLS forecast residuals**




### *5.2 VAR Results*

Below are the regression tables from the first-difference VAR(2) with three exogenous variables: USD-CAD exchange rate, Canadian merchandise imports, and WTI oil prices as they relate to the variable of interest, manufacturing.

**Table 11: First-differenced VAR(2) results**

| Variable | Lags | Coefficient | Standard Error |
|---|---|---|---|
| Manufacturing | 1 | -0.368*** | 0.0702 |
| | 2 | -0.118* | -0.0702 |
| USD / CAD | 1 | 5835926** | 2579062 |
| | 2 | -6790174*** | 2542159 |
| Exports | 1 | 181.9*** | -69.96 |
| | 2 | 148.3** | -68.54 |
| WTI | 1 | 71,037*** | -11,797 |
| | 2 | -1,030 | -12,894 |
| Constant | | 81,745* | -43,319 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | |

For the first differenced VAR(2), there is evidence that the given the past values manufacturing, the past value of exchange rate, exports and oil prices help predict Canadian manufacturing. The three exogenous variables all share a positive sign and are significant at the 95% level. A Portmanteau test for white noise is shown below:

**Table 12: Portmanteau test for white noise in the VAR model**

| | |
|---|---|
| $H_o$: No serial correlation | |
| $H_a$: Serial correlation of unknown form | |
| **Portmanteau Statistic: $\chi^2(12)$** | **P – Value** |
| 23.868 | 0.021 |

This test rejects the null that there is no serial correlation, so a vector error correction model (VECM) is run. The VECM estimation table contains the estimates of the short-run parameters, along with their standard errors. The two coefficients on L.ce are the adjustment parameters. The output indicates that the model does not fit very well. Except for exports, no other variables have significant coefficients in both of their lag differences, with full results as they relate to manufacturing outlined on the following page:

**Table 13: VECM results**

| Observations: 334 | | |
|---|---|---|
| **Variable** | **Lagged Difference** | **Coefficient** |
| L.ce | 1 | -0.0768*** |
| | 2 | 437494 |
| Manufacturing | 1 | -0.336*** |
| | 2 | -0.109 |
| USD / CAD | 1 | 4324378 |
| | 2 | -8700753*** |
| Exports | 1 | 150.2** |
| | 2 | 137.8** |
| WTI | 1 | 71,728*** |
| | 2 | -2045 |
| Constant | | -0.000773 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

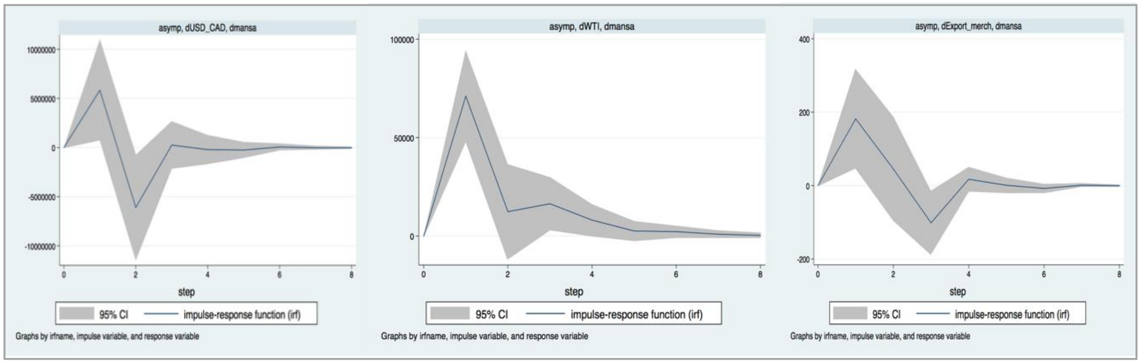
Overall, the signs of coefficients from first differenced VAR and VECM are consistent with each other, as shown above. Note that, for all the significant coefficients of the two models, the difference between the coefficients are not huge, same as the standard errors. For example, the coefficients of manufacturing for one lag are very close between the VEC (-0.368 (0.702)) and the VAR (-0.336 (0.072)). Furthermore, all of the coefficients were significant with the exception of the second lag on WTI oil prices. That said, some of these coefficients have the opposite sign as was expected following the AR(1) results. For example, the relationship of lagged manufacturing with itself is negative for both the first and second lags. It is possible that de-trending takes away most of the variation in the series leading to uninformative results.

Another way to gather insight into this relationship is to examine the impulse response functions for the impact of various shocks on manufacturing, as shown in the three figures which follow. The first examines the impact of a shock to the exchange rate on manufacturing. As mentioned, based on our definition of the exchange rate, we expected there to be a positive relationship between the two. In other words, an increase in the exchange rate would imply a depreciation of the Canadian dollar and therefore an increase in manufacturing. This is seen in the period immediately following the shock, but it is then counteracted by a decrease in manufacturing before returning to the original steady state, confirming the idea that in more recent periods the positive relationship between a low dollar and increased manufacturing output may not be as clear cut as originally anticipated based on historical data.

The middle figure below shows the impulse response function for a shock to WTI crude oil prices on manufacturing. Originally this series was included to allow for a comparison with the oil price dynamics in Canada and it was not expected to have explanatory power for manufacturing. However, it was found to be significant in both the Granger causation study and the regression analysis. As shown, an increase in crude prices appears to cause a short term increase in manufacturing. Perhaps this is a result of the income effect where if oil demand is inelastic suppliers would have more income to spend in all sectors of the economy, including the purchase of manufactured goods. In the long run, consumers would be able to find substitutes to oil use and demand would decrease, therefore decreasing the income of suppliers and returning manufacturing levels back to steady state.

Finally, the figure on the right depicts the response of manufacturing to an export shock. As anticipated, an increase in exports leads to an increase in manufacturing, which is intuitive since higher exports in general will cause higher demand across sectors, including the demand for manufactured goods. That said, the subsequent drop in manufacturing followed by a return to steady state is less easily explained.

**Figure 12: IRFs for Granger causing variables (Exchange rate, WTI, and Exports)**




Forecasts were then generated for manufacturing based on the stationary VAR. The period for the forecast is January 2016 to January 2018, which does not allow for a comparison between the forecast and the actual data. The model predicts a quick return to steady state, as would be expected from a model with little predictive power as it is unlikely that any information currently available would inform growth rates two years in the future. In addition, a slight downturn in manufacturing is predicted.

While the relationship between manufacturing and the exchange rate, WTI crude oil prices, and exports have all been analyzed above, it is of note that the relationship between imports and manufacturing has not been discussed. This is due to the fact that Granger causation was not found between these variables and imports did not have a significant coefficient in the regression. Imports were originally included in the model as it was expected that the amount of imports going to manufacturing would impact the magnitude of the relationship between exchange rates and the size of the manufacturing sector. It is possible that this relationship still exists and that it just needs to be introduced into the model in another way, such as by using data which indicates the proportion of manufacturing inputs which come from imports rather than the import numbers themselves.

### *5.3 Structural Break Results*

Given the inconsistent results, especially in the forecasting exercises for both the OLS and VAR models, a series of structural break tests were performed on the non-stationary OLS model. The first test was for an unknown break date on the full sample, which gave significant results under all specifications as shown below:

**Table 14: Structural break with unknown date for the full sample**

| Full sample: 1988m1 – 2016m4 | | |
|---|---|---|
| Trimmed sample: 1990m11 – 2013m7 | | |
| $H_o$: No structural break | | |
| Break Variable: U.S. – Canada exchange rate | | |
| **Test** | **Statistic** | **P - Value** |
| Supremum Wald | 16.2259*** | 0.0016 |
| Average Wald | 4.5973*** | 0.0084 |
| Exponential Wald | 4.6922*** | 0.0006 |
| Supremum Likelihood Ratio | 14.7114*** | 0.0034 |
| Average Likelihood Ratio | 5.0092*** | 0.0054 |
| Exponential Likelihood Ratio | 4.6609*** | 0.0006 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

Based on the time series graph of manufacturing in Canada as shown in the methods, and historical analysis, the potential structural break date is estimated to be around the Great Recession. Given this, various structural break tests are run using known break dates between 2008 and 2009. These estimated dates some significant results, mainly around August 2008 and June 2009, though their test statistics were valid only with a 95% confidence interval compared to the 99% confidence interval indicated by the test with an unknown break date. The full results are shown below:

**Table 15: Estimated structural break dates around the Great Recession**

| Sample: 1988m1 - 2016m4 | | |
|---|---|---|
| Break Variable: U.S. – Canada exchange rate | | |
| **Break Date** | $\chi^2$ | **P - Value** |
| June 2008 | 2.4240 | 0.1195 |
| July 2008 | 3.2265* | 0.0725 |
| August 2008 | 4.3291** | 0.0375 |
| September 2008 | 2.4698 | 0.1161 |
| October 2008 | 1.9501 | 0.1626 |
| November 2008 | 0.9730 | 0.3239 |
| December 2008 | 0.0021 | 0.9632 |
| January 2009 | 1.1019 | 0.2939 |
| February 2009 | 2.4223 | 0.1196 |
| March 2009 | 1.7876 | 0.1812 |
| April 2009 | 3.5686* | 0.0589 |
| May 2009 | 3.2109* | 0.0731 |
| June 2009 | 5.2440** | 0.0220 |
| July 2009 | 3.9336** | 0.0473 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

Given the limited significance of these results, another structural break test with an unknown date was run, this time restricting the sample period to exclude data past the last recession. These results are also highly significant, indication that the break point likely happened prior to the housing price crash in the U.S. which occurred in 2008.

**Table 16: Structural break with unknown date excluding the recession**

| Full sample: 1988m1 – 2016m4 | | |
|---|---|---|
| Trimmed sample: 1989m7 – 2007m12 | | |
| $H_o$: No structural break | | |
| Break Variable: U.S. – Canada exchange rate | | |
| **Test** | **Statistic** | **P - Value** |
| Supremum Wald | 16.2259*** | 0.0015 |
| Average Wald | 5.4077*** | 0.0040 |
| Exponential Wald | 4.9074*** | 0.0005 |
| Supremum Likelihood Ratio | 14.7114*** | 0.0031 |
| Average Likelihood Ratio | 5.7627*** | 0.0025 |
| Exponential Likelihood Ratio | 4.9232*** | 0.0005 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

With this result a second section of potentially significant break dates were chosen, this time in the period between 1990 and 1994, when the Free Trade Agreement between Canada and the U.S. was being implemented. A subset of the significant results are shown below:

**Table 17: Estimated structural break dates around the implementation of the FTA**

| Sample: 1988m1 - 2016m4 | | |
|---|---|---|
| Break Variable: U.S. – Canada exchange rate | | |
| **Break Date** | $\chi^2$ | **P - Value** |
| January 1990 | 6.9190*** | 0.0085 |
| February 1990 | 6.9070*** | 0.0086 |
| March 1990 | 7.2277*** | 0.0072 |
| April 1990 | 7.8306*** | 0.0051 |
| May 1990 | 7.1955*** | 0.0073 |
| June 1990 | 8.8917*** | 0.0029 |
| July 1990 | 9.1193*** | 0.0025 |
| August 1990 | 9.6487*** | 0.0019 |
| September 1990 | 9.1317*** | 0.0025 |
| October 1990 | 8.9334*** | 0.0028 |
| November 1990 | 10.2772*** | 0.0013 |
| December 1990 | 9.0104*** | 0.0027 |
| January 1991 | 8.9522*** | 0.0028 |
| February 1991 | 9.3822*** | 0.0022 |

| Break Date | $\chi^2$ | P - Value |
|---|---|---|
| March 1991 | 8.2743*** | 0.0040 |
| April 1991 | 8.5843*** | 0.0034 |
| May 1991 | 10.4845*** | 0.0012 |
| June 1991 | 10.5601*** | 0.0012 |
| July 1991 | 11.2105*** | 0.0008 |
| August 1991 | 11.2429*** | 0.0008 |
| September 1991 | 11.0844*** | 0.0009 |
| October 1991 | 12.5143*** | 0.0004 |
| November 1991 | 12.7606*** | 0.0004 |
| December 1991 | 12.3210*** | 0.0004 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

Additional results from the beginning of the FTA implementation are reported in appendix III. These results are extremely significant, but it should be noted that the tests are mutually exclusive, so the results do not indicate that a break occurred at each of these dates, rather that the break could have occurred at any point between 1990 and 1994. This is logical given that the Free Trade Agreement between Canada and the United states took a number of years to implement, and the changes to the manufacturing sector would have had a delayed response. It is also intuitive that NAFTA would not have as much as an impact, since it simply amended the FTA to include Mexico, which is not a large trading partner for Canada and is unlikely to impact the relationship between Canadian manufacturing and the exchange rate between the U.S. and Canada.

Finally, the sample is trimmed to exclude both the Great Recession and the first few years of the FTA implementation, leaving a sample of just over ten years from 1996 to 2007. The results to the test for a structural break of unknown date with this subset of the data are shown below:

**Table 18: Structural break with unknown date excluding the FTA and the recession**

| Full sample: 1988m1 – 2016m4 | | |
|---|---|---|
| Trimmed sample: 1996m7 – 2007m11 | | |
| $H_o$: No structural break | | |
| Break Variable: U.S. – Canada exchange rate | | |
| **Test** | **Statistic** | **P - Value** |
| Supremum Wald | 7.3911** | 0.0498 |
| Average Wald | 2.3459* | 0.0981 |
| Exponential Wald | 1.6347* | 0.0795 |
| Supremum Likelihood Ratio | 8.9998** | 0.0234 |
| Average Likelihood Ratio | 2.5399* | 0.0842 |
| Exponential Likelihood Ratio | 1.8359* | 0.0625 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | |

Though still significant at the 10% confidence level, this final structural break test indicates that it is likely that the real structural break occurred following the implementation of the FTA, though a further break may have occurred during the Great Recession. Unfortunately the data does not extend far enough past the last recession to test both dates simultaneously for a dual structural break.

# 6 Conclusion

## *6.1 Implications of the Project*

Based on the limited fit of the OLS and VAR models, as well as the significant results reported through the structural break test this research shows that depreciation of the dollar will not necessarily lead to manufacturing growth as it once did. It is possible that this break comes from a structural change to the industry following recent trade agreements, or other factors such as a potential decline in the importance of manufacturing to exports. For example, Canada tends to produce high-end, specialized products which are sold to countries with a high average income, of which Canada is one of few in the world. In this case manufacturing may be mainly for domestic use, without benefitting from increased demand for exports due to a depreciated dollar.

In practice, though this research does not directly allow one to argue for or against policy which leads to the intentional depreciation of the dollar, it does give evidence against using benefits to the manufacturing sector as support for a depreciative policy. Though this relationship was observed at one time, it is likely that globalization following the various free trade agreements in the early 1990s, along with the diversification of exports following the housing crash in the U.S. have diminished this link between manufacturing and the exchange rate. As a result, this research suggests that economists should not anticipate growth in the manufacturing sector due to the relative attractiveness of exports which comes with a depreciating dollar, without other factors which would encourage manufacturing investment.

### *6.2 Limitations of the analysis and future work*

This project established that the relationship between Canadian manufacturing and the Canada / U.S. exchange rate has changed over time, and offers potential explanations for why this may be the case through the literature review. Such reasons include changes to the international exposure of the manufacturing sector, differences in which countries import Canadian goods, and changes to the relative importance of manufacturing on Canada's GDP. However, a specific break date is not determined, and it is outside the scope of this project to empirically analyze the specific reasons for a decline in this relationship.

Future work could support this conclusion in a number of different ways. Given the structural break results additional OLS models could be examined using only a subset of the data in order to evaluate changes in the coefficients before and after the estimated break dates, confirming that the relationship has changed. Another step would be to examine the manufacturing share of exports. This analysis requires the generation of new data, as export data decomposition follows the Standard International Trade Classification (SITC) system while manufacturing is part of the North American Industry Classification System (NAICS). It would be possible to back out this information using existing Statistics Canada data. A similar project could examine the import content of manufacturing, and the share of inputs acquired abroad. These two perspectives would give empirical evidence for the reason that the relationship between Canadian manufacturing and the Canada / U.S. exchange rate has weakened over the last two decades.

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## Appendix I: Definitions

Below are some commonly used acronyms used in this research which are not explained explicitly in the text:

GDP: Gross Domestic Product

U.S.: United States of America

USD: United States Dollars

CAD: Canadian Dollars

OLS: Ordinary Least Squares regression

AR: Auto-regression

VAR: Vector Auto-regression

## Appendix II: Data Sources

| Name | Description | Source | Table | Vector ID |
| --- | --- | --- | --- | --- |
| employed_manu | Employment in manufacturing, unadjusted for seasonality | Monthly | CANSIM | 282-0007 |
| Ex_All | Total exports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Ex_All_US | U.S. exports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Ex_Manu | Total manufacturing exports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Ex_Manu_US | U.S. manufacturing exports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Export_merch | Merchandise Exports, balance of payments, seasonally adjusted | Monthly | CANSIM | 228-0059 |
| GDPBP | GDP at basic prices, chained 2007 dollars | Monthly | CANSIM | 379-8031 |
| hrs_manu | Actual hours worked in the manufacturing sector | Monthly | CANSIM | 282-0021 |
| Im_All | Total imports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Im_All_US | U.S. imports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Im_Manu | Total manufacturing imports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Im_Manu_US | U.S. manufacturing imports, Paasche weighted index | Monthly | CANSIM | 228-0066 |
| Import_merch | Merchandise Imports, balance of payments, seasonally adjusted | Monthly | CANSIM | 228-0059 |
| Manu_GDPBP | Manufacturing GDP at basic prices, chained 2007 dollars | Monthly | CANSIM | 379-8031 |
| manu_SA | Monthly survey of manufacturing, sales of goods manufactured, seasonally adjusted | Monthly | CANSIM | 304-0014 |
| raw_mat_SA | Monthly survey of manufacturing, raw materials, seasonally adjusted | Monthly | CANSIM | 304-0014 |
| USD_CAD | U.S. Noon average spot rate in Canadian dollars | Monthly | CANSIM (Bank of Canada) | 176-0064 |
| WTI | Global price of WTI crude in U.S. dollars, unadjusted for seasonality | Monthly | FRED | N/A |

## Appendix III: Additional Structural Break Test Results

| Sample: 1988m1 - 2016m4 | | | | | |
|---|---|---|---|---|---|
| Break Variable: U.S. – Canada exchange rate | | | | | |
| **Break Date** | $\chi^2$ | **P - value** | **Break Date** | $\chi^2$ | **P - value** |
| September 1988 | 0.6466 | 0.4213 | March 1993 | 13.0420*** | 0.0003 |
| October 1988 | 0.9169 | 0.3383 | April 1993 | 13.8867*** | 0.0002 |
| November 1988 | 0.7977 | 0.3718 | May 1993 | 13.0665*** | 0.0003 |
| December 1988 | 1.2562 | 0.2624 | June 1993 | 12.1418*** | 0.0005 |
| January 1989 | 1.6130 | 0.2041 | July 1993 | 11.8145*** | 0.0006 |
| February 1989 | 2.1604 | 0.1416 | August 1993 | 11.2099*** | 0.0008 |
| March 1989 | 2.4888 | 0.1147 | September 1993 | 12.0007*** | 0.0005 |
| April 1989 | 2.6539 | 0.1033 | October 1993 | 12.9810*** | 0.0003 |
| May 1989 | 2.7558* | 0.0969 | November 1993 | 11.7858*** | 0.0006 |
| June 1989 | 3.0451* | 0.0810 | December 1993 | 11.3951*** | 0.0007 |
| July 1989 | 3.3895* | 0.0656 | January 1994 | 10.0610*** | 0.0015 |
| August 1989 | 4.4838** | 0.0342 | February 1994 | 10.4154*** | 0.0012 |
| September 1989 | 4.2005** | 0.0404 | March 1994 | 9.7997*** | 0.0017 |
| October 1989 | 4.9807** | 0.0256 | April 1994 | 11.5198*** | 0.0007 |
| November 1989 | 5.8440** | 0.0156 | May1994 | 11.4445*** | 0.0007 |
| December 1989 | 6.1389** | 0.0132 | June 1994 | 12.4908*** | 0.0004 |
| … | | | July 1994 | 12.6073*** | 0.0004 |
| January 1992 | 11.5696*** | 0.0007 | August 1994 | 11.6126*** | 0.0007 |
| February 1992 | 11.5309*** | 0.0007 | September 1994 | 12.7260*** | 0.0004 |
| March 192 | 12.2038*** | 0.0005 | October 1994 | 11.8953*** | 0.0006 |
| April 1992 | 11.9814*** | 0.0005 | November 1994 | 12.1875*** | 0.0005 |
| May1992 | 12.4399*** | 0.0004 | December 1994 | 13.4538*** | 0.0002 |
| June1992 | 12.3236*** | 0.0004 | January 1995 | 13.8410*** | 0.0002 |
| July 1992 | 13.3478*** | 0.0003 | February 1995 | 16.2259*** | 0.0001 |
| August 1992 | 12.7515*** | 0.0004 | March 1995 | 13.1440*** | 0.0003 |
| September 1992 | 12.9628*** | 0.0003 | April 1995 | 12.4196*** | 0.0004 |
| October 1992 | 12.7431*** | 0.0004 | May 1995 | 11.3349*** | 0.0008 |
| November 1992 | 13.5764*** | 0.0002 | June 1995 | 11.6514*** | 0.0006 |
| December 1992 | 12.8251*** | 0.0003 | July 1995 | 10.8552*** | 0.0010 |
| January 1993 | 13.2414*** | 0.0003 | August 1995 | 9.5447*** | 0.0020 |
| February 1993 | 12.5001*** | 0.0004 | September 1995 | 11.6213*** | 0.0007 |
| *Significant at 10%, **Significant at 5%, ***Significant at 1% | | | | | |