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The Effects of Oil Price Shocks on Consumer Prices and Industrial Production in the United States, Canada and Mexico

by

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ABSTRACT

Oil is an important input in the production process, both as a form of energy and as an intermediate good. It intuitively follows that large swings in oil prices would have significant effects on economic activity. How these effects are translated into the economy has important implications in the policy initiatives (if any) used to counteract the large price swings. While much of the literature to date has focused on the oil price - GDP relationship, this thesis uses a single equation approach and a multi-equation vector autoregression approach in an attempt to decompose the effects into price and production effects. Furthermore, this study attempts to isolate the different responses to oil price shocks of the three North American economies. Finally, the hypothesis that oil price shocks affect the economy asymmetrically is examined.

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DEDICATION

To Laura. Thank you for your support, encouragement and patience, but most of all for your love.

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Chapter 1: Introduction

Energy has been an important part of the production process since the industrial revolution. Energy is a main input in almost every industry in terms of powering the machinery and the factories. Oil, in particular, is one of the most widely used forms of energy in production. While the use of oil as a form of energy is one of the primary applications of oil, it is also used extensively as an input in the form of an intermediate good in the production process. This duofold use of oil makes it a particularly interesting commodity to study in that intuitively it would appear that oil price changes must surely have some effect on economic activity.

The importance of energy in general, and oil in particular, in the economy became a source of widespread analysis in the early 1970's. The first major oil price shock occurred when the Organization of Petroleum Exporting Countries (OPEC) cut back supply. Prior to this, oil prices were remarkably stable. Roughly at the same time as the oil price shocks occurred, the major economies fell into a worldwide recession. The timing of the two events tended to suggest a line of causality from oil prices to economic activity that spawned an exhaustive search for the macroeconomic effects of oil price shocks. Despite a large volume of research, there seems to be very little consensus in the conclusions. These studies, however, have almost exclusively focused on the relationship between oil price and Gross Domestic Product (or Gross National Product).

While the relationship between oil prices and the economy as a whole is important, studying simply the relationship between oil prices and GDP does not necessarily lead to policy conclusions. The reason for this is that the policy conclusions may be considerably different depending on the mechanisms through which the oil price affects GDP. For example, if oil prices were found to affect GDP through prices but not production, that is, if oil price increases were simply passed on to the consumer without initially affecting production, the policy implication may be for the central bank to raise interest rates at the first sign of an oil price increase in order to stem the inflation which would follow. If, on the other hand, oil prices were found to affect the economy through a reduction in productive activity as the cost of inputs increased rather than through prices, the central bank may take an oil price increase as a sign to lower interest rates in order to stimulate investment to offset any production losses. Indications that the oil price shocks translate into the economy through both prices and production may lead to an altogether different set of policies, such as fiscal regulation of oil prices. For these reasons, this study attempts to separate the macroeconomic effects of oil price shocks into the effects on the Consumer Price Index (CPI) and the effect on the Industrial Production Index (IPI). The analysis in this study is done separately for the three North American economies: the United States, Canada and Mexico. This is done with the recognition that the oil price shocks will not affect every economy in the same way. Therefore, different economies may require different policy initiatives (if any) in response to sudden oil price changes.

A second difference between this study and most other studies on this topic is the data used in the analysis. Whereas most studies use either quarterly or annual data, this study uses monthly data. The main reason for using monthly data rather than quarterly or annual data is that the West Texas Intermediate (WTI) price has been determined on the monthly spot market since 1981. As this is the benchmark North American oil price and therefore the price used in this analysis, it would seem consistent that the economy would respond to these prices on a monthly basis. This does, however, limit the data sets that are available. While the U.S. provides monthly macroeconomic data back to 1947, the Canadian set contains monthly economic data only back to 1961. The Mexican data set is even smaller, with monthly data extending back only to 1972. Despite these limitations, the monthly data is expected to be a more accurate indicator for the present response of the economies to oil price shocks.

In attempting to analyze the effect of oil price shocks on the CPI and the IPI, this study will first use a single equation approach to study the bivariate relationships between the oil price and the two individual macroeconomic indicators. Because the variables are all found to contain a single unit root, this entails the use of cointegration analysis. If the variables are found to cointegrate, an error correction model is built. If cointegration is not found to be present, the variables will be analyzed in first differences. The single equation approach, while useful in partially defining the relationship between the oil price and the selected macroeconomic indicator, neglects interactive effects in the economy, as well as neglecting many feedback effects. Taking this into consideration, the analysis will also be done in a multi-equation model. Specifically, this study will use a vector autoregression (VAR) framework to perform Granger causality tests as well as to generate the impulse response functions and variance decompositions of the effects on the CPI and IPI of shocks to the oil price.

A further consideration that this study takes into account is the effect of oil price volatility on the results of the analysis. This is done with the expectation that oil price shocks will have more of an effect on an economy when they occur in an atmosphere of stable prices than when they occur in times of volatile price movements. The relative volatility of the oil prices will be calculated using a GARCH(1,1) model, with the conditional variance used to normalize the unanticipated price changes. In addition to testing the effect of the anticipated and unanticipated volatility in a single equation, the unanticipated price shocks will be used in a VAR. Finally, the price shocks will be separated into positive and negative shocks in order to test for asymmetric price effects. That is, the data will be tested to determine if positive price shocks affect the macroeconomic variables differently than do negative price shocks. This has been the focus of much of the recent research, influenced largely by the oil price declines in the latter part of the 1980's.

This study will proceed in the following manner. Chapter 2 will present a synopsis of some of the literature regarding macroeconomic effects of oil price shocks, from the late 1970's to the mid 1990's. This will be separated in two main sections: one dealing with studies focusing primarily on causality and the second outlining studies which focus on the hypothesis of asymmetric price effects. Chapter 3 will then proceed with a discussion of the data used in this study, including the summary statistics and the results of unit root tests. Chapters 4 and 5 will present the analysis and results involved in this study. Chapter 4 will outline the methodologies for the single equation approach, particularly the cointegration analysis, and the multi-equation approach, that is the VAR model, and present the results for the analysis of effects of the oil price on the CPI and the IPI for the three North American economies. Chapter 5, after a brief discussion of the GARCH model, will present the results for the single equation and multi-equation analysis when account is taken of oil price volatility. As well, the results of the analysis when the assumption of symmetry in the responses is relaxed are presented in this chapter. The conclusions of this study are presented in Chapter 6.

Chapter 2: Existing Empirical Evidence

2.1 Introduction

There is a considerable amount of literature concerning the relationship between oil prices and the macroeconomy. Although the paper by Hamilton (1983) is often cited as one of the earliest contributions to seriously tackle this issue, the true catalyst to this subject area was the 1974 oil price increase which preceded a world wide recession. Given the timing of the two events, it is not surprising that many observers began attributing the recession to the sudden increase in oil prices. Economists therefore began studying this problem, in the hopes of explaining the worldwide recession and developing policy to prevent this from reoccurring.

The earlier studies focused primarily on the direction of causality between oil price increases and macroeconomic activity. One interesting aspect of these studies is that there is no real consensus on the macroeconomic effects of oil price shocks. In particular, depending on which study you read, you may find that Granger causality runs in either direction, both directions, or neither direction. While still often addressing the causality issue, later studies have focused more on looking at whether price increases and decreases have symmetric or asymmetric effects. This arose subsequent to the large price decreases in oil prices beginning in 1986. Prior to this, the oil price shocks were price increases. Again, there is no real consensus on whether the effects are symmetric or asymmetric.

The following sections are intended to give the reader a brief overview on the diverse literature regarding the macroeconomic effects of oil price shocks. This is by no means an exhaustive summary. The articles mentioned below are separated into two categories: those that deal primarily with Granger causality and those that deal with asymmetric price effects. This is not to imply that the articles mentioned in each section deal only with these issues, but refers merely to the main theme of the article in relation to this paper.

2.2 Granger Causality Studies

In studying the relationship between oil prices and the economy, many papers have been devoted almost exclusively to the line of causation between the two. In one of the earliest papers published, Kraft and Kraft (1978) tested several hypotheses using data for GNP and energy inputs in the United States and found evidence suggesting that the line of causation did not run from energy inputs to GNP, but from GNP to energy inputs. Their tests involved simple OLS regressions on the levels of each variable and found a high R^2 in the regressions. In a response to this paper, Akarca and Long (1980) rejected a hypothesis of unidirectional causality both from energy to GNP and GNP to energy. They found only evidence of instantaneous causality between the two variables. Yu and Huang (1984) followed this up and found no causal relationship between energy consumption and GNP. They did, however, find slight unidirectional causation from employment to energy consumption. Abosedra and Baghestani (1991), in a comment on all three of these studies, found unidirectional causation from GNP to energy consumption with no feedback effects. They found that this causation was strongest at the 4th year lag. It is important to note that these studies focused primarily on energy consumption, leaving the effect of prices on the economy an implicit assumption in the model.

Hamilton (1983) studied oil prices and several macroeconomic variables since the end of the Second World War. Using quarterly data, he found that all but two recessions in that time period had been preceded by an oil price increase with about a three-quarter year lag. He also tested changes in oil prices individually against six key macroeconomic indicators: real GNP, unemployment, the implicit price deflator for non-farm business income, hourly compensation per worker, import prices and M1. Only 1 of these indicators, import prices, was found to be statistically significant in predicting changes in oil prices, and that relationship was found only when eight lags were included in the model. Conversely, he found evidence that changes in oil prices tended to predict changes in the macroeconomic indicators.

Burbidge and Harrison (1984), in a widely cited paper, remarked that although most models predict that oil price shocks lead to increases in wages and prices and decreases in real output, most of the testing had been done using simulation methods. They used a seven variable vector autoregression (VAR) to determine the relationship between oil prices and the macroeconomy for 7 OECD countries. The variables they chose were oil prices, total industrial production in other OECD countries, domestic industrial production, short term interest rates, currency and demand deposits, average hourly earning in manufacturing and the Consumer's Price Index. They converted their VAR estimation into a vector moving average (VMA) representation to examine the impact of oil price shocks and used this to analyze the 1973/74 and 1979/80 oil price shocks. They found that while both shocks led to downturns in economic activity, the effects of the latter shock were minimal, especially in comparison to the 1973/74 shock.

Burgess (1984) found that the literature at that time suggested that increases in energy prices will permanently reduce the growth potential of net energy importing economies. He suggested, however, that the linkages between rising energy prices, capital formation and potential GNP are very sensitive to model specification. He further suggested that increases in energy prices could actually stimulate capital formation rather that deter it. Reverse feedback effects through capital could therefore offset any reduction in potential GNP due to higher energy prices. He still found that for net importing economies increases in world energy prices led to immediate real income losses, but that the magnitude of the losses depended upon the imports' share of the economy's energy requirements and the energy costs' share in production of final output. The reduction in real income coincides with a reduction in potential GNP adjusted for terms of trade effects and reflects a net transfer of income from domestically owned primary factors to foreign suppliers of energy.

Gisser and Goodwin (1986) found little or no evidence that the impact of oil price shocks is largely in the form of cost-push inflation, but rather that the shocks have an impact on a broad array of macroeconomic indicators. They also found little or no support for the theory that crude oil prices affected the economy differently after the 1973 price increase than prior to the shock, although they found limited evidence supporting the idea that crude oil prices were determined differently after this shock than before it. Their evidence suggests that prior to the 1973 price increase, oil prices were determined by state agencies such as the Texas Railroad Commission (TRC) and that the inflation rate was strongly informative about the course of future oil prices. After 1973, however, oil prices were determined by OPEC and that a wider array of macroeconomic indicators is weakly informative about the course of future oil prices. They also performed Chow tests on multivariate relationships which showed that the null hypothesis of no structural shift could be rejected for both GNP and investment at the 10% level, although they could not pinpoint the source of the break. They could not find evidence that the oil price Granger causality shifted.

2.3 Asymmetric Effects Studies

A second focus of study has been whether oil price decreases affect the economy in the same way that oil price increases affect the economy. Recall that much of the literature was stimulated mainly by the price increases of the 1970's. In 1986, however, the price shocks were in the opposite direction. Prices dropped dramatically. Since then, much of the literature has been devoted to the possibility of asymmetric effects and if these effects are asymmetric, to addressing the reasons for this result. Using dispersion hypothesis, Loungani (1986) suggested that the reallocation of resources due to oil price shocks was a significant cause of unemployment. He further suggested that this was strictly a reallocative effect and therefore a price decrease should also lead to increased unemployment.

Tatom (1987) was one of the first to apply and test the conventional theory of the effect of oil price shocks on the economy to price decreases. Tatom outlined two main channels through which an oil price shock affects the economy: through aggregate supply or through aggregate demand. Energy price shocks will affect the economy through aggregate supply by changing relative prices. Therefore to make the changes effective, the supply of energy must be altered which changes the production possibilities and thus aggregate supply. Energy price shocks also change the incentives for firms to use energy resources and alter their optimal methods of production (less energy intensive technologies are used). The effects on aggregate demand depend on the net oil export status of the economy. For example, net-exporting countries should find that aggregate demand increases when oil prices increase. This, however, ignores the effect on productivity, which tends to decrease, regardless of the oil trade status of the economy. Tatom does find that in most models of the economy, price shocks through aggregate supply dominate the aggregate demand effect. Thus, a fall in oil price should increase economic activity.

Olson (1988) argues that attempts to trace productivity slowdowns directly to higher energy prices are wrong, but that oil shocks had a significant indirect impact on the productivity slowdown. He states that when the productivity losses on the supply and demand side of the U.S. oil market are added up, they are much too small to explain much of the productivity slowdown of the 1970's and early 1980's, let alone all of it. He also suggests that if rising oil prices caused the productivity slowdown and the economy exhibited symmetry, then falling oil prices should greatly increase productivity, but this did not happen after the 1986 oil price crash. He concludes that the oil price shocks of the 1970's came at the same time as other institutional adjustments were beginning to occur, such as stronger union negotiations, and changing wage and inflation expectations. Thus the oil price shock merely added slightly to a productivity slowdown which was already on the way.

Hamilton (1988) concluded that the total effect on the economy of an energy price shock is not the dollar share of energy but the dollar share of the products whose use depends critically on energy. This would account for an exaggerated effect of an energy price shock on an economy in which the share of energy is quite low. Hamilton also suggests that difficulties in relocating specialized labour could be another explanation for the exaggerated effects on an economy of a seemingly small supply disruption.

Mork (1989) found evidence of asymmetric effects of oil price increases and decreases. Price increases were found to have significant, negative effects on the economy, while the economic effects of price decreases were found to be ambiguous and insignificant.

Bohi (1991) has suggested that the effects of energy price shocks on economic stability are uncertain. Although GNP growth declined when prices increased, it did not improve noticeably when prices decreased. He suggests two possible reasons for why energy may be more important to the economy than is indicated by its small cost share of GNP and why these effects may be more immediate than is indicated by the speed of adjustment in energy consumption. The first is that there is an induced rise in unemployment when wage rates are sticky. The second is that there is a reduction in capital services due to the increased obsolescence of the capital stock. He suggests a third, related, possibility is that energy induced shifts in the composition of aggregate demand aggravated the problem of adjusting to changes in relative factor prices when wages are sticky and factors of production are immobile. He uses simple bivariate correlations to test the connection between energy used in production and the behaviour of selected industrial activity variables in Germany, Japan, the United Kingdom and the United States. He concludes that doubts about the importance of energy prices are reinforced by the absence of any apparent connection between energy intensity and the various industrial activity variables in these countries. He does concede that the energy connection may be more complex than can be revealed by simple bivariate correlations. Bohi concludes by stating that the energy price shocks coincided with periods of tight monetary policy and that it is possible that the shocks added to concerns about inflation, thereby reinforcing the decisions of the monetary authority; that is, the timing was unfortunate. He suggests those energy price shocks in the past have affected the economy more in this way than in direct destabilization.

Dotsey and Reid (1992) contrasts Hamilton's (1983) finding that major downturns in economic activity are associated with prior exogenous oil price increases with Romer and Romer's (1989) findings which indicate that exogenous tightening of monetary policy was the major cause of the decline in industrial production and increases in unemployment. They found that including oil prices in Romer and Romer's study made monetary policy insignificant. In their model, they found both oil prices and monetary policy to be significant. They also found that there were asymmetric oil price effects on industrial production and hypothesized that this could be due to the labour effects outlined by Hamilton (1988). A second explanation could be that there may be differences in financing when retained earnings are used, as opposed to external financing. Theoretically, a decrease in energy prices that had the short-term effect of increasing profits would lead to financing using retained earnings rather than external financing.

Gately (1993) outlined several sources of irreversibility of the demand effects of rising oil prices. These included the durability of capital-stock improvements, the irreversibility of improved technological knowledge and the non-reversal of some government policies.

Smyth (1993) found that changes in energy prices have extremely asymmetrical effects on private sector output. Increases in relative energy prices above previous peak levels decrease private sector output, but decreases in relative energy prices were not found to help private sector output.

Tatom (1993) begins by going back to the basics. He explains that oil and energy prices affect the economy because energy resources are used to produce most goods and services. Therefore, an increase in energy prices will increase the total cost of the efficient producer's output, change the most efficient means for producing output, decrease the profit maximizing level of output and increase the long-run equilibrium price of output. Price increases will also decrease the capacity output of each firm's stock of capital because firms will use less energy and energy using capital, some capital will become obsolete and firms will reallocate labour and capital to economize on energy costs by using less energy intensive methods of production. His study finds that the 1990/91 oil price shock affected the economy in a similar manner as the previous shocks of the 1970's. He also does not find evidence of asymmetric price effects.

Mory (1993) put forth two main reasons for the possible lack of symmetry in the effects of oil price shocks. From a Keynesian point of view, full employment may pose a relative short run constraint. If there is full employment, the economy may be better able to adapt to an oil price increase than to an oil price decrease because it will be possible for the economy to contract but not to expand. The second reason he puts forth is that dislocations of demand in any direction are always damaging to the economic system. As well, the uncertainty and income distribution effects may be asymmetric. His empirical results found evidence of a lack of symmetry. Price increases led to detrimental economic effects, while price decreases did not show substantial favourable or detrimental effects.

Mork, Olsen and Mysen (1994) studied the oil price-GDP relationship for seven countries: the United States, Canada, Japan, Germany, France, the United Kingdom and Norway. They found evidence of a negative relationship between price increases and GDP for most of these countries using data through 1992. They also found strong indications of asymmetric effects, although the results varied from country to country. Their results, which indicated that price increases and decreases seem to hurt the development of the business cycle, were strongest for the United States. They also indicate that while Japan showed a significant negative effect of oil price increases but not decreases, the Norwegian economy, which has a strong reliance on the oil producing sector, seems to be buoyed by price increases and depressed by price decreases. They built on Kim and Loungani's (1992) analysis of energy price shocks, extending the model to include the energy-producing sector. They found that the magnitude and direction of the effects of an oil price shock seem to depend on whether the country is a net importer or exporter of oil and suggest using the ratio of energy imports to GDP as a variable. They also suggest that the prediction of symmetric effects of price increases and decreases follows if the frictions arising in the transfer of resources between various sectors of the economy are ignored. If these frictions are introduced, as in Hamilton (1988), the benefits of a price decrease become smaller than the damages caused by a similar price increase. They introduce the possibility that the loss of output due to this reallocation could outweigh the gains from an oil price decrease, meaning that both a price increase and decrease could negatively affect the economy. They also introduce the possibility that the asymmetric effects may be due to asymmetric policy responses: for example, price increases may lead to anti-inflationary policies, but price decreases may not lead to inflationary policies. They tested their model by including price increases and price decreases as different variables and tested for Granger causality with GDP growth as the left-hand side variable, as introduced in Hamilton (1983). This model, however, does not indicate the nature of the link. There could, for instance, be some underlying variable that is driving both oil prices and GDP growth. They investigate this further by estimating the partial effects of price changes within a reduced form model including lags of other macroeconomic variables (similar to Hamilton (1983), Burbidge and Harrison (1984) and Mork (1989)). Their three main conclusions were that, generally, a negative relationship between oil price increases and GDP exists, the effects on GDP are not symmetric for oil price increases and decreases and that the effects seem to vary from country to country depending on the oil trade status of the country.

Lee, Ni and Ratti (1995) also assert that oil price increases and decreases have asymmetric effects on the economy and that the effects vary across time and country. They further assert that real oil price has not lost its predictive power for growth in real GNP as long as appropriate account is taken of oil price shocks and the variability of real oil price movement. They conjecture that an oil shock is likely to have more of an impact on the economy when oil prices have been stable than when oil price movements have been frequent and erratic. They test this by introducing an oil price shock variable into their VAR that reflects the unanticipated component of an oil price shock and the time-varying conditional variance of oil price change forecasts, using a GARCH model to normalize unexpected movements. The effect of a change in the real oil price is found to depend on whether it is an unusual event or an adjustment in response to a change in the previous period. They also find asymmetric effects between positive and negative normalized shocks: a positive shock is related to negative real GDP growth, but a negative shock is not statistically significant.

2.4 Conclusion

Despite there being a large literature on the subject of the macroeconomic effect of oil price shocks, there is very little consensus on the results. There is considerable disagreement with regards to the lines of causality between macroeconomic indicators and oil price shocks. As well, there is considerable disagreement whether oil price decreases and increases have symmetric or asymmetric effects on the economy. The only real consensus seems to be that those studying symmetric and asymmetric effects appear to implicitly agree that oil price shocks Granger cause fluctuations in GDP. One perhaps understated argument to come out of this literature that would lend itself to further study is the idea the effects of oil price shocks will have vastly different effects depending on whether the economy in question is a net oil importer or exporter. This is a question that could be applied on a national level, or on a regional level. For example, the results for Canada as a whole may suggest one line of effects, but the results for the Alberta and Manitoba economies may be completely opposite. While this study does not attempt to address this question, it is important to keep this disaggregated possibility in mind when interpreting the results at the national level.

This study will attempt to answer some of the questions that are much debated in the literature. A vector autoregression (VAR) approach similar to Burbidge and Harrison (1984), although with fewer variables, will be used in an attempt to trace the effect on the macroeconomy of oil price shocks in terms of Granger causality. This study will also try to shed some light on the debate about asymmetric price effects and price volatility, using a model similar to Lee, Ni and Rotti (1995).

Chapter 3: Data Issues

3.1 Introduction

In order to properly undertake a study on the macroeconomic effects of oil price shocks, the macroeconomic variables to be included in the analysis need to be chosen. For the purpose of this study, the model will be kept comparatively simple. While similar studies, such as Burbidge and Harrison (1984), included a number of variables, this study will focus only on three: the oil price, the Industrial Production Index (IPI) and the Consumer Price Index (CPI). This allows the separation of the macroeconomic effects into the effects on the industrial activity of an economy and the effects on prices or inflation. The data selected were gathered for the three North American economies: Canada, the United States and Mexico. This chapter will discuss the data selected for the study on a country by country basis. Close attention will be paid to the descriptive statistics and the time series properties of each data set.

The data will also be tested for unit roots. A variable is considered stationary if it does not contain a unit root. A variable contains one unit root if it is stationary in first differences. The variable in this case is also considered to be integrated of order 1 [I(1)]. In general, the number of times the variable must be differenced in order to be considered stationary depends on the number of unit roots a variable contains, also known as the order of integration.

To determine the order of integration, the augmented Dickey-Fuller (ADF) test is used. The Dickey-Fuller (DF) test begins with the null hypothesis that the variable is integrated of order 1. The alternative hypothesis can be one of three types: stationary, stationary with drift and stationary around trend. Although the variables were tested under all three alternatives, it would seem that for the macroeconomic indicators used in this analysis, stationarity around trend would be the most appropriate. For oil prices, however, this is not necessarily the case. The presence of a trend in oil prices is questionable and therefore it may be more appropriate to consider the hypothesis of stationarity around drift for oil prices.

The Dickey-Fuller test estimates the equation

(3.1) $$X_t = \gamma X_{t-1} + u_t.$$

The test is for $\hat{\gamma} = 1$. The test statistic therefore becomes

(3.2) $$Q = \frac{(\hat{\gamma} - 1)}{se(\hat{\gamma})}$$

where $\hat{\gamma}$ is the estimate of γ. If we manipulate this equation, we can estimate

(3.3) $$\Delta X_t = \rho X_{t-1} + u_t$$

where $\rho = \gamma - 1$. Therefore, the test statistic becomes

(3.4) $$Q = \frac{\hat{\rho}}{se(\hat{\rho})},$$

or the t-statistic of $\hat{\rho}$. This statistic will not, however, have a t-distribution and must be compared instead to the critical values generated by Dickey and Fuller.

For this test to be valid, $\hat{\rho}$ must converge to the true ρ. In order for this to occur, u_t must be spherical (i.e. $u_t \sim N(0, \sigma^2)$ or "well-behaved"). This may not be the case.

The ADF test is performed to deal with this problem by including lags of the dependent variable. Therefore, the model estimated is now

(3.5) $$\Delta X_t = \rho X_{t-1} + \sum_{i=2}^{p} \lambda_i \Delta X_{t-i+1} + \varepsilon_t .$$

The number of lags p can be determined by estimating this equation with a number of different lag lengths and using a model selection criterion, such as the Akaike Information Criterion (AIC), for determining the optimal lag length. However, according to Said and Dickey (1984), increasing the order of the autoregression at a controlled rate of $T^{1/3}$, where T is the sample size, will produce an asymptotically valid ADF test. For both the Canadian and the U.S. data, this translates into a lag length of 8. For the Mexican data, this translates into a lag length of 7.

After a brief description of the data, the descriptive statistics and results of the unit root tests will first be presented for the Canadian data. Those for the U.S. data will be presented next, followed by the statistics and results for the Mexican data.

3.2 The Data

The oil prices used in all three of the analyses will be the West Texas Intermediate (WTI) crude oil monthly spot price. This is generally viewed as the benchmark price for oil in North America. This price was collected, in U.S. dollars per barrel (U.S.$/B), from the United States Federal Reserve Bank's economic database (FRED). From 1947 to 1980, this price was adjusted on a quarterly basis by the Texas Railroad Commission

(TRC), although between 1973 and 1980 this was based largely on the price set by OPEC. From 1981 to the present, the WTI has been a monthly market based price. The rest of the data were collected on a country by country basis.

3.2.1 Canadian Data

The data representing the Canadian economy are the Consumer Price Index (CPI), a seasonally adjusted Industrial Production Index (IPI) and the WTI spot oil price. Figure 3.1 represents the log levels of the Canadian data graphically. The Canadian data were collected on a monthly basis from January 1961 to April 1997 (436 observations) from Statistics Canada's Cansim database. The Industrial Production Indices were constructed by normalizing the monthly value of industrial production by the average monthly value for 1992. 1992 was chosen as the normalization period because this was the base year for the Industrial Production Index for the United States. As discussed above, the oil price is represented by the WTI oil price collected from FRED. In order to convert the oil price into Canadian dollars, the oil price in U.S.$/Barrel was multiplied by the Canadian/U.S. exchange rate in Cdn$/U.S.$. This exchange rate, also collected from Cansim, is the average monthly exchange rate. Table 3.1.1 shows the descriptive statistics for the log levels of the Canadian variables involved in the analysis. The skewness statistics of the CPI, the IPI and the oil price seem to be consistent with symmetry. The kurtosis statistics for all three variables, however, indicate non-normality, with the possible exception of the IPI. The descriptive statistics for the first differences of the logs of the Canadian variables are shown in Tables 3.1.2. The skewness statistics for the CPI and the IPI are consistent with symmetry. With the exception of the IPI, the kurtosis statistics for all of the variables indicate significant deviations from normality. The results of the ADF tests of stationarity for the Canadian variables, along with the critical values are presented in Table 3.1.3. As this table shows, the null hypothesis that each variable is I(1) cannot be rejected for any of the variables at the 90% confidence level.

Because strong evidence has been found that each of the variables is non-stationary, the next step is to determine the order of integration for each variable. This is done by taking the first differences of the variables and performing the ADF test on the first differences. For these tests, the null hypothesis is that the variable is I(2) - integrated of order 2. Again there are three alternative hypothesis for this test: I(1), I(1) with drift and I(1) around trend. It is often assumed, however, that first differencing removes the trend component. Nevertheless, the ADF tests were performed against all three alternative hypotheses. Table 3.1.4 presents the results for the ADF tests on the first differences of the logs of the Canadian data under the three alternative hypotheses, with the critical values at the bottom. As this table indicates, the null hypothesis is rejected for all of the variables, except for the CPI, at both the 95% and 90% levels. The null hypothesis is rejected for the CPI only against the alternative hypothesis of I(1) with drift at the 90% level. Despite this ambiguity, the results indicate that there is strong evidence that all of the variables are all integrated of order 1.

3.2.2 U.S. Data

The data for the U.S. economy includes a seasonally adjusted Consumer Price Index and a seasonally adjusted Industrial Price Index on a monthly basis from January 1947 to May 1997 (605 observations) and were collected from FRED. Figure 3.2 represents the log levels of the U.S. data graphically. Table 3.2.1 shows the descriptive statistics for the log levels of the U.S. variables involved in the analysis. The skewness statistics for all three of these variables are consistent with symmetry, including the oil price. The kurtosis statistics for the three variables, however, indicate deviations from normality. The descriptive statistics for the first differences of the logs of the U.S. variables are shown in Tables 3.2.2. The skewness statistics for the CPI and the IPI are consistent with symmetry. The skewness statistic for the oil price indicates significant deviation from normality. Again, the kurtosis statistics for all of three variables indicate significant deviations from normality.

The results of the ADF tests of stationarity for the U.S. variables, along with the critical values are presented in Table 3.2.3. As this table shows, the null hypothesis that each variable is I(1) cannot be rejected for any of the variables at the 90% confidence level. Because strong evidence has been found that each of the variables are non-stationary, the ADF test is repeated on the first differences of the variables. Table 3.2.4 presents the results for the ADF tests on the first differences of the logs of the U.S. data under the three alternative hypotheses, with the critical values at the bottom. As this table indicates, the null hypothesis is rejected for all of three variables at both the 95% and

90% levels. The results therefore indicate that there is strong evidence all of the U.S. variables are all integrated of order 1.

3.2.3 Mexican Data

The data for the Mexican economy include a seasonally adjusted Consumer Price Index and a seasonally adjusted Industrial Price Index on a monthly basis from April 1972 to December 1996 (297 observations). Figure 3.3 represents the log levels of the Mexican data graphically. This data was compiled from the International Monetary Fund's *International Financial Statistics*. Although data is available back to July, 1952, the IPI for Mexico was only found on a monthly basis beginning in April 1972. As discussed above, the oil price is represented by the WTI oil price collected from FRED. In order to convert the oil price into Mexican Pesos, the oil price in U.S.$/Barrel was multiplied by the Mexican/U.S. exchange rate in pesos/U.S.$. One new peso, the current currency referred to in the Mexican/U.S. exchange rate, is equivalent to 1,000 pesos. This exchange rate, also collected from the International Monetary Fund's *International Financial Statistics*, is the average monthly exchange rate. Table 3.3.1 shows the descriptive statistics for the log levels of the Mexican variables involved in the analysis. The skewness statistics for all three of these variables, including the oil price, are consistent with symmetry. The kurtosis statistics for the three variables, however, indicate deviations from normality, with the possible exception of the kurtosis statistic for the IPI. The descriptive statistics for the first differences of the logs of the Mexican variables are shown in Tables 3.3.2. Only the skewness statistic for the IPI is consistent with symmetry. The skewness statistics for the CPI and for the oil price indicate significant deviations from normality. As well, the kurtosis statistics for the CPI and the oil price indicate significant deviations from normality.

The results of the ADF tests of stationarity for the Mexican variables, along with the critical values are presented in Table 3.3.3. As this table shows, the null hypothesis that each variable is I(1) cannot be rejected for any of the variables at the 90% confidence level. Because strong evidence has been found that each of the variables are non-stationary, the ADF test is repeated on the first differences of the variables. Table 3.3.4 presents the results for the ADF tests on the first differences of the logs of the Mexican data under the three alternative hypotheses, with the critical values at the bottom. Similar to the data for the Canadian economy, this table indicates that the null hypothesis is rejected for the Mexican IPI and oil price variables, but not the CPI, at both the 95% and 90% levels. The null hypothesis is rejected for the CPI only against the alternative hypothesis of I(1) with drift at the 90% level. Despite this ambiguity, the results indicate that there is strong evidence that all of the variables are integrated of order 1.

3.3 Conclusion

The data involved in this analysis are the monthly values of the oil price, the Consumer Price Index (CPI) and the Industrial Production Index (IPI) for Canada, the U.S. and Mexico. The log levels of these data were illustrated graphically. Although the oil price used for all three countries is the WTI index in U.S.$/Barrel, it is converted into

Canadian dollars and Mexican pesos by multiplying by the respective exchange rates. Descriptive statistics have been provided for the log levels and the first differences of the logs of the data. These statistics indicate significant deviations from normality, with the possible exceptions of the IPI in both Canada and Mexico. Unit root tests were also performed on each of the variables in question. These tests showed strong evidence that each of the variables contained a single unit root, although there was some ambiguity with respect to the CPI in Canada and Mexico. These are the data that will be included in the single equation and vector autoregression analysis of the effects of oil price shocks on the macroeconomy. The analysis that follows will be done on a country by country basis.

Figure 3.1: Log Levels of the Canadian Data

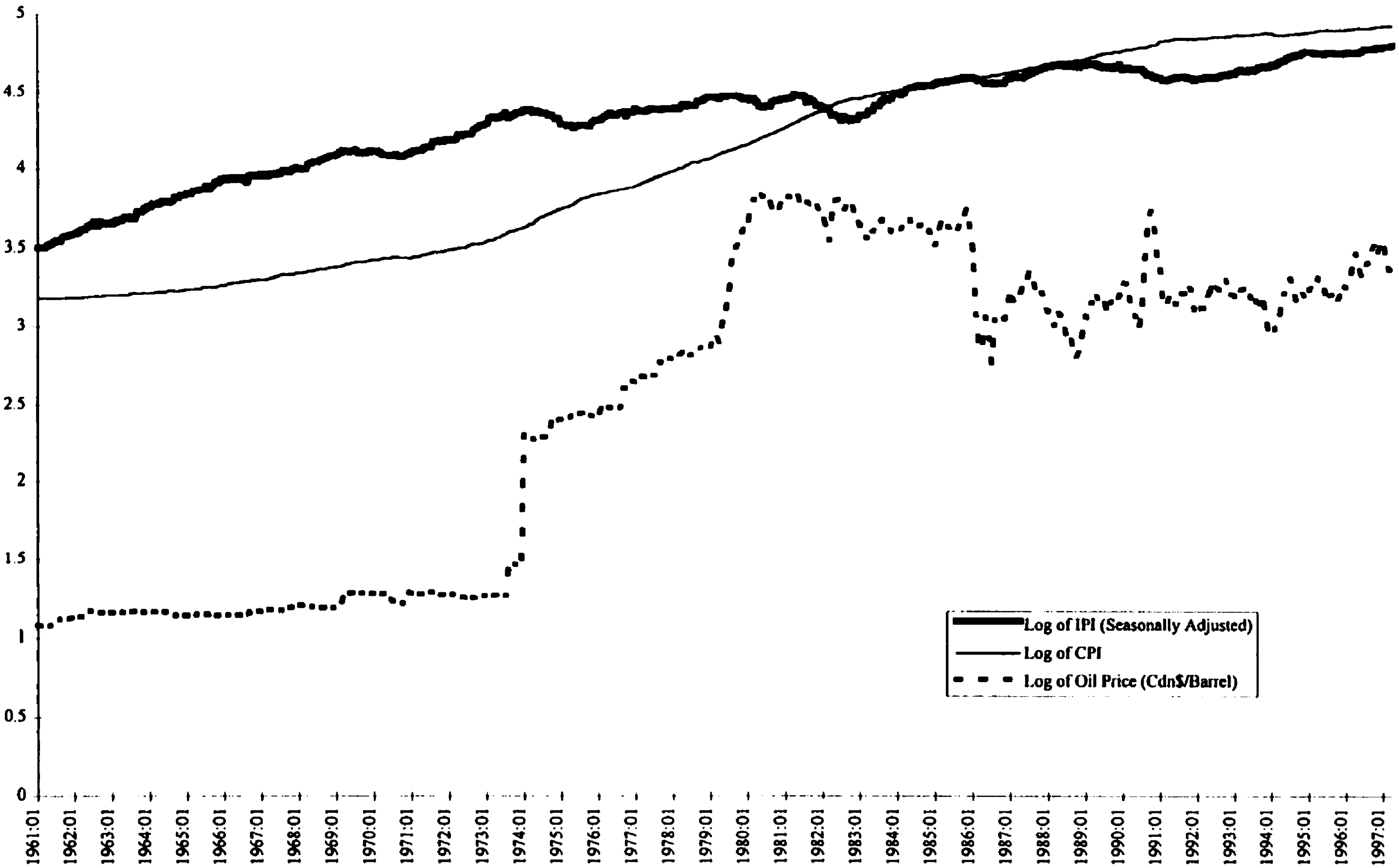

Table 3.1.1: Descriptive Statistics - Canadian Data (log levels)

	CPI	*IPI (SA)*	*Oil Price ($Cdn/Barrel)*
Mean	4.064	4.330	2.479
Standard Deviation	0.631	0.331	1.011
Kurtosis	1.410	2.608	1.401
Skewness	-0.054	-0.742	-0.287
Minimum	3.174	3.500	1.076
Maximum	4.924	4.805	3.847

Table 3.1.2: Descriptive Statistics - Canadian Data (logs - first differences)

	CPI	*IPI (SA)*	*Oil Price ($Cdn/B)*
Mean	0.004	0.003	0.005
Standard Deviation	0.004	0.011	0.069
Kurtosis	4.804	3.835	55.956
Skewness	0.850	-0.299	4.079
Minimum	-0.007645	-0.042	-0.398208
Maximum	0.025933	0.040	0.844539

Table 3.1.3: Results of ADF Unit Root Tests on Canadian Data (log levels)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
CPI	2.08	-0.73	-1.35
IPI (SA)	2.21	-1.99	-2.89
Oil Price ($Cdn/B)	0.87	-1.16	-1.19
*Critical Values:			
90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Table 3.1.3: Results of ADF Unit Root Tests on Canadian Data (log - first differences)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
CPI	-1.46	-2.61	-2.61
IPI (SA)	-4.35	-5.00	-5.12
Oil Price ($Cdn/B)	-6.21	-6.34	-6.36
*Critical Values:			
90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Figure 3.2: Log Levels of U.S. Data

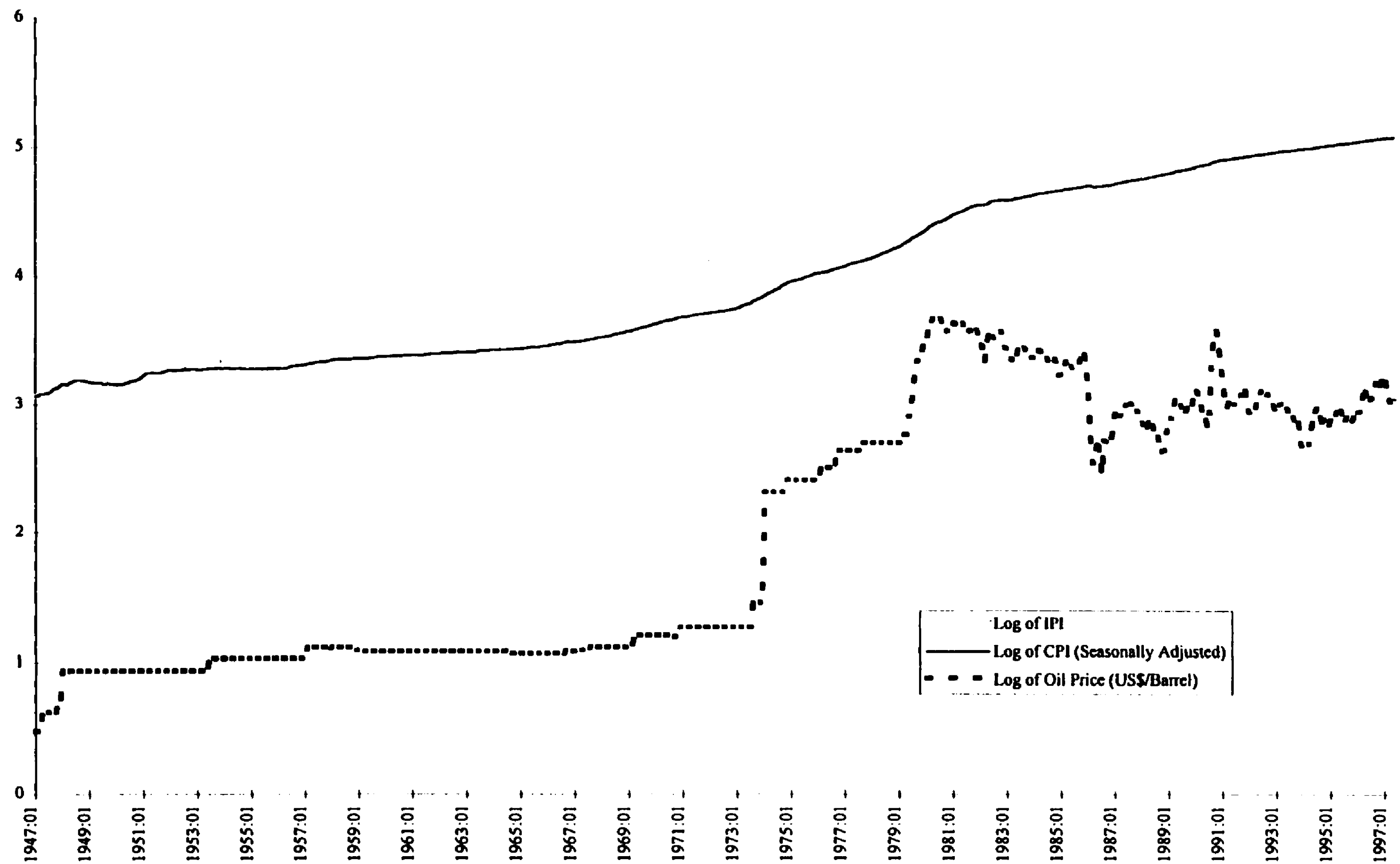

Table 3.2.1: Descriptive Statistics - U.S. Data (log levels)

	Oil Price (\$US/Barrel)	*CPI (SA)*	*IPI (SA)*
Mean	1.966	3.963	4.033
Standard Deviation	1.001	0.658	0.503
Kurtosis	1.354	1.543	1.879
Skewness	0.292	0.369	-0.400
Minimum	0.482	3.068	3.027
Maximum	3.676	5.076	4.785

Table 3.2.2: Descriptive Statistics - U.S. Data (log - first differences)

	Oil Price (\$US/Barrel)	*CPI (SA)*	*IPI (SA)*
Mean	0.004	0.003	0.003
Standard Deviation	0.060	0.004	0.011
Kurtosis	73.866	4.921	7.300
Skewness	4.776	0.740	0.264
Minimum	-0.396	-0.008	-0.042
Maximum	0.853	0.018	0.062

Table 3.2.3: Results of ADF Unit Root Tests on U.S. Data (log levels)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
IPI	3.09	-1.25	-2.52
CPI (SA)	2.94	0.85	-2.42
Oil Price (\$US/B)	0.88	-1.09	-1.60
*Critical Values:			
90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Table 3.2.3: Results of ADF Unit Root Tests on U.S. Data (log - first differences)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
IPI	-6.63	-7.49	-7.53
CPI (SA)	-2.38	-3.42	-3.61
Oil Price (\$US/B)	-7.37	-7.50	-7.50
*Critical Values:			
90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Figure 3.3: Log Levels of Mexican Data

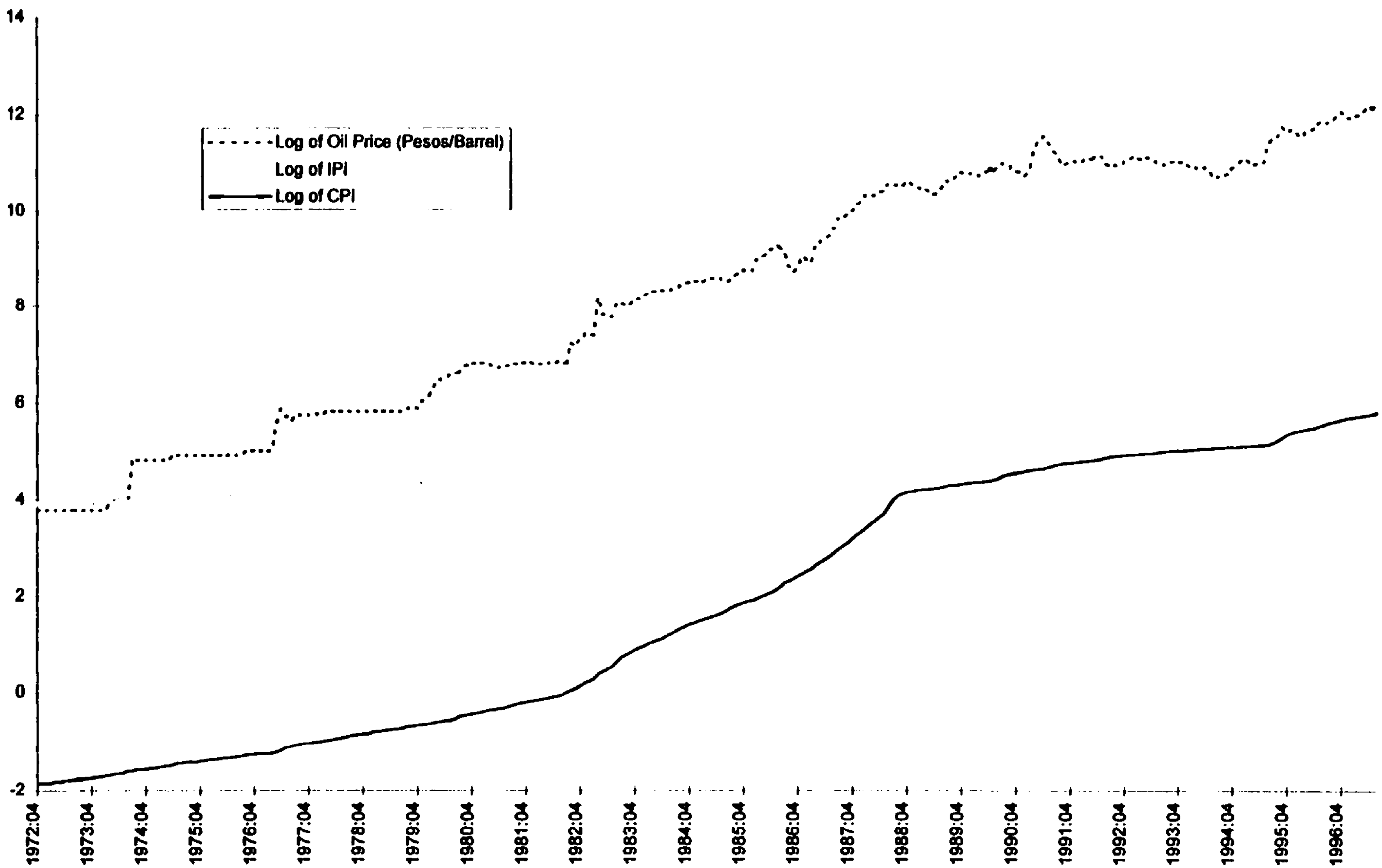

Table 3.3.1: Descriptive Statistics - Mexican Data (log levels)

	CPI	*IPI*	*Oil Price (Pesos/Barrel)*
Mean	1.801	4.408	8.314
Standard Deviation	2.681	0.239	2.615
Kurtosis	1.369	2.251	1.615
Skewness	0.082	-0.576	-0.205
Minimum	-1.864	3.888	3.795
Maximum	5.809	4.810	12.208

Table 3.3.2: Descriptive Statistics - Mexican Data (logs - first differences)

	CPI	*IPI*	*Oil Price (Pesos/Barrel)*
Mean	0.026	0.003	0.028
Standard Deviation	0.023	0.043	0.110
Kurtosis	7.396	3.406	22.537
Skewness	1.851	0.450	3.149
Minimum	-0.004	-0.102	-0.348
Maximum	0.144	0.139	0.853

Table 3.3.3: Results of ADF Unit Root Tests on Mexican Data (log levels)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
CPI	0.32	-0.36	-1.98
IPI	2.76	-1.84	-2.52
Oil Price (Pesos/B)	3.47	-0.86	-1.69

*Critical Values:

90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Table 3.3.3: Results of ADF Unit Root Tests on Mexican Data (log - first differences)*

	No Drift, No Trend	With Drift, No Trend	With Drift, With Trend
CPI	-1.58	-2.85	-2.82
IPI	-8.23	-9.05	-9.16
Oil Price (Pesos/B)	-4.91	-6.26	-6.28

*Critical Values:

90%	-1.62	-2.57	-3.13
95%	-1.94	-2.87	-3.42

Chapter 4: The Empirical Framework and Results

4.1 Introduction

The purpose of this study is to analyze the effects on the macroeconomy of shocks in world oil prices. Two different approaches will be used to infer the effects of oil price shocks on the CPI and the IPI. The first method will be a single equation approach, in which the models constructed will be bivariate models with either the IPI or the CPI as the dependent variable and the oil price as the independent variable. The variables in each equation will be tested for cointegration and if they are found to cointegrate, an error correction model will be built. If cointegration is not found, because the variables were found to be I(1), the first differences of the variables will be used in the regressions.

The second method that will be employed to analyze the effects of an oil price shock on the CPI and the IPI will be a multi-equation approach. The model used to do this will be a vector autoregression (VAR) that will include the oil price, the IPI and the CPI for Canada, the U.S. and Mexico. The VAR will be used to test for Granger causality between the oil price and the two macroeconomic variables. Impulse response functions and variance decompositions will be generated through the VAR. These tools will be used to infer the macroeconomic effects of oil price shocks. Only the effects of disturbances in the oil price variable will be studied, as this is the focus of the study.

This chapter will begin with the single equation approach. A brief discussion of the empirical framework will precede the empirical results in order to lend a broader understanding to the results. The empirical results will be presented in three sections: the results from the U.S. data followed by the results from the Canadian data and finally the results from the Mexican data. The multi-equation approach will follow, again beginning with a brief discussion of the methodology followed by the results from the U.S., Canadian and Mexican data.

4.2 The Single Equation Approach: The Empirical Framework

A single equation approach is first employed to determine if the oil price has any causal effect on either the IPI or the CPI. Because it was determined that the variables are all I(1), that is, contain one unit root, it is first necessary to determine whether the variables are cointegrated. If they are cointegrated, it will be necessary to construct an error correction model. If they do not cointegrate, then a simple model of first differences is sufficient for the analysis. In order to determine whether the variables are cointegrated, the Johansen test for cointegration is used. Separate bivariate tests for cointegration between the IPI and the oil price and between the oil price and the CPI are performed for three samples using the Canadian and U.S. data and two samples using the Mexican data. Three samples of the data for the United States and Canada were used in the analysis: one using the full sample (beginning in 1947 for the U.S. data and beginning in 1961 for the Canadian data), one using the sub-sample beginning in January 1974 and one using the sub-sample beginning in January 1981. The sub-sample beginning in January 1974 was tested as this corresponds to the first major oil price increase. Prior to this date, oil prices were very stable. The second sub-sample, beginning in January 1981, was used for a more pragmatic reason: this is when the WTI price became a true market based price.

Prior to this date, the WTI price was set by the Texas Railroad Commission. Therefore, although there was considerable movement in the 1970's as the result of the OPEC world oil prices, these prices may not reflect the true market price, but rather reflect in part some market conditions but also some U.S. public policy issues. Only two sets of analyses were performed on the data for Mexico. Because the full sample for the Mexican data begins in April 1972, there did not seem to be enough data in the pre 1974 sub-sample to warrant performing the analyses on the sub-sample beginning in 1974.

4.2.1 Cointegration and Error Correction Models

To test the variables for cointegration, the Johansen cointegration test is used. The Johansen test estimates the system of equations:

(4.1) $$Z_t = A_1 Z_{t-1} + \varepsilon_t$$

where Z is a vector of n variables. By manipulation, this becomes

(4.2) $$\Delta Z_t = (A_1 - I)Z_{t-1} + \varepsilon_t$$

or

(4.3) $$\Delta Z_t = \pi Z_{t-1} + \varepsilon_t .$$

The Johansen test basically tests the rank of the π-matrix. If the rank is 0, then the variables do not cointegrate. If π is of full rank (i.e. n) then all variables are stationary. If the rank of this matrix is greater than zero but less than n, then the rank of π will be the number of cointegrating vectors. The eigenvalues (characteristic roots) of the π-matrix are used in the trace test to determine the rank of the π-matrix. The trace test is:

(4.4) $$\lambda_{trace} = -T\sum_{i=r+1}^{n}\ln(1-\lambda_i)$$

where λ_i is the estimated value of the eigenvalues, T is the number of useable observations and n is the number of eigenvalues calculated. The trace test is performed with a null hypothesis that the number of cointegrating vectors is r or less against an alternative that the number of cointegrating vectors is greater than r. The Johansen test can also include lags of the dependent variable in order to ensure that the residual is white noise. For the purpose of this study, 4 lags of the dependent variable are included in the cointegration test, as is a linear deterministic trend in the data and an intercept in the cointegrating equation.

Tables 4.2.1 through 4.2.3 show the results from the different samples of the Johansen cointegration tests between the oil price and the CPI and between the oil price and the IPI for the U.S., Canadian and Mexican data respectively. As these tables show, cointegration is found between the CPI and the oil price in the full and 1974 samples of the U.S. data, in all three samples of the Canadian data and in the 1981 sample of the Mexican data. Cointegration between the IPI and the oil price is found for the 1974 samples of the Canadian and U.S. data. In these cases, where cointegration between the oil price and the relevant macroeconomic variable is found to exist, the single equation analysis entails the construction of an error correction model. The error correction model used in this analysis is:

(4.5) $$\Delta Y_t = \alpha + \lambda\hat{\varepsilon}_{t-1} + \sum_{i=1}^{4}\beta_i\Delta Y_{t-i} + \sum_{i=1}^{4}\gamma_i\Delta P_{t-i}$$

$$\Delta P_t = \alpha + \lambda \hat{\varepsilon}_{t-1} + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \Delta P_{t-i} \tag{4.6}$$

where Y_t is either the IPI or the CPI, P_t is the oil price and $\hat{\varepsilon}$ is the error term from the equation

$$Y_t = \phi + \pi P_t + \varepsilon_t \tag{4.7}$$

In all other cases, where cointegration is not found, the analysis is performed in the context of first differences.

4.3 Single Equation Results from the U.S. Data

To establish the relationships between the oil price and the CPI and between the oil price and the IPI, a single equation approach is used. This is done twice for each of the three samples: once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included in the regressions.

Table 4.3.1 shows the results from the regressions for the different sample periods of the U.S. data. According to this table, when the IPI is the dependent variable, the oil price does not appear to have any explanatory power in any of the samples. As well, the error correction term in the 1974 sample does not seem to be significant. When the CPI is the dependent variable, the first lag of the oil price seems to be significant for all three samples. The third lag of the oil price and the error correction term also appear to be significant in the 1974 sample.

Table 4.3.2 shows the results from Granger causality tests from the single equation regressions. In those cases where an error correction model was constructed, the test included a joint null hypothesis that the coefficients of the relevant variable as well as the error correction term were equal to zero. According to this table, the null hypothesis that the oil price does not Granger cause the CPI can be rejected for all three samples. The null hypotheses that the oil price does not Granger cause the IPI cannot be rejected for all three samples. As well, according to this table, neither the CPI nor the IPI is found to Granger cause the oil price.

4.4 Single Equation Results from the Canadian Data

As with the U.S. data, to establish the relationships between the oil price and the Canadian macroeconomic variables, a single equation approach is first employed. This is done twice for each of the three samples: once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included in the regressions.

Table 4.4.1 shows the results from the regressions for the different sample periods of the Canadian data. According to this table, when the IPI is the dependent variable, only the third lag of the oil price seems to have any significant effect, other than the lags of the IPI, in the full and 1974 samples. In the 1981 sample the oil price does not seem to have any significant effect. As well, the error correction term in the 1974 sample does not seem to be significant. When the CPI is the dependent variable, only the fourth lag of the oil price seems to be significant for the full sample and only the second lag of the oil price seems to be significant using the 1981 sample. In all three samples, when the CPI was the dependent variable, the error correction term was found to be significant.

Table 4.4.2 shows the results from Granger causality tests from the single equation regressions. In those cases where an error correction model was constructed, the test included a joint null hypothesis that the coefficients of the relevant variable as well as the error correction term were equal to zero. According to this table, the null hypothesis that the oil price does not Granger cause the CPI can be rejected for all three samples. The null hypotheses that the oil price does not Granger cause the IPI cannot be rejected for all three samples. As well, according to this table, neither the CPI nor the IPI is found to Granger cause the oil price.

4.5 Single Equation Results from the Mexican Data

As with the U.S. and Canadian data, a single equation approach is used to establish the relationships between the oil price and the Mexican macroeconomic variables. This is done twice for both samples (recall that, in contrast to the U.S. and Canadian data, only two samples of the Mexican data are analyzed): once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included.

Table 4.5.1 shows the results from the regressions for the different sample periods of the Mexican data. According to this table, when the IPI is the dependent variable, the oil price does not appear to have any explanatory power in either of the samples. When the CPI is the dependent variable, only the first lag of the oil price seems to be significant for the full sample. As well, the error correction term in the 1981 sample does not seem to be significant.

Table 4.5.2 shows the results from Granger causality tests from the single equation regressions. In those cases where an error correction model was constructed, the test included a joint null hypothesis that the coefficients of the relevant variable as well as the error correction term were equal to zero. According to this table, the null hypothesis that the oil price does not Granger cause the CPI cannot be rejected for both samples. The null hypotheses that the oil price does not Granger cause the IPI cannot be rejected for both samples. While the tests also lead to the conclusions that the IPI does not Granger cause the oil price for both samples and the CPI does not Granger cause the oil price for the full sample, the CPI is found to Granger cause the oil price for the 1981 sample.

4.6 The Multi-Equation Approach : The VAR Framework

The second method of analyzing the macroeconomic effects of oil price shocks uses a multi-equation approach, specifically a vector autoregression (VAR). In particular, the variables will be tested for Granger causality in a multi-variate framework. The VAR's will also be used to generate the impulse response functions and variance decompositions. Before discussing the results, the theory behind the use of a VAR[1] will briefly be discussed.

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[1] This section gives a peripheral description of VAR's. For a more in depth discussion, see Enders (1995).

4.6.1 The Structural and Standard VAR

Given two variables, if we have prior knowledge that one variable is exogenous and exhibits no feedback effects, intervention analysis and transfer functions would be appropriately used in analyzing the relationship between the variables. In practice, however, it is unlikely that in the study of economics two variables could be found in which this type of relationship exists. If we are not certain of exogeneity, we should treat each variable symmetrically. This can be done through a vector autoregression (VAR). An example of a two-variable VAR is:

(4.8) $$y_t = b_{10} - b_{12}z_t + \gamma_{11}y_{t-1} + \gamma_{12}z_{t-1} + \varepsilon_{yt}$$

(4.9) $$z_t = b_{20} - b_{21}y_t + \gamma_{21}y_{t-1} + \gamma_{22}z_{t-1} + \varepsilon_{zt}$$

In matrix form, this is:

(4.10) $$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} - \begin{bmatrix} b_{12} \\ b_{21} \end{bmatrix} \begin{bmatrix} z_t \\ y_t \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

This is referred to as a structural VAR or the primitive system. The assumptions of this model are that y_t and z_t are both stationary and that the shocks to y and z, as represented by the error terms ε_{yt} and ε_{zt} respectively, are white noise with standard deviations σ_y and σ_z respectively and are serially uncorrelated. The order of the VAR is the length of the longest lag. The above system is therefore a first order VAR. In this system, each variable is a function of the contemporaneous value of the other variable as well as the lagged values of both variables, and thus the model incorporates feedback effects. b_{12} is the contemporaneous effect of z on y, while b_{21} is the contemporaneous effect of y on z. γ_{11} and γ_{12} represent the lagged effects of y and z respectively on y. If $b_{21} \neq 0$, then ε_{yt} has a contemporaneous indirect effect on z. If $b_{12} \neq 0$, then ε_{zt} has a similar effect on y.

The primitive system can be manipulated to produce the reduced form, or standard, VAR:

(4.11) $$y_t = a_{10} + a_{11}y_{t-1} + a_{12}z_{t-1} + e_{1t}$$

(4.12) $$z_t = a_{20} + a_{21}y_{t-1} + a_{22}z_{t-1} + e_{2t}$$

Since

(4.13) $$\varepsilon_t = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

and

(4.14) $$e_t = \beta^{-1}\varepsilon_t$$

then each error term e_{1t} and e_{2t} are both composites of ε_{yt} and ε_{zt}. That is,

(4.15) $$e_{1t} = (\varepsilon_{yt} - b_{12}\varepsilon_{zt})/(1 - b_{12}b_{21})$$

(4.16) $$e_{2t} = (\varepsilon_{zt} - b_{21}\varepsilon_{yt})/(1 - b_{12}b_{21})$$

The assumption that ε_{yt} and ε_{zt} are white noise means that

(4.17) $$e_{1t} \sim N(0,\sigma_1)$$

(4.18) $$e_{2t} \sim N(0,\sigma_2)$$

However, the covariance between e_{1t} and e_{2t} $\neq 0$, therefore these standard form shocks will be correlated unless $b_{12} = b_{21} = 0$ (that is, there are no contemporaneous effects of y on z or z on y). The variance/covariance matrix of e will be

(4.19) $$\Sigma_e = \begin{bmatrix} \sigma_1^2 & \sigma_1\sigma_2 \\ \sigma_2\sigma_1 & \sigma_2^2 \end{bmatrix}$$

The standard or reduced form VAR has one property that allows for simplicity in estimation. Because the right hand side of the standard form VAR contains only predetermined variables and the errors are assumed to be serially uncorrelated with constant variance, the equation system can be estimated using OLS. In contrast, the structural VAR cannot be estimated directly because of feedback effects, meaning that z_t is correlated with ε_{yt} and y_t is correlated with ε_{zt}. The structural VAR has ten parameters to be estimated. The standard VAR has only nine parameters. Therefore, the structural VAR is only identifiable from the OLS estimates of the standard form VAR if the structural system is restricted - without these restrictions, the structural VAR is underidentified.

4.6.2 Granger Causality

The standard VAR can be tested for causality. A test of causality is whether the lags of one variable enter into the equation for another variable. One variable does not Granger cause another variable if it does not improve the forecasting performance of the second variable. Thus, in the model

(4.20) $$y_t = a_{10} + a_{11}(1)y_{t-1} + a_{11}(2)y_{t-2} + \ldots + a_{11}(n)y_{t-n} + a_{12}(1)z_{t-1} + a_{12}(2)z_{t-1} + \ldots + a_{12}(n)z_{t-n} + e_{1t}$$

(4.21) $$z_t = a_{20} + a_{21}(1)y_{t-1} + a_{21}(2)y_{t-2} + \ldots + a_{21}(n)y_{t-n} + a_{22}(1)z_{t-1} + a_{22}(2)z_{t-1} + \ldots + a_{22}(n)z_{t-n} + e_{2t}$$

y_t does not Granger cause z_t if $a_{21}(1) = a_{21}(2) = \ldots = a_{21}(n) = 0$. This restriction can be tested using a standard F-test.

4.6.3 Impulse Response Function and Variance Decomposition

In the same way that an autoregression can be represented as a moving average, the VAR can be represented as a Vector Moving Average (VMA). In this way,

(4.22) $$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$$

becomes

(4.23) $$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^i \begin{bmatrix} e_{1t-i} \\ e_{2t-i} \end{bmatrix}$$

Given that

(4.24) $$\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = \frac{1}{(1 - b_{12}b_{21})} \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix}$$

the VMA representation can be written in terms of the structural errors rather than the standard errors as follows:

(4.25) $$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \frac{1}{(1 - b_{12}b_{21})} \sum_{i=0}^{\infty} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^i \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{zt-i} \end{bmatrix}$$

which reduces to

(4.26) $$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{zt-i} \end{bmatrix}$$

where

(4.27) $$\phi(i) = \frac{A_1^{\,i}}{(1-b_{12}b_{21})} \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix}$$

and

(4.28) $$A_1 = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}.$$

The coefficients of $\phi(i)$ are known as the impulse response functions and can be used to generate the effects of ε_{yt} and ε_{zt} shocks on the entire time paths of y_t and z_t. The elements of $\phi(0)$ are the impact multipliers. For example, $\phi_{12}(0)$ is the instantaneous impact on y_t of a one-unit change in ε_{zt}. The elements of $\phi(1)$ are the one period responses, and so on. Plotting the impulse response functions against time is a practical way to visually represent the response of y_t and z_t to shocks. The accumulated effects of unit impulses in ε_{yt} and ε_{zt} can be obtained by adding up the coefficients of the impulse response functions. For example, after n periods, the effect of ε_{zt} on y_{t+n} is $\phi_{12}(n)$. Therefore, the cumulated sum of effects of ε_{zt} on y_t is:

(4.29) $$\sum_{i=0}^{n} \phi_{12}(i)$$

As n approaches infinity, this yields the long run multiplier. If y_t and z_t are stationary, then all of the long run multipliers are finite.

As previously mentioned, while the standard VAR can be estimated using OLS, the structural VAR cannot be estimated directly. Unless we are willing to restrict one of the parameters of the structural system, the structural VAR will be underidentified. One possible type of restriction is to impose a zero value on one of the contemporaneous effects. For example, we may impose the restriction that z_t affects y_t both contemporaneously and in lags, but y_t only has a lagged effect on z_t (i.e. $b_{12} \neq 0$ and $b_{21}=0$). In this way, the error term from the second structural equation is equivalent to the error term from the second standard equation, while the error term from the first standard equation is a combination of the two structural error terms:

(4.30) $$e_{2t} = \varepsilon_{zt}$$

(4.31) $$e_{1t} = \varepsilon_{yt} - b_{12}\varepsilon_{zt}$$

This type of triangular decomposition of the residuals, in which ε_{yt} and ε_{zt} affect y_t contemporaneously but only ε_{zt} affects z_t contemporaneously, is called a Choleski decomposition. This implies a certain ordering of the variables. This example suggests that z occurs prior to y. In practice, the general consensus seems to be that the ordering of the variables is important only if the correlation between e_{1t} and e_{2t} is greater than about 0.2: If this correlation is higher than 0.2, a particular ordering should be used to obtain the impulse response functions, which should then be compared to the results from the reverse ordering. While this is relatively simple to do in a two variable VAR, this quickly becomes cumbersome as more variables are introduced into the model.

Understanding the properties of the forecast errors is also helpful in uncovering the interrelationship between the system's variables. If we take the equation

(4.32) $$x_t = A_0 + A_1 x_{t-1} + e_t$$

the n-step ahead forecast, conditional upon x_t is

(4.33) $$E(x_{t+n}) = (I + A_1 + A_1^2 + \dots + A_1^{n-1})A_0 + A_1^n x_t$$

which leaves the forecast error as

(4.34) $$e_{t+n} + A_1 e_{t+n-1} + A_1^2 e_{t+n-2} + \dots + A_1^{n-1} e_{t+1}$$

Considering the VMA representation of the forecast yields

(4.35) $$x_{t+n} = \mu + \sum_{i=0}^{n-1} \phi \varepsilon_{t+n-i}$$

which gives an n-period forecast error of

$$x_{t+n} - E_t(x_{t+n}) = \sum_{i=0}^{n-1} \phi \varepsilon_{t+n-i} \tag{4.36}$$

If, for simplicity, we only examine the y_t sequence, the n-step ahead forecast error is

$$\begin{aligned} y_{t+n} - E(y_{t+n}) = {} & \phi_{11}(0)\varepsilon_{yt+n} + \phi_{11}(1)\varepsilon_{yt+n-1} + \ldots + \phi_{11}(n-1)\varepsilon_{yt+1} + \phi_{12}(0)\varepsilon_{zt+n} \\ & + \quad + \phi_{12}(1)\varepsilon_{zt+n-1} + \ldots + \phi_{12}(n-1)\varepsilon_{zt+1} \end{aligned} \tag{4.37}$$

Denoting the variance of the n-step ahead forecast error of y_{t+n} as $\sigma_y(n)^2$,

$$\begin{aligned} \sigma_y(n)^2 = {} & \sigma_y^2[\phi_{11}(0)^2 + \phi_{11}(1)^2 + \ldots + \phi_{11}(n-1)^2] \\ & + \quad + \sigma_z^2[\phi_{12}(0)^2 + \phi_{12}(1)^2 + \ldots + \phi_{12}(n-1)^2] \end{aligned} \tag{4.38}$$

Since all values of $\phi_{jk}(i)^2$ are non-negative, the variance of the forecast error will increase as n increases. It is possible to separate this variance into components due to each one of the shocks. The proportions of $\sigma_y(n)^2$ attributable to shocks in the ε_{yt} and ε_{zt} sequences are, respectively,

$$\frac{\sigma_y^2[\phi_{11}(0)^2 + \phi_{11}(1)^2 + \ldots + \phi_{11}(n-1)^2}{\sigma_y(n)^2} \tag{4.39}$$

and

$$\frac{\sigma_z^2[\phi_{12}(0)^2 + \phi_{12}(1)^2 + \ldots + \phi_{12}(n-1)^2}{\sigma_y(n)^2} \tag{4.40}$$

This decomposition tells us the proportion of movement in y that is due to its own shock and the proportion of the movement due to shocks in the other variable. If y_t is entirely exogenous, shocks in ε_{zt} will explain none of the forecast error variance of y_t at all forecast horizons. In contrast, if y_t is entirely endogenous, shocks in ε_{zt} will explain all of the forecast error variance in the y_t sequence at all forecast horizons. In practice, it is common to find that a variable will explain the majority of its own forecast error variance over short horizons, but that this proportion diminishes at longer horizons. This is to be expected if ε_{zt} has little contemporaneous effect on y_t, but affects y_t with a lag.

One criticism of VAR's is that they are devoid of any economic content: the sole role of the economist is to determine which variables should be included in the VAR. Because there is very little economic input into the VAR, there is also very little economic content in the results. The Choleski decomposition is only one way in which the primary VAR can be identified from the standard VAR. Although this requires an ordering of the variables, this is generally ad hoc. This also makes a strong assumption about the underlying structural errors. Unless this assumption is theoretically correct, the underlying shocks will be improperly identified, which will result in impulse response functions and variance decompositions that are misleading. As discussed above, the residuals from the standard VAR are composite shocks of the underlying shocks ε_{yt} and ε_{zt}. These composite shocks are also the one-step ahead forecast errors. Therefore, if the purpose of the VAR is only to forecast, the underlying components of the forecast errors are not important. If, however, the VAR's are being used to obtain the impulse response function or a variance decomposition, the structural errors need to be used. Thus, the underlying components of the forecast errors are important.

In general, in order to identify the structural model from an estimated VAR, $(n^2 - n)/2$ restrictions must be imposed. Such restrictions can involve coefficient restrictions (such as restricting b_{21} to 1 instead of 0), variance restrictions or symmetry restrictions. The goal of a structural VAR is to use economic theory to impose these restrictions in order to recover the structural innovations from the residuals in the estimated VAR.

4.6.4 Non-Stationary Variables

The discussion of VAR's to this point has assumed that both of the variables are stationary. The question is, do they need to be stationary in order to use the VAR methodology? Since stationarity can be imposed by first differencing, this question becomes one of whether or not to difference the variables in order to impose stationarity. Although there is no clear answer to this question, some, such as Sims (1980) and Doan (1992) argue that first differencing throws away information regarding the comovements in the data. Since the goal of VAR analysis is to determine the interrelationships among the variables and not to determine the parameter estimates, the form of the variables should mimic the true data-generating process. This is also an argument against detrending the data.

With the theory of the VAR in hand, the results from the analysis can now be interpreted. VARs were used to perform Granger causality tests and generate impulse response functions using data from the U.S., Canada and Mexico. Because the question in mind is the effect of oil price shocks on the economy, attention will be paid only to the relationship between the oil price and the CPI and the relationship between the oil price and the IPI. That is, any relationship between the IPI and the CPI will not be explored in the context of this discussion.

In order to generate the impulse response functions and variance decompositions for each country, the three variables in question (the oil price, the CPI and the IPI) were run in a VAR format, with 13 lags of each variable. The number of lags follows Sims (1992), in which it is suggested that the optimal number of lags be the equivalent of the number of observations equivalent to one year plus 1. In the case of monthly data, this is equal to 13.

4.7 Multi-Equation Results from the U.S. Data

The three samples for the U.S. data outlined above were also used in the VAR analysis of the U.S. data.

4.7.1 Granger Causality Tests

Part A of Table 4.7.1 shows the results from the Granger causality for the U.S. data when the full sample is used. Using the full sample, the p-values indicate that we cannot reject the null hypotheses that the oil price does not Granger cause the IPI and that the IPI does not Granger cause the oil price. The p-values do indicate that we can reject the null hypotheses that the oil price does not Granger cause the CPI and that the CPI does not Granger cause the oil price. Therefore, the data seems to indicate bi-directional Granger causality between the oil price and the CPI and no Granger causality between the oil price and the IPI when the full sample is used. Part B of this table shows the results from the Granger causality tests when the sub-sample beginning in 1974 is used. The p-values, while different from those in Part A, still indicate the same conclusions: bi-directional Granger causality between the oil price and the CPI and no Granger causality between the oil price and the IPI. The results change somewhat when the sub-sample beginning in 1981 is used. As Part C of Table 4.7.1 shows, the p-values indicate that while there is still no evidence of Granger causality between the oil price and the IPI, there is now only evidence of uni-directional Granger causality from the oil price to the CPI.

4.7.2 Variance Decomposition

As stated above, the variance decomposition indicates the proportion of the movement in a variable that can be attributed to shocks in that variable, as well as the proportion of the movement that can be attributed to the shocks in the other variables. This decomposition, as previously mentioned, will generally be sensitive to the ordering of the variables if the correlation between the error terms of the standard VAR is greater than 0.2. Therefore, the correlation matrices for the error terms from the VAR on the U.S. data for the three different sample periods are presented in Table 4.7.2 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). Part A of this table indicates that when the full sample is considered, none of the correlation coefficients exceeds 0.2. Parts B and C both indicate that the correlation between the oil price and the CPI exceeds the 0.2 mark, which would suggest that the ordering may matter when calculating the variance decompositions using the 1974 and 1981 sub-samples.

Table 4.7.3 shows the variance decomposition for the U.S. data for five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months. Although the correlation coefficients between the oil price and the CPI was above 0.2 for the 1974 and 1981 sub-samples, calculating the variance decompositions for the different orderings produced no significant difference. Therefore, only the variance decomposition for the {oil price-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The oil price tends to dominate the IPI in predicting the CPI for the first four time horizons, although the oil price does not seem to have a significant effect on the forecast variance of the IPI.

Part B of Table 4.7.3 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The results from the forecast variance of the IPI are similar to those of the full sample. The CPI shows vastly different results for the 1974 sub-sample than for the full sample. The oil price does not seem to have a significant role in predicting the CPI at every time horizon shown.

The results from the sub-sample beginning in 1981, shown in Part C of Table 4.7.3, are similar to the results from the full sample, although the proportion of the forecast variance of the oil price explained by the CPI is considerably lower. As well, the oil price does not appear to be as significant in predicting the CPI. Finally, the oil price tends to explain over 90% of its own forecast variance at every time horizon considered, indicating that the oil price is very close to being considered exogenous for this sub-sample.

4.7.3 Impulse Response Functions

Figure 4.7.1 shows the impulse response functions for the different sample periods. The solid line in each graph represents the response of a one-standard-error shock in the oil price, while the dotted lines represent plus and minus two standard errors, which were calculated by taking one hundred random draws from the posterior distribution of the VAR coefficient. Again, as with the variance decompositions, because the correlation between the oil price and the CPI was greater than 0.2. the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {oil price-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to a shock in the oil price when the full sample is used. This indicates that there is a positive response in the oil price which, although it begins to decay almost immediately, appears to be significant for the entire sixty-month period following the oil price shock. The response of the CPI to a shock in the oil price also seems to be positive and significant for the entire sixty month period, although unlike the oil price, it is ever increasing, albeit at a decreasing rate. The IPI shows a persistent negative response that peaks at about sixteen months and then levels off, although this effect does not seem to be significant at any time during the sixty-month period.

The impulse response functions change significantly when the 1974 sub-sample is considered, as Part B of Figure 4.7.1 shows. The response of the oil price to a shock in the oil price again peaks in the second period and then begins to decay. However, although the peak is slightly higher than in the full sample, the decay is much faster, to the point that the response no longer seems to be significant after about the thirty-second month. The response of the CPI to a shock in the oil price also changes significantly. Using the 1974, the response of the CPI to a shock in the oil price levels off beginning in the second period and begins to decay after the thirtieth period. The response, however, does not seem to be significant after the two year mark. The response of the IPI is similar in that it is persistently negative following a shock to the oil price, peaks at about sixteen months and does not appear to be significant throughout the sixty-month period. However, unlike the full sample, the response begins to decay back toward zero after peaking.

As Part C of Figure 4.7.1 shows, the impulse response functions change even more dramatically when the sub-sample beginning in 1981 is used. The response of the oil price to a shock in the oil price, although similar in appearance to the response in the 1974 sub-sample, decays even faster and is no longer significant after the fourteenth month. The response of the CPI to a shock in the oil price begins to decay after peaking in the third month and actually appears to become negative just before the two year mark, although the effects no longer appear to be significant after the ninth month. The response of the IPI to an oil price shock is initially positive for the first four months and again after the thirtieth month, although this effect still does not appear to be significant.

4.8 Multi-Equation Results from the Canadian Data

The three samples for the Canadian data outlined above were also used in the VAR analysis of the Canadian data.

4.8.1 Granger Causality Tests

Part A of Table 4.8.1 shows the results from the Granger causality for the Canadian data when the full sample is used. Using the full sample, the p-values indicate that we cannot reject the null hypotheses that the oil price does not Granger cause the IPI and that the IPI does not Granger cause the oil price. The p-values do indicate that we can reject the null hypothesis that the oil price does not Granger cause the CPI, but not the null hypothesis that the CPI does not Granger cause the oil price. Therefore, the data seems to indicate uni-directional Granger causality from the oil price to the CPI and no Granger causality between the oil price and the IPI when the full sample is used. Part B of this table shows the results from the Granger causality tests when the sub-sample beginning in 1974 is used. The p-values, while different from those in Part A, still indicate the same conclusions: uni-directional Granger causality from the oil price to the CPI and no Granger causality between the oil price and the IPI. The results change somewhat when the sub-sample beginning in 1981 is used. As Part C of Table 4.8.1 shows, the p-values indicate that the evidence of Granger causality from the oil price to the CPI disappears, leading to the conclusion that in this sub-sample, there is no evidence of any Granger causality between the oil price and either the IPI or the CPI.

4.8.2 Variance Decomposition

The correlation matrices for the error terms from the VAR on the Canadian data for the three different sample periods are presented in Table 4.8.2 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). Unlike the U.S. data, none of the correlation coefficients in any of the samples exceeds 0.2. This suggests that the ordering does not matter when calculating the variance decompositions.

Table 4.8.3 shows the variance decomposition for the Canadian data for five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months. As the residual correlations suggest that the ordering does not matter, only the variance decomposition for the {oil price-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon, with the exception of the CPI at the forty-eight and sixty month horizons, in which case the IPI is the dominant variable in predicting the CPI. The oil price tends to dominate the IPI in predicting the CPI for the first three time horizons. The oil price does not appear to have a significant effect in predicating the IPI at every time horizon.

Part B of Table 4.8.3 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The results from the forecast variance of the IPI are similar to those of the full sample. The results for the CPI are also quite similar for this sub-sample as for the full sample, with the exception that the oil price tends to dominate the IPI in predicting the CPI at every time horizon, and dominates the CPI at the forty-eight and sixty month horizons.

The results from the sub-sample beginning in 1981, shown in Part C of Table 4.8.3, are similar to the results from the 1974 sub-sample, with the exception that shocks to the CPI explain the majority of its own forecast variance at every time horizon considered. Again, the oil price tends to explain over 95% of its own forecast variance at every time horizon considered, indicating that the oil price is very close to being considered exogenous for this sub-sample.

4.8.3 Impulse Response Functions

Figure 4.8.1 shows the impulse response functions for the different sample periods. The solid line in each graph represents the response of a one-standard-error shock in the oil price, while the dotted lines represent plus and minus two standard errors, which were calculated by taking one hundred random draws from the posterior distribution of the VAR coefficient. Again, as with the variance decompositions, because the correlations between the residuals were all less than 0.2, the ordering should not matter. Thus, only the {oil price-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to a shock in the oil price when the full sample is used. This indicates that there is a positive response in the oil price which, although it begins to decay almost immediately, appears to be significant for the entire sixty-month period following the oil price shock, except, perhaps, the last three months. The response of the CPI to a shock in the oil price also seems to be positive and significant for the entire sixty month period, although unlike the oil price, it is ever increasing, albeit at a decreasing rate. The IPI shows a persistent negative response that peaks at about eighteen months and then levels off, although this effect does not seem to be significant at any time during the sixty-month period.

The impulse response functions change significantly when the 1974 sub-sample is considered, as Part B of Figure 4.8.1 shows. The response of the oil price to a shock in the oil price again peaks in the second period and then begins to decay. However, although the peak is slightly higher than in the full sample, the decay is much faster, to the point that the response no longer seems to be significant after about the fortieth month. The response of the CPI to a shock in the oil price also changes significantly. Using the 1974 sub-sample, the response of the CPI to a shock in the oil price levels off beginning at the two year mark and begins to decay after the thirtieth period. The response, however, does not seem to be significant before the fourth month. The response of the IPI is similar in that it is persistently negative following a shock to the oil price, although it peaks at about twenty-four months. As well, unlike the full sample, the response begins to decay back toward zero after peaking, it appears to be significant for the 10-month period surrounding its peak and it actually becomes positive during the last five months of the response period.

As Part C of Figure 4.8.1 shows, the impulse response functions change even more dramatically when the sub-sample beginning in 1981 is used. The response of the oil price to a shock in the oil price, although similar in appearance to the response in the 1974 sub-sample, decays even faster and is no longer significant after the fourteenth month. The response of the CPI to a shock in the oil price begins to decay after peaking in the sixth month and actually appears to become negative just after the two-year mark, although the effects appear to be significant only between the fourth and fourteenth months. The response of the IPI to an oil price shock is initially negative but appears to become positive after the thirty-third month, although the response still does not appear to be significant at any time during the period.

4.9 Multi-Equation Results from the Mexican Data

The two samples for the Mexican data outlined above were also used in the VAR analysis of the Mexican data.

4.9.1 Mexican Granger Causality Tests

Table 4.9.1 shows the results from the Granger causality tests for the Mexican data. Using the full sample, the p-values, shown in Part A, indicate that, while we cannot reject the null hypotheses that the oil price does not Granger cause the IPI, the evidence does suggest that the null hypothesis that the IPI does not Granger cause the oil price can be rejected. As well, the p-values indicate that the null hypotheses that the oil price does not Granger cause the CPI and that the CPI does not Granger cause the oil price can both be rejected. Therefore, the data seems to indicate bi-directional Granger causality from the oil price to the CPI and uni-directional Granger causality from the IPI to the oil price when the full sample is used. Part B of Table 4.9.1 shows the results from the Granger causality tests when the sub-sample beginning in 1981 is used. The p-values indicate that the evidence of Granger causality from the IPI to the oil price disappears, although there is still evidence of bi-directional Granger causality between the oil price and the CPI.

4.9.2 Variance Decomposition

The correlation matrices for the error terms from the VAR on the Mexican data for the three different sample periods are presented in Table 4.9.2 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). Parts A and B of this table both indicate that the correlation between the oil price and the CPI exceeds the 0.2 mark, which would suggest that the ordering may matter when calculating the variance decompositions using the full sample and the 1981 sub-sample.

Table 4.9.3 shows the variance decomposition for the Mexican Data for five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months. Although the correlation coefficients between the oil price and the CPI was above 0.2 for both the full sample and the 1981 sub-sample, calculating the variance decompositions for the different orderings produced no significant difference. Therefore, only the variance decomposition for the {oil price-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The oil price tends to dominate the IPI in predicting the CPI for the first three time horizons. The oil price does not appear to have a significant effect in predicating the IPI for every time horizon.

Part B of Table 4.9.3 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1981 is considered. The results from the forecast variance of the IPI are similar to those of the full sample. The results for the CPI using the 1981 sub-sample are also similar to those from the full sample. The oil price dominates the IPI in predicting the CPI at every time horizon shown, although the proportion of the forecast variance of the CPI explained by the oil price declines significantly as the horizon gets longer.

4.9.3 Impulse Response Functions

Figure 4.9.1 shows the impulse response functions for the different sample periods. The solid line in each graph represents the response of a one-standard-error shock in the oil price, while the dotted lines represent plus and minus two standard errors, which were calculated by taking one hundred random draws from the posterior distribution of the VAR coefficient. Again, as with the variance decompositions, because the correlation between the oil price and the CPI was greater than 0.2, the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {oil price-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to a shock in the oil price when the full sample is used. This indicates that there is a positive response in the oil price which, although it begins to decay almost immediately, appears to be significant until about the two-year mark. The response of the CPI to a shock in the oil price also seems to be positive and significant for the same period, although it appears to peak at eighteen months. The IPI shows an initial negative response that bottoms out at about six months and then begins climbing, becomes positive at eight month and levels off at its peak after about two and a half years. This effect, however, does not seem to be significant until the thirtieth month, when it levels off.

As Part B of Figure 4.9.1 shows, the impulse response functions change somewhat when the sub-sample beginning in 1981 is used. The response of the oil price to a shock in the oil price, although similar in appearance to the response in the full sample, decays even faster to the point where it becomes negative after two and a half years, but no longer appears to be significant after the fourteenth month. The response of the CPI to a shock in the oil price begins to decay after peaking at about the one-year mark and actually appears to become negative just before the three-year mark, although the effects appear to be significant only for the first eighteen months. The response of the IPI to an oil price shock is initially positive, becomes negative at the third month and becomes positive again after the twentieth month, although the response still does not appear to be significant at any time during the period.

4.10 Conclusion

A single equation approach and a multi-equation approach were used in an attempt to analyze the effects of oil price shocks on the CPI and the IPI. The analysis was performed on data for the U.S., Canada and Mexico. For the U.S. and Canadian data, three sets of test were performed for each country: one using the full sample (beginning in 1947 for the U.S. and 1961 for Canada), one using a sub-sample of the data beginning in 1974 and one using a sub-sample beginning in 1981. The 1974 sub-sample was used because 1974 was the beginning of the period of volatility in oil prices. The 1981 sub-sample was chosen because this is when the WTI price became a true market determined price. The analysis was run only twice for the Mexican data, on the full sample and the 1981 sub-sample. Analysis on the 1974 sub-sample was not done because the full sample only began in April 1972.

In the single equation approach, bivariate cointegration tests were performed using the oil price as the independent variable and either the CPI or the IPI as the dependent variable because the variables were all found to be I(1). If cointegration was between the variables was found, an error correction model was built. If no cointegration was found, then the data was first-differenced. Once the cointegration analysis was completed, bivariate regressions with the oil price as the independent variable and either the CPI or the IPI as the dependent variable were run. Bivariate Granger causality tests were also performed between the oil price and the macroeconomic variables. The results from the single equation analysis tended to suggest that while the oil price does not show a significant effect on the IPI in all samples for all three countries, it does have a significant impact on the CPI in the U.S. and Canada, regardless of the sample considered. The oil price does not seem to have a significant impact on the Mexican CPI, although there is some suggestion that for the 1981 sample, the CPI has some impact on the oil price.

For the multi-equation approach, Granger causality tests were performed on a model that included the oil price, the CPI and the IPI. Vector autoregressions were run on the variables to generate the impulse response functions and the variance decompositions. The results tended to vary based on the country and the sample used. Where there was evidence of Granger causality, it tended to be between the oil price and the CPI and not between the oil price and the IPI. Although the correlations of the error terms in the U.S. and Mexican VAR's indicated that the ordering may matter, there were not significant differences in the results when the different ordering were used to generate the variance decompositions and impulse response functions.

The variance decomposition for each of the countries also tended to vary significantly depending on the sample. The impulse response functions varied somewhat for each country depending on the sample used, although there were some similarities. The biggest difference was that the period of significance declined as the sample got smaller. In general, however, the direction of the effects were the same across time periods and across countries: the response of the oil price to an oil price shock was positive but declining, the response of the CPI was positive and the response of the IPI was generally negative, at least initially, but was not significant. Overall, as with the single equation approach, the results seem to indicate that the oil price shocks tend to affect the macroeconomy more through the CPI than through the IPI.

The differences in the variance decompositions and the impulse response functions across time periods tends to suggest that there was some sort of structural change in the macroeconomic responses to oil price shocks. However, this may be the result of differences in the volatility of the oil prices at the time of the oil price shocks. This hypothesis is the focus of the next chapter.

Table 4.2.1: Results from the Johansen Cointegration Test for the U.S. Data

Full Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	600	0.0312	1.78E-05	19.00975*	r=0
Oil Price and IPI	600	0.0085	0.0055	8.5937	r=0

1974 Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	281	0.0695	0.0432	32.64971*	r=0
Oil Price and IPI	281	0.0617	0.0001	17.91478*	r=0

1981 Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	197	0.0522	0.0227	15.0699	r=0
Oil Price and IPI	197	0.0450	0.0001	9.0930	r=0

5% Critical Value =15.41. * indicates rejection of H_0.

Table 4.2.2: Results from the Johansen Cointegration Test for the Canadian Data

Full Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	431	0.0398	0.0024	18.52816*	r=0
Oil Price and IPI	431	0.0131	0.0105	10.2322	r=0

1974 Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	280	0.0821	0.0515	38.81835*	r=0
Oil Price and IPI	280	0.0577	0.0017	17.11469*	r=0

1981 Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	196	0.0652	0.0392	21.04391*	r=0
Oil Price and IPI	196	0.0563	0.0039	12.1236	r=0

5% Critical Value =15.41. * indicates rejection of H_0.

Table 4.2.3: Results from the Johansen Cointegration Test for the Mexican Data

Full Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	297	0.0374	0.0013	11.7241	r=0
Oil Price and IPI	297	0.0273	0.0048	9.6563	r=0

1981 Sample

Test for cointegration between:	T	λ_1	λ_2	λ_{trace}	H_0
Oil Price and CPI	192	0.0719	0.0241	19.02546*	r=0
Oil Price and IPI	192	0.0280	0.0114	7.6603	r=0

5% Critical Value =15.41. * indicates rejection of H_0

Table 4.3.1: Results from the Single Equation Regressions[2] for the U.S. Data

$$Y_t = \alpha + \lambda\varepsilon_{t-1} + \sum_{i=1}^{4}\beta_i Y_{t-i} + \sum_{i=1}^{4}\gamma_i P_{t-i}$$

Y=IPI - Full Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0016	0.0004	3.7273	0.0002
β_1	0.3416	0.0404	8.4465	0.0000
β_2	0.0508	0.0415	1.2239	0.2215
β_3	0.1412	0.0375	3.7670	0.0002
β_4	-0.0390	0.0358	-1.0883	0.2769
γ_1	-0.0035	0.0069	-0.5038	0.6146
γ_2	-0.0004	0.0070	-0.0516	0.9589
γ_3	-0.0078	0.0070	-1.1124	0.2664
γ_4	0.0015	0.0069	0.2137	0.8308

Y=CPI - Full Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0009	0.0002	4.9070	0.0000
λ	-0.0006	0.0005	-1.3172	0.1883
β_1	0.3466	0.0415	8.3414	0.0000
β_2	0.1980	0.0434	4.5619	0.0000
β_3	0.0996	0.0421	2.3651	0.0183
β_4	0.0818	0.0398	2.0542	0.0404
γ_1	0.0066	0.0020	3.3822	0.0008
γ_2	-0.0003	0.0020	-0.1726	0.8630
γ_3	-0.0024	0.0020	-1.1830	0.2373
γ_4	0.0009	0.0020	0.4456	0.6561

Y=IPI - 1974 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0010	0.0005	2.2285	0.0267
λ	-0.0008	0.0029	-0.2880	0.7736
β_1	0.3198	0.0606	5.2759	0.0000
β_2	0.1597	0.0631	2.5312	0.0119
β_3	0.0662	0.0632	1.0475	0.2958
β_4	-0.0389	0.0602	-0.6462	0.5187
γ_1	-0.0026	0.0053	-0.4880	0.6259
γ_2	-0.0002	0.0055	-0.0416	0.9669
γ_3	-0.0070	0.0055	-1.2780	0.2023
γ_4	0.0014	0.0054	0.2632	0.7926

Y=CPI - 1974 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0014	0.0003	4.6381	0.0000
λ	-0.0017	0.0005	-3.3668	0.0009
β_1	0.4677	0.0626	7.4701	0.0000
β_2	0.1076	0.0677	1.5890	0.1132
β_3	0.1098	0.0677	1.6222	0.1059
β_4	-0.0207	0.0588	-0.3510	0.7259
γ_1	0.0069	0.0014	4.8048	0.0000
γ_2	-0.0001	0.0015	-0.0741	0.9409
γ_3	-0.0037	0.0015	-2.4627	0.0144
γ_4	0.0014	0.0015	0.9236	0.3565

Y=IPI - 1981 Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0009	0.0005	1.8657	0.0636
β_1	0.0945	0.0726	1.3012	0.1948
β_2	0.1398	0.0715	1.9554	0.0520
β_3	0.1604	0.0713	2.2485	0.0257
β_4	0.0997	0.0715	1.3947	0.1648
γ_1	0.0012	0.0063	0.1955	0.8452
γ_2	-0.0039	0.0068	-0.5670	0.5714
γ_3	-0.0043	0.0068	-0.6398	0.5231
γ_4	-0.0074	0.0063	-1.1613	0.2470

Y=CPI - 1981 Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0012	0.0003	4.3619	0.0000
β_1	0.3911	0.0754	5.1872	0.0000
β_2	0.1113	0.0805	1.3822	0.1685
β_3	0.1306	0.0806	1.6202	0.1069
β_4	-0.0144	0.0676	-0.2133	0.8313
γ_1	0.0110	0.0018	6.1217	0.0000
γ_2	-0.0020	0.0020	-0.9675	0.3345
γ_3	-0.0028	0.0021	-1.3438	0.1806
γ_4	-0.0013	0.0019	-0.6779	0.4987

Table 4.3.2: p-values from Granger Causality Tests on the U.S. Data

A. Full Sample

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0081**	0.0459
IPI	0.8094	0.5483

B. 1974 Sub-Sample

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0000**	0.2793
IPI	0.8447	0.9153

C. 1981 Sub-Sample 1981

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0000**	0.2725
IPI	0.4978	0.7206

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[2] λ=0 indicates that the variables do not cointegrate, therefore an error correction model is not necessary.

Table 4.4.1: Results from the Single Equation Regressions[3] for the Canadian Data

$$Y_t = \alpha + \lambda\varepsilon_{t-1} + \sum_{i=1}^{4}\beta_i Y_{t-i} + \sum_{i=1}^{4}\gamma_i P_{t-i}$$

Y=IPI - Full Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0018	0.0006	3.1090	0.0020
β_1	-0.1216	0.0481	-2.5294	0.0118
β_2	0.1330	0.0465	2.8587	0.0045
β_3	0.2548	0.0465	5.4739	0.0000
β_4	0.1542	0.0478	3.2275	0.0013
γ_1	-0.0092	0.0076	-1.2071	0.2281
γ_2	0.0053	0.0078	0.6762	0.4993
γ_3	-0.0186	0.0078	-2.3754	0.0180
γ_4	0.0066	0.0077	0.8656	0.3872

Y=CPI - Full Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0017	0.0003	5.2422	0.0000
λ	-0.0025	0.0007	-3.3875	0.0008
β_1	0.0472	0.0472	0.9995	0.3181
β_2	0.1197	0.0463	2.5870	0.0100
β_3	0.1805	0.0462	3.9022	0.0001
β_4	0.2203	0.0469	4.6948	0.0000
γ_1	0.0027	0.0024	1.1362	0.2565
γ_2	0.0033	0.0025	1.3385	0.1815
γ_3	0.0011	0.0025	0.4297	0.6676
γ_4	0.0048	0.0024	1.9911	0.0471

Y=IPI - 1974 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0009	0.0006	1.3699	0.1719
λ	-0.0031	0.0046	-0.6656	0.5062
β_1	-0.1070	0.0606	-1.7649	0.0787
β_2	0.1935	0.0577	3.3526	0.0009
β_3	0.3096	0.0578	5.3546	0.0000
β_4	0.0826	0.0603	1.3704	0.1717
γ_1	-0.0090	0.0075	-1.2016	0.2306
γ_2	0.0056	0.0077	0.7264	0.4683
γ_3	-0.0203	0.0077	-2.6266	0.0091
γ_4	0.0084	0.0076	1.1055	0.2699

Y=CPI - 1974 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0028	0.0005	5.3504	0.0000
λ	-0.0045	0.0010	-4.5879	0.0000
β_1	-0.0334	0.0595	-0.5621	0.5745
β_2	0.0929	0.0588	1.5809	0.1151
β_3	0.1514	0.0587	2.5784	0.0105
β_4	0.1570	0.0593	2.6451	0.0086
γ_1	0.0015	0.0024	0.6328	0.5274
γ_2	0.0032	0.0024	1.3091	0.1916
γ_3	0.0002	0.0024	0.0652	0.9481
γ_4	0.0043	0.0024	1.8323	0.0680

Y=IPI - 1981 Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0008	0.0007	1.1459	0.2533
β_1	-0.0831	0.0730	-1.1386	0.2563
β_2	0.1425	0.0664	2.1457	0.0332
β_3	0.4264	0.0662	6.4427	0.0000
β_4	0.0441	0.0721	0.6119	0.5414
γ_1	-0.0047	0.0096	-0.4840	0.6289
γ_2	0.0075	0.0104	0.7183	0.4735
γ_3	-0.0112	0.0105	-1.0676	0.2871
γ_4	0.0095	0.0097	0.9863	0.3253

Y=CPI - 1981 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0014	0.0004	3.3615	0.0009
λ	-0.0053	0.0021	-2.5607	0.0112
β_1	-0.0251	0.0702	-0.3571	0.7215
β_2	0.1331	0.0685	1.9439	0.0534
β_3	0.2155	0.0666	3.2344	0.0014
β_4	0.2362	0.0685	3.4500	0.0007
γ_1	0.0007	0.0032	0.2137	0.8310
γ_2	0.0087	0.0035	2.4838	0.0139
γ_3	0.0022	0.0035	0.6203	0.5358
γ_4	0.0027	0.0033	0.8170	0.4150

Table 4.4.2: p-values from the Granger Causality Tests on the Canadian Data

A. Full Sample

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0002**	0.5938
IPI	0.1451	0.8901

B. 1974 Sub-Sample

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0000**	0.8459
IPI	0.1349	0.9844

C. 1981 Sub-Sample 1981

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	**0.0252**	0.2017
IPI	0.7995	0.8182

[3] λ=0 indicates that the variables do not cointegrate, therefore an error correction model is not necessary.

Table 4.5.1: Results from the Single Equation Regressions[4] for the Mexican Data

$$Y_t = \alpha + \lambda\varepsilon_{t-1} + \sum_{i=1}^{4}\beta_i Y_{t-i} + \sum_{i=1}^{4}\gamma_i P_{t-i}$$

Y=IPI - Full Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0079	0.0025	3.1807	0.0016
β_1	-0.5333	0.0582	-9.1594	0.0000
β_2	-0.1242	0.0658	-1.8856	0.0604
β_3	-0.0063	0.0659	-0.0955	0.9240
β_4	-0.1416	0.0585	-2.4198	0.0161
γ_1	-0.0110	0.0197	-0.5592	0.5764
γ_2	-0.0199	0.0197	-1.0124	0.3122
γ_3	-0.0248	0.0197	-1.2590	0.2090
γ_4	-0.0243	0.0198	-1.2307	0.2194

Y=CPI - Full Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0031	0.0012	2.6152	0.0094
β_1	0.6744	0.0601	11.2228	0.0000
β_2	0.0026	0.0717	0.0365	0.9709
β_3	0.1281	0.0711	1.8034	0.0724
β_4	0.0401	0.0578	0.6941	0.4882
γ_1	0.0142	0.0070	2.0237	0.0439
γ_2	-0.0001	0.0070	-0.0137	0.9891
γ_3	0.0075	0.0070	1.0700	0.2855
γ_4	0.0135	0.0069	1.9403	0.0533

Y=IPI - 1981 Sample (λ=0)

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0053	0.0028	1.8966	0.0595
β_1	-0.3933	0.0732	-5.3743	0.0000
β_2	-0.1184	0.0784	-1.5091	0.1330
β_3	-0.0289	0.0784	-0.3682	0.7131
β_4	-0.0964	0.0731	-1.3185	0.1890
γ_1	-0.0064	0.0227	-0.2822	0.7781
γ_2	-0.0407	0.0226	-1.7994	0.0736
γ_3	-0.0099	0.0228	-0.4336	0.6651
γ_4	-0.0222	0.0228	-0.9733	0.3317

Y=CPI - 1981 Sample

	Coefficient	Std. Error	t-Stat.	Prob.
α	0.0041	0.0019	2.1632	0.0318
λ	-0.0019	0.0047	-0.4087	0.6832
β_1	0.8513	0.0807	10.5455	0.0000
β_2	-0.2194	0.1055	-2.0794	0.0390
β_3	0.1561	0.1059	1.4744	0.1421
β_4	0.0531	0.0796	0.6679	0.5050
γ_1	-0.0065	0.0103	-0.6305	0.5291
γ_2	0.0103	0.0103	0.9993	0.3190
γ_3	0.0112	0.0104	1.0766	0.2831
γ_4	0.0175	0.0096	1.8243	0.0698

Table 4.5.2: p-values from the Single Equation Granger Causality Tests on the Mexican Data

A. Full Sample

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	0.0722	0.2289
IPI	0.3313	0.3302

B. 1981 Sub-Sample 1981

Variable:	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
CPI	0.1655	**0.0104**
IPI	0.3303	0.6389

[4] λ=0 indicates that the variables do not cointegrate, therefore an error correction model is not necessary.

Table 4.7.1: p-values from the Multi-Equation Granger Causality Tests on the U.S. Data

A. Full Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	**0.00022**	**0.003697**
IPI	0.717668	0.989141

B. 1974 Sub-Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	**0.000001**	**0.000002**
IPI	0.827173	0.859938

C. 1981 Sub-Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	**0.000001**	0.376045
IPI	0.780243	0.713681

Table 4.7.2: Residual Correlation Matrix from the VAR on the U.S. Data

A. Full Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	0.181855	1.000000	
IPI	-0.015696	0.054820	1.000000

B. 1974 Sub-Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	**0.229601**	1.000000	
IPI	-0.035282	0.087564	1.000000

C. 1981 Sub-Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	**0.222270**	1.000000	
IPI	0.044674	0.121558	1.000000

Table 4.7.3: Variance Decomposition for the U.S. Data {Oil Price-CPI-IPI}

A. Full Sample

	12 Month Horizon				*24 Month Horizon*				*36 Month Horizon*		
	Forecast Variable:				Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	93.79	17.03	0.49	Oil Price	85.85	18.67	3.74	Oil Price	82.04	21.18	4.50
CPI	5.90	76.66	0.39	CPI	12.75	68.97	5.11	CPI	14.80	62.33	8.68
IPI	0.31	6.30	99.12	IPI	1.40	12.36	91.16	IPI	3.16	16.48	86.82

	48 Month Horizon				*60 Month Horizon*		
	Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	79.97	23.36	5.03	Oil Price	78.33	24.89	5.36
CPI	14.92	55.62	10.16	CPI	14.35	49.41	10.99
IPI	5.11	21.02	84.80	IPI	7.31	25.70	83.65

B. 1974 Sub-Sample

	12 Month Horizon				*24 Month Horizon*				*36 Month Horizon*		
	Forecast Variable:				Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	84.11	20.02	0.96	Oil Price	73.79	13.24	5.04	Oil Price	65.81	9.75	6.12
CPI	10.87	59.20	4.34	CPI	14.77	44.25	16.70	CPI	13.14	27.64	23.26
IPI	5.02	20.77	94.71	IPI	11.44	42.51	78.26	IPI	21.06	62.61	70.62

	48 Month Horizon				*60 Month Horizon*		
	Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	60.39	7.29	6.63	Oil Price	57.58	5.80	6.65
CPI	12.33	17.96	24.39	CPI	13.23	13.72	24.53
IPI	27.28	74.75	68.97	IPI	29.19	80.48	68.82

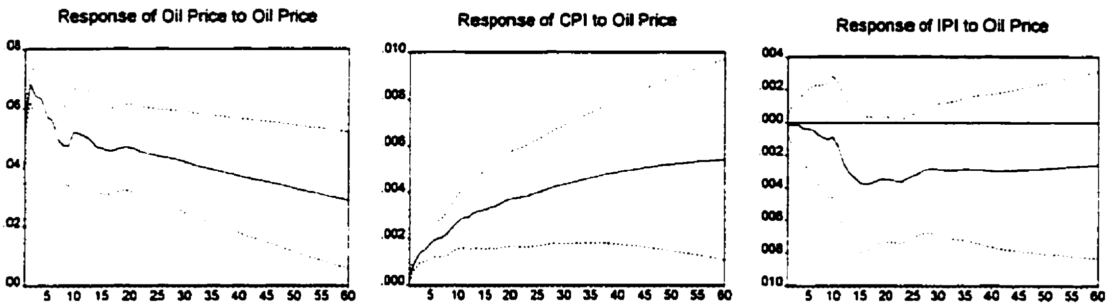
C. 1981 Sub-Sample

	12 Month Horizon				*24 Month Horizon*				*36 Month Horizon*		
	Forecast Variable:				Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	93.84	16.39	1.37	Oil Price	93.06	6.88	1.32	Oil Price	91.85	8.15	1.36
CPI	1.87	60.22	2.21	CPI	2.95	63.54	12.76	CPI	3.83	61.86	17.95
IPI	4.28	23.39	96.42	IPI	3.99	29.58	85.92	IPI	4.32	29.99	80.69

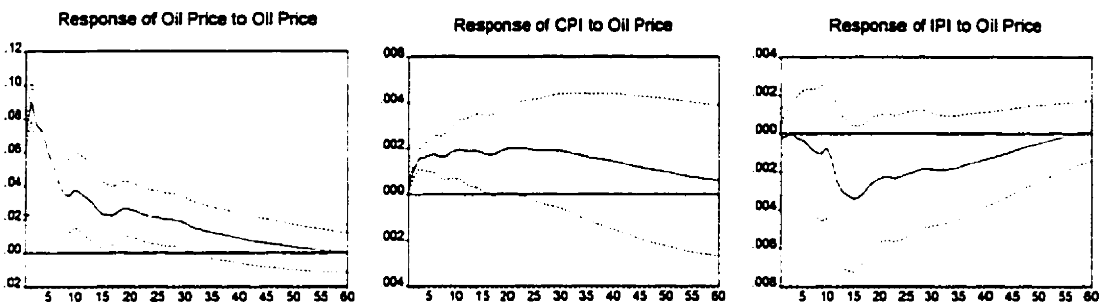
	48 Month Horizon				*60 Month Horizon*		
	Forecast Variable:				Forecast Variable:		
	Oil Price	CPI	IPI		Oil Price	CPI	IPI
Oil Price	91.43	12.93	2.17	Oil Price	91.32	17.40	2.87
CPI	3.92	57.59	17.97	CPI	4.02	53.87	17.96
IPI	4.65	29.48	79.86	IPI	4.66	28.73	79.17

Figure 4.7.1: Impulse Response Functions for the U.S. Data {Oil Price-CPI-IPI}

A. Full Sample



B. 1974 Sub-Sample



C. 1981 Sub-Sample

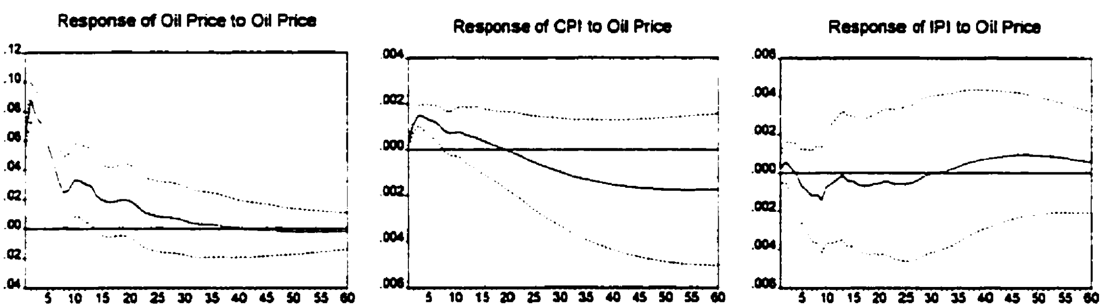


Table 4.8.1: p-values from the Multi-Equation Granger Causality Tests on the Canadian Data

A. Full Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	**0.004625**	0.24485
IPI	0.305383	0.501066

B. 1974 Sub-Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	**0.001073**	0.734466
IPI	0.437509	0.663176

C. 1981 Sub-Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	0.155286	0.944489
IPI	0.953793	0.914092

Table 4.8.2: Residual Correlation Matrix from the VAR on the Canadian Data

A. Full Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	0.004979	1.000000	
IPI	0.025151	-1.057120	1.000000

B. 1974 Sub-Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	-0.016641	1.000000	
IPI	0.036960	-0.092469	1.000000

C. 1981 Sub-Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	0.046200	1.000000	
IPI	-0.047650	-0.127880	1.000000

Table 4.8.3: Variance Decomposition for the Canadian Data {Oil Price-CPI-IPI}

A. Full Sample

12 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	94.20	16.90	0.90
CPI	3.40	79.70	4.85
IPI	2.39	3.40	94.25

24 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	86.92	24.91	4.25
CPI	5.27	62.48	14.69
IPI	7.81	12.61	81.07

36 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	82.36	28.70	4.85
CPI	5.18	46.46	21.47
IPI	12.45	24.84	73.68

48 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	77.90	29.94	5.16
CPI	4.45	33.14	24.73
IPI	17.65	36.92	70.11

60 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	73.42	29.42	5.35
CPI	3.91	23.31	26.36
IPI	22.67	47.26	68.28

B. 1974 Sub-Sample

12 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	94.98	21.07	1.21
CPI	2.83	77.56	14.45
IPI	2.20	1.37	84.35

24 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	93.59	30.24	9.19
CPI	2.49	59.98	35.98
IPI	3.93	9.78	54.83

36 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	93.53	35.00	12.99
CPI	2.28	43.10	38.44
IPI	4.19	21.90	48.57

48 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	93.45	36.67	14.16
CPI	2.22	32.71	37.50
IPI	4.33	30.62	48.35

60 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	93.48	37.25	13.83
CPI	2.03	27.62	38.71
IPI	4.32	35.13	47.46

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	96.74	15.81	1.78
CPI	0.51	83.90	22.38
IPI	2.75	0.29	75.84

24 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	95.67	11.89	8.36
CPI	1.03	86.13	36.08
IPI	3.30	1.98	55.55

36 Month Horizon

	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	95.81	10.97	9.79
CPI	1.00	75.17	36.90
IPI	3.19	13.86	53.31

48 Month Horizon

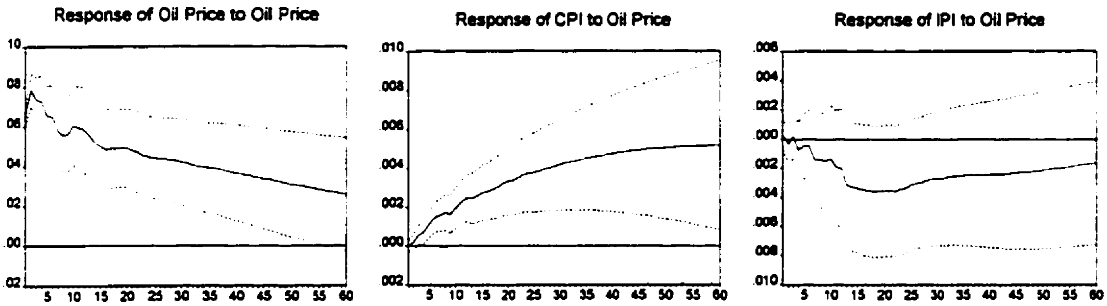
	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	95.80	16.08	10.11
CPI	1.05	59.08	37.85
IPI	3.15	24.83	52.04

60 Month Horizon

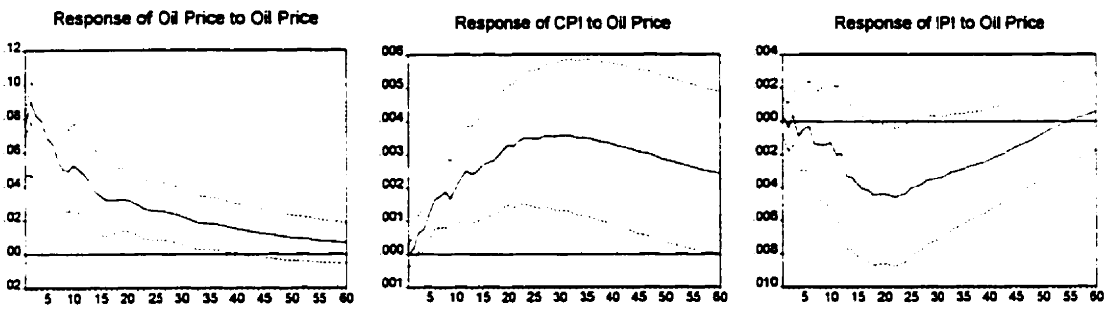
	Forecast Variable:		
	Oil Price	CPI	IPI
Oil Price	95.75	21.40	10.55
CPI	1.11	50.44	39.75
IPI	3.14	28.17	49.70

Figure 4.8.1: Impulse Response Functions for the Canadian Data {Oil Price-CPI-IPI}

A. Full Sample



B. 1974 Sub-Sample



C. 1981 Sub-Sample

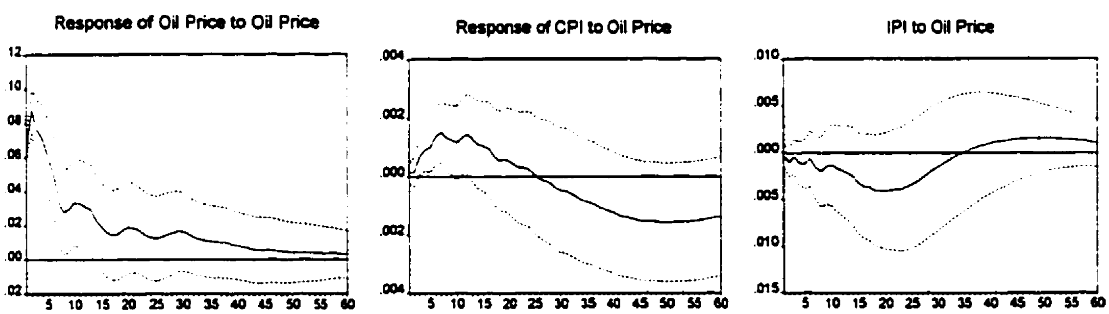


Table 4.9.1: p-values from the Multi-Equation Granger Causality Tests on the Mexican Data

A. Full Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	0.008883	0.016061
IPI	0.162297	0.071115

B. 1981 Sub-Sample

	Oil Price Granger Causes Variable	Variable Granger Causes Oil Price
Variable:		
CPI	0.027337	0.024305
IPI	0.720563	0.659744

Table 4.9.2: Residual Correlation Matrix from the VAR on the Mexican Data

A. Full Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	**0.229769**	1.000000	
IPI	-0.017051	-0.046962	1.000000

B. 1981 Sub-Sample

	Oil Price	CPI	IPI
Oil Price	1.000000		
CPI	**0.373873**	1.000000	
IPI	-0.020977	-0.041892	1.000000

Table 4.9.3: Variance Decomposition for the Mexican Data {Oil Price-CPI-IPI}

A. Full Sample

12 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	91.16	20.41	2.44
CPI	6.05	78.93	10.57
IPI	2.78	0.67	86.99

24 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	66.22	16.76	4.21
CPI	22.45	80.30	23.21
IPI	11.32	2.94	72.58

36 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	52.17	21.04	8.69
CPI	29.04	81.08	27.53
IPI	18.80	6.88	63.78

48 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	45.12	9.64	12.93
CPI	29.79	79.01	27.22
IPI	25.90	11.35	59.85

60 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	41.56	8.69	15.81
CPI	28.48	75.51	28.82
IPI	29.96	15.80	58.37

B. 1981 Sub-Sample

12 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	90.50	35.91	6.27
CPI	8.02	64.05	9.02
IPI	1.48	0.04	84.70

24 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	65.46	24.11	6.65
CPI	33.14	75.52	17.28
IPI	1.40	0.37	76.07

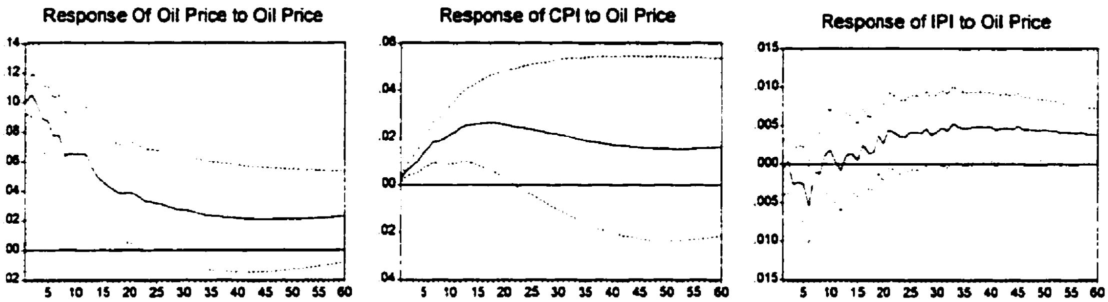
36 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	46.47	12.98	9.31
CPI	52.04	86.21	19.28
IPI	1.50	0.81	71.41

48 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	36.86	8.84	13.23
CPI	61.63	90.15	18.66
IPI	1.51	1.01	68.11

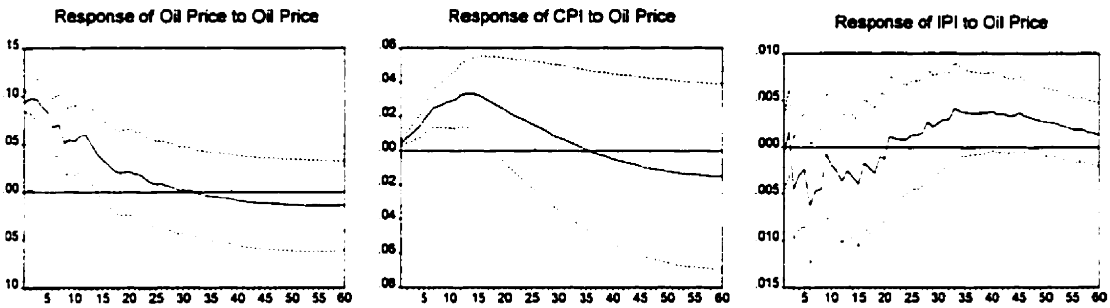
60 Month Horizon	Forecast Variable: Oil Price	CPI	IPI
Oil Price	32.24	7.69	14.28
CPI	66.30	91.25	20.39
IPI	1.46	1.06	65.33

Figure 4.9.1: Impulse Response Functions for the Mexican Data {Oil Price-CPI-IPI}

A. Full Sample



B. 1981 Sub-Sample



Chapter 5: Accounting for Oil Price Volatility

5.1 Introduction

Does the volatility of oil prices have any bearing on the effect of oil price shocks on the economy? The theory behind this question revolves around expectations. Theoretically, an expected oil price shock should have less of an effect on the economy than would an unexpected shock, as an expected shock would allow the economy time to prepare for the shock while an unexpected shock would catch the economy off guard. Taking this argument one step further, it seems consistent that an oil price shock in a period of relatively stable oil prices would be less expected than an oil price shock during a period of oil price volatility. If the expectations argument holds, then an oil price shock should have less of an effect on the economy when prices are volatile than when prices are relatively stable.

The model that will be used in this chapter to account for oil price volatility will be a generalized autoregressive conditional heteroscedasticity (GARCH) model. As with the previous chapter, the effects of oil price volatility on the macroeconomic variables considered will be done in the context of both the single equation approach and the multi-equation approach. The results of the single equation approach will follow a brief discussion on ARCH and GARCH models, the method that will be used to determine the volatility of the oil price shocks. The results from the single equation approach will be followed by the results from the multi-equation VAR approach.

5.2 Estimating Volatility: The ARCH Model

One way to incorporate the recent volatility or stability of oil prices into the analysis is through the use of an autoregressive conditional heteroscedasticity (ARCH) model. This allows us to model the conditional variance (i.e. the variance conditional upon realized values of the independent variables). In the case of an ARCH model, the model estimates both the mean of the dependent variable and the conditional variance. That is, the ARCH model estimates the equation

(1) $$y_t = \lambda x_t + \varepsilon_t$$

where x_t represents a vector of independent variables on which forecasts of y_t are based and ε_t is assumed to have a mean of zero and a conditional variance σ_t^2 where

(2) $$\sigma_t^2 = \phi + \alpha\varepsilon_{t-1}^2$$

This is referred to as an ARCH(1) model because the conditional variance has only one lag of the error term. In times of volatile price movements, the conditional variance will be higher than in period of relatively stable prices. However, we are not only interested in the actual volatility, but whether the actual volatility is anticipated or unanticipated. The expectation is that the unanticipated portion of the actual volatility will have more of an effect on the economy than the anticipated.

A variation of the ARCH model is the generalized ARCH (GARCH) model in which the conditional variance of e_t is an ARMA process. That is

(3) $$\sigma_t^2 = \phi + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

This study will use a GARCH(1,1) process to estimate the anticipated and unanticipated volatility of the growth rate of oil prices. The mean equation for the change in the oil price includes only a constant and lagged observations of the dependent variable, as suggested in Lee, Ni and Rotti (1995). The lag length for the dependent variable in the mean equation will be selected by minimizing the Schwartz Criterion (SC). The anticipated volatility will be represented by the conditional variance σ_t^2. The unanticipated component of the oil price growth rate is represented by the error term ε_t. However, this term on its own does not reflect changes in the conditional variance over time. Therefore, the error term will be normalized (or standardized) by the conditional variance, such that the unanticipated volatility of the oil price will be represented by $\hat{\varepsilon}_t / \hat{\sigma}_t$. This term can also be used to represent the volatility-corrected unanticipated price shock.

5.3 Single Equation Results from the U.S. Data

Table 5.3.1 shows the estimates of the GARCH(1,1) model for the U.S. data. For the full sample and the 1974 sub-sample, the SC was minimized with one lag of the dependent variable. For the 1981 sub-sample, the SC was minimized when two lags of the oil price change were used. As this table shows, the ARCH and GARCH parameters are significant in all three of the samples considered.

To establish the relationship between the macroeconomic variables considered earlier and the anticipated and unanticipated volatility in the oil price changes, a single equation approach is used. This is done twice for each sample: once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included. Table 5.3.2 shows the results of the regressions for the different sample periods when the effects of the unanticipated volatility are treated symmetrically. When the IPI is the dependent variable (Parts A-C), only the third lag of the anticipated volatility seems to have any significant effect, other than the lags of the IPI, in the full sample. Using the 1974 sample, only the third lag of the anticipated volatility measure seems to be significant. In the 1981 sample, none of the volatility measures, anticipated or unanticipated, seems to have any significant effect. When the CPI is the dependent variable (Parts D-F), none of the volatility measures seems to be significant in the full sample. Using the 1974 sample, the first lag of the unanticipated volatility measure seems to be significant, while the first and third lags of the unanticipated volatility measure seems to be significant when the 1981 sample is studied.

Table 5.3.3 shows the results of the single equation regressions when the oil price shocks are treated asymmetrically. In this case, the positive and negative error terms from the mean equation of the GARCH(1,1) system, standardized by the conditional variance, are separated. Using the IPI as the dependent variable, the regression of the full sample seems to indicate that the second lag of the positive unanticipated volatility measure and the fourth lag of the anticipated volatility measure used are significant. The second lag of the positive unanticipated volatility measure also seems to be significant when the 1974 sample is used, as are the second and third lags of the anticipated volatility measures. None of the volatility measures seem to be significant when the 1981 sample is used. When the CPI is the dependent variable, the first lag of the negative unanticipated volatility measure in all three samples seems to be significant. As well, when the 1981 sample is used, the first lag of the positive unanticipated volatility measure seems to be significant.

Table 5.3.4 shows the results of selected parameter tests from the single equation regressions assuming symmetric price effects. The first two columns show the p-values of Granger causality tests of the unanticipated and anticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the anticipated and unanticipated volatility effects. The null hypothesis that the unanticipated volatility does not Granger cause the CPI is rejected only for the 1974 and the 1981 samples. The remainder of null hypotheses of no Granger causality can not be rejected at the 5% level. The null hypotheses of symmetry between the anticipated and unanticipated volatility measures can not be rejected for any of the regression equations.

Table 5.3.5 shows the results of selected parameter tests from the single equation regressions with the assumption of symmetric price effects relaxed. The first two columns show the p-values of Granger causality tests of the positive and negative unanticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the positive and negative unanticipated volatility effects. Only the null hypothesis that the positive unanticipated volatility measures do not Granger cause the IPI for the 1974 sample and the negative unanticipated volatility measures do not Granger cause the CPI for the 1974 sample can be rejected at the 5% level. As well, the null hypothesis of symmetry between the positive and negative unanticipated volatility measures can be rejected for the regression equation with the CPI as the dependent variable using the 1981 sample.

5.4 Single Equation Results from the Canadian Data

Table 5.4.1 shows the estimates of the GARCH(1,1) model for the Canadian data. For the full sample, the SC was minimized with one lag of the dependent variable. For the 1974 and 1981 sub-samples, the SC was minimized when two lags of the oil price change were used. As this table shows, the ARCH and GARCH parameters are significant in all three of the samples considered.

As with the U.S. data, to establish the relationship between the Canadian macroeconomic variables considered earlier and the anticipated and unanticipated volatility in the oil price changes, a single equation approach is used. This is done twice for each sample: once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included. Table 5.4.2 shows the results of the regressions for the different sample periods when the effects of the unanticipated volatility are treated symmetrically. That is, a positive oil price shock is assumed to have the same effect as a negative oil price shock. This table indicates several interesting characteristics. When the IPI is the dependent variable (Parts A-C), only the third lag of the anticipated volatility seems to have any significant effect, other than the lags of the IPI, in the full and 1974 samples. In the 1981 sample, none of the volatility measures, anticipated or unanticipated, seems to have any significant effect. When the CPI is the dependent variable (Parts D-F), none of the volatility measures seems to be significant in the full sample. Using the 1974 sample, the second lag of the unanticipated volatility measure seems to be significant, while only the fourth lag of the anticipated volatility measure seems to be significant when the 1981 sample is studied.

Table 5.4.3 shows the results of the single equation regressions when the oil price shocks are treated asymmetrically. As with the U.S. data, the positive and negative error terms from the mean equation of the GARCH(1,1) system, standardized by the conditional variance, are separated. Using the IPI as the dependent variable, the regression of the full sample seems to indicate that none of the volatility measures used are significant. The first lag of the positive unanticipated volatility measure seems to be significant when both the 1974 and 1981 samples are used. As well, when the 1974 sample is used, the third lag of the anticipated volatility measure is again significant. When the CPI is the dependent variable, the fourth lag of the anticipated volatility measure in the 1981 sample is the only volatility measure that seems to be significant.

Table 5.4.4 shows the results of selected parameter tests from the single equation regressions assuming symmetric price effects. The first two columns show the p-values of Granger causality tests of the unanticipated and anticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the anticipated and unanticipated volatility effects. The null hypotheses that either the anticipated or unanticipated volatility measures do not Granger cause the CPI or IPI can not be rejected at the 5% level for all of the sample periods. As well, the null hypothesis of symmetry between the anticipated and unanticipated volatility measures can not be rejected for any of the regression equations.

Table 5.4.5 shows the results of selected parameter tests from the single equation regressions with the assumption of symmetric price effects relaxed. The first two columns show the p-values of Granger causality tests of the positive and negative unanticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the positive and negative unanticipated volatility effects. The null hypotheses that either the positive or negative unanticipated volatility measures do not Granger cause the CPI or IPI can not be rejected at the 5% level for all of the sample periods. As well, the null hypothesis of symmetry between the positive and negative unanticipated volatility measures can not be rejected for any of the regression equations.

5.5 Single Equation Results from the Mexican Data

Table 5.5.1 shows the estimates of the GARCH(1,1) model for the Mexican data. For both the full sample and the 1981 sub-sample, the SC was minimized when no lags of the oil price change were used, that is, when the change in the oil price was regressed only on a constant. As this table shows, the ARCH and GARCH parameters are significant in the 1981 sample. Although the GARCH parameter is significant when the full sample is used, the significance of the ARCH parameter is borderline.

To establish the relationship between the Mexican macroeconomic variables considered earlier and the anticipated and unanticipated volatility in the oil price changes, a single equation approach is used. This is done twice for each sample: once with the IPI as the dependent variable and once with the CPI as the dependent variable. In each of the equations, 4 lags of each variable, including the dependent variable, are included. Table 5.5.2 shows the results of the regressions for the different sample periods when the effects of the unanticipated volatility are treated symmetrically. None of the volatility measures, anticipated or unanticipated, seem to be significant using the full sample when either the IPI or the CPI is the dependent variable (Parts A&C). Nor does either of the volatility measures seem to be significant using the 1981 sample when the IPI is the dependent variable (Part B). In the 1981 sample when the CPI is the dependent variable (Part D), however, the last two lags of the anticipated volatility measures seem to be significant.

Table 5.5.3 shows the results of the single equation regressions when the oil price shocks are treated asymmetrically. That is, the positive and negative error terms from the mean equation of the GARCH(1,1) system, standardized by the conditional variance, are separated. Using the IPI as the dependent variable, the regressions of both the full sample and the 1981 sample seem to indicate that the second lag of the positive unanticipated volatility is significant. When the CPI is the dependent variable, the fourth lag of the positive unanticipated volatility measure and the last two lags of the anticipated volatility measures in both samples seem to be significant. As well, when the full sample is used, the second lag of the anticipated volatility measure also seems to be significant.

Table 5.5.4 shows the results of selected parameter tests from the single equation regressions assuming symmetric price effects. As with the U.S. and Canadian data, the first two columns show the p-values of Granger causality tests of the unanticipated and anticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the anticipated and unanticipated volatility effects. The null hypothesis that the anticipated volatility does not Granger cause the CPI is rejected only for the 1981 sample. The null hypotheses of no Granger causality from the anticipated volatility measure to the CPI using the full sample and from the unanticipated volatility measure to either the IPI or the CPI in the full sample and the 1981 sample can not be rejected at the 5% level. The null hypothesis of symmetry between the anticipated and unanticipated volatility measures is rejected only for the regression equation with the CPI as the dependent variable using the 1981 sample.

Table 5.5.5 shows the results of selected parameter tests from the single equation regressions with the assumption of symmetric price effects relaxed. The first two columns show the p-values of Granger causality tests of the positive and negative unanticipated volatility measures respectively. The third column shows the p-values associated with the test for symmetry between the positive and negative unanticipated volatility effects. Only the null hypothesis that the positive unanticipated volatility does not Granger cause the CPI for the full sample and the 1981 sample can be rejected at the 5% level. The null hypothesis of symmetry between the positive and negative unanticipated volatility measures can not be rejected for any of the regression equations.

5.6 The Multi-Equation Approach

The effects of unanticipated price shock, as well as unanticipated positive and negative price shocks was also tested in the context of the VAR. The unanticipated price shock measures generated through the GARCH(1,1) model were placed in a VAR along with the change in the log of the CPI and the change of the log of the IPI. A second set of VAR's was generated which included the CPI and the IPI as well as the positive and negative price shocks, which were generated from the GARCH(1,1) model. This followed the procedure found in Lee, Ni and Rotti (1996). As in the previous chapter, the VARs were used to perform Granger causality tests as well as to generate the impulse response functions and variance decompositions.

5.7 Multi-Equation Results from the U.S. Data

As with the previous analysis, three sets of tests were performed on the data for the United States: one using the full sample beginning in 1947, one using the sub-sample beginning in January 1974 and one using the sub-sample beginning in January 1981.

5.7.1 Granger Causality Tests

Table 5.7.1 shows the results of the Granger causality tests for the U.S. data when the three different samples are used. According to this table, the p-values indicate that the null hypothesis that the change in the unanticipated shock in the oil price does not Granger cause the change in the CPI is rejected using the 1974 and 1981 sub-samples, although this null hypothesis cannot be rejected for the full sample. The null hypothesis that the unanticipated shock in the oil price does not Granger cause the IPI cannot be rejected in any of the three samples. As well, the null hypotheses that either the IPI or the CPI do not Granger cause the unanticipated shock in the oil price cannot be rejected for all three samples. As Table 5.7.2 shows, when the unanticipated price shocks are treated asymmetrically, that is, separated into positive and negative shocks, only the null hypothesis that the negative price shock does not Granger cause the CPI for the 1981 sample can be rejected. No other Granger causality is found.

5.7.2 Variance Decomposition

The correlation matrices for the error terms from the VAR on the U.S. data for the three different sample periods are presented in Table 5.7.3 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). This table indicates that the correlation between the unanticipated price shock and the CPI exceeds the 0.2 mark, which would suggest that the ordering might matter when calculating the variance decompositions in all three samples. The correlation matrices for the error terms when the positive and negative price shocks are treated asymmetrically are shown in Table 5.7.4. This table indicates that the correlation between the CPI and the positive price shock exceeds 0.2 for the full and the 1981 samples. As well, the correlation between the positive and negative price shocks exceeds 0.2 for the 1974 and 1981 samples.

Table 5.7.5 shows the variance decomposition for the U.S. data at five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months when the effects of price shocks are assumed to be symmetric. Although the correlation coefficient between the unanticipated price shock and the CPI was above 0.2 for the 1974 and 1981 sub-samples, calculating the variance decompositions for the different orderings produced no significant difference. Therefore, only the variance decomposition for the {Unanticipated Price Shock-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The unanticipated price shock explains the bulk of the forecast variance in the CPI growth rate that is not explained by the CPI, although this is still only about 12%.

Part B of Table 5.7.5 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The forecast variance of the CPI declines significantly more than in the full sample. For the first two time horizons, the unanticipated price shock dominates the IPI in explaining the CPI, although over the last three time horizons, they are almost equivalent. The CPI dominates the unanticipated price shock in explaining the forecast variance of the IPI in all but the 24-month horizon.

The results for the sub-sample beginning in 1981, shown in Part C of Table 5.7.5, are similar to the results for the full sample, in that the portion of the forecast variance of the unanticipated price shock and the IPI explained by the forecast variable is very high and that a significant portion of the forecast variance of the CPI is explained by either the unanticipated price shock or the IPI. In this case, however, the unanticipated price shock significantly dominates the IPI in explaining the forecast variance of the CPI for all of the time horizons considered. As well, the unanticipated price shock dominates the CPI in explaining the forecast variance of the IPI for all five of the time horizons shown.

Table 5.7.6 shows the variance decomposition for the U.S. data for the five different time horizons when the effects of price shocks are assumed to be asymmetric. Although some of the correlation coefficients between the error terms were found to be above 0.2, calculating the variance decompositions for the different orderings produced no significant difference. Therefore, only the variance decomposition for the {Positive Price Shock- Negative Price Shock-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The positive price shock dominates the negative price shock and the IPI in explaining the portion of the forecast variance in the CPI growth rate which is not explained by the CPI, although this is still under 12%.

Part B of Table 5.7.6 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The forecast variance of the CPI declines significantly more than in the full sample. For this sample, it is the negative price shock that dominates the positive price shock and the IPI in explaining the forecast variance of the CPI. The CPI dominates both the positive and negative price shocks in explaining the forecast variance of the IPI in all time horizons shown.

The results for the sub-sample beginning in 1981, shown in Part C of Table 5.7.6, are similar to the results for the full sample, in that the positive price shock dominates the negative price shock and the IPI in explaining the forecast variance of the CPI. One difference is that for this sample, the positive price shock also dominates the negative price shock and the CPI in explaining the forecast variance of the IPI.

One common thread in all three of the samples is that the bulk of the change in the forecast variances seems to occur within the first year, regardless of whether the price shocks are treated symmetrically or asymmetrically.

5.7.3 Impulse Response Functions

Figure 5.7.1 shows the impulse response functions for the different sample periods when the price shocks are treated symmetrically. Again, as with the variance decompositions, because the correlation between the unanticipated price shock and the CPI was greater than 0.2 the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {Unanticipated Price Shock-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to an unanticipated price shock when the full sample is used. The response of the CPI to an unanticipated price shock seems to be positive and significant for the first year. The IPI shows a mainly negative response that seems to be significant only at about the twelfth month.

The impulse response functions are similar when the 1974 sub-sample is considered, as Part B of Figure 5.7.1 shows. The response of the CPI to an unanticipated price shock is again positive, but does not seem to be significant past the third month. The response of the IPI is again predominantly negative following a shock to the unanticipated price shock, although this does not appear to be significant throughout the sixty-month period.

As Part C of Figure 5.7.1 shows, the impulse response functions generated when the sub-sample beginning in 1981 is used are again similar in the patterns. The response of the CPI to an unanticipated price shock is positive for the first three months, but then no longer appears to be significant. The response of the IPI to an unanticipated price shock is again predominantly negative and does not appear to be significant, except, perhaps, at the fifth month.

Figure 5.7.2 shows the impulse response functions for the different sample periods when the price shocks are treated asymmetrically. Again, as with the variance decompositions, because some of the correlations between the error terms were greater than 0.2 the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {Positive Price Shock- Negative Price Shock -CPI-IPI} ordering is shown. Part A of this figure shows the response of the four variables to a positive price shock when the full sample is used. The response of the CPI to a positive price shock seems to be positive and significant for about the first year. The IPI shows a mainly negative response that seems to be significant only at about the twelfth month. Part B of this figure indicates that the CPI responds negatively to a negative price shock, although the effect seems to be significant only at the two-month mark. The response of the IPI to a negative price shock seems to be predominantly negative, although it does not appear to be significant at any time. The difference in the responses to positive and negative price shocks when the full sample is considered adds support to the hypothesis of asymmetric price effects.

The impulse response functions when the 1974 sub-sample is considered are shown in Parts C and D of Figure 5.7.2. As Part C indicates, the response of the CPI to a positive price shock is again positive, but does not seem to be significant past the third month. The response of the IPI is again predominantly negative following a shock to the positive price shock, although does not appear to be significant throughout the sixty-month period. Part D indicates that the response of the CPI to innovations in the negative price shocks when the 1974 sample is used is similar to the full sample response, although the response between the 16th month and the two-year mark now appears to be significant. The response of the IPI to a negative price shock is again predominantly negative, although for this sample, the response seems to be significant at the second, third and sixth months.

As Parts E and F of Figure 5.7.2 shows, the impulse response functions generated when the sub-sample beginning in 1981 is used are again similar in the patterns. According to Part E, the response of the CPI to a positive price shock is positive for the first three months, but then no longer appears to be significant. The response of the IPI to a positive price shock is initially negative and does not appear to be significant, except, perhaps, at the fifth month. The response of the CPI to an innovation in the negative price shock is negative for the first three months, but then no longer appears to be significant, as shown in Part F. This impulse response appears to be more like the mirror image of the response to a positive shock we would expect if the effects were symmetric. The response of the IPI to a negative price shock appears to oscillate between positive and negative, although it does not seem to be significant at any time. There still seems to be some indication of asymmetric effects on the IPI.

5.8 Multi-Equation Results from the Canadian Data

As with the previous analysis, three sets of tests were also performed on the Canadian data: one using the full sample beginning in 1961, one using the sub-sample beginning in January 1974 and one using the sub-sample beginning in January 1981.

5.8.1 Granger Causality Tests

Table 5.8.1 shows the results of the Granger causality tests for the Canadian data when the three different samples are used. According to this table, the p-values indicate that the null hypothesis that the change in the unanticipated shock in the oil price does not Granger cause the change in the CPI cannot be rejected for any of the samples. As well, the null hypothesis that the unanticipated shock in the oil price does not Granger cause the IPI cannot be rejected in any of the three samples. Finally, the null hypotheses that either the IPI or the CPI do not Granger cause the unanticipated shock in the oil price are rejected for all three samples. As Table 5.8.2 indicates, the null hypotheses of no Granger causality cannot be rejected in any of the cases when the unanticipated price shocks are separated into positive and negative shocks.

5.8.2 Variance Decomposition

The correlation matrices for the error terms from the VAR on the Canadian data, assuming symmetric effects, for the three different sample periods are presented in Table 5.8.3 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). This table indicates that none of the correlations between the error terms exceed the 0.2 mark, suggesting that the ordering does not matter when calculating the variance decompositions in all three samples. Table 5.8.4 shows the correlations between the error terms when the effects of price shocks are assumed to be asymmetric. As this table indicates, the correlation between the positive and negative price shocks exceeds 0.2 in all three of the samples, indicating that the ordering may matter.

Table 5.8.5 shows the variance decomposition for the Canadian data at five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months when the effects of price shocks are assumed to be symmetric. Given that none of the correlation coefficients between the error terms were above 0.2, only the variance decomposition for the {Unanticipated Price Shock-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The unanticipated price shock explains the bulk of the forecast variance in the CPI growth rate that is not explained by the CPI, although this is still only about 8%.

Part B of Table 5.8.5 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The forecast variance of the CPI declines slightly more than in the full sample. As with the full sample, the unanticipated price shock dominates the IPI in explaining the CPI.

The results for the sub-sample beginning in 1981, shown in Part C of Table 5.8.5, are again similar to the results for the full and 1974 samples. The unanticipated price shock dominates the IPI in explaining the forecast variance of the CPI for all of the time horizons considered. One difference in this sample is that the CPI dominates the unanticipated price shock in explaining the forecast variance of the IPI for all five of the time horizons shown.

Table 5.8.6 shows the variance decomposition for the Canadian data at five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months when the effects of price shocks are assumed to be asymmetric. Given that the correlation coefficients between positive and negative price shocks were above 0.2, different orderings of the variables were used to generate the variance decompositions. However, because these different orderings did not show any significant difference, only the variance decomposition for the {Positive Price Shock-Negative Price Shock-CPI-IPI} ordering is shown for the three different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The positive price shock dominates the negative price shock and IPI in explaining the portion of the forecast variance in the CPI growth rate that is not explained by the CPI.

Part B of Table 5.8.6 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1974 is considered. The forecast variance of the CPI declines significantly more than in the full sample. Again, it is the positive price shock that dominates the negative price shock and the IPI in explaining the forecast variance of the CPI. The positive price shock also dominates the negative price shocks and the CPI in explaining the forecast variance of the IPI in all time horizons shown.

The results for the sub-sample beginning in 1981, shown in Part C of Table 5.8.6, are similar to the results for the full and 1974 samples in that the positive price shock dominates the negative price shock and the IPI in explaining the forecast variance of the CPI. As with the 1974 sample, the positive price shock also dominates the negative price shock and the CPI in explaining the forecast variance of the IPI.

As with the U.S. data, in all three of the samples for the Canadian data the bulk of the change in the forecast variances seems to occur within the first year, regardless of whether the price shocks are treated symmetrically or asymmetrically.

5.8.3 Impulse Response Functions

Figure 5.8.1 shows the impulse response functions for the different sample periods when the price shocks are treated symmetrically. Because none of the correlations between the error terms was greater than 0.2, only the {Unanticipated Price Shock-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to an unanticipated price shock when the full sample is used. The response of the CPI to an unanticipated price shock seems to be positive, although it only seems to be significant at about the one-year mark. The IPI shows a mainly negative response that seems to be significant only at about the twelfth month.

The impulse response functions are similar when the 1974 sub-sample is considered, as Part B of Figure 5.8.1 shows. The response of the CPI to an unanticipated price shock is again positive and appears to be periodically significant through the first two years. The response of the IPI oscillates between a positive and negative effect following a shock to the unanticipated price shock, although this does not appear to be significant throughout the sixty-month period.

As Part C of Figure 5.8.1 shows, the impulse response functions generated when the sub-sample beginning in 1981 is used are again similar in the patterns. The response of the CPI to an unanticipated price shock is predominantly positive, although only appears to be significant at the three-month mark. The response of the IPI to an unanticipated price shock is similar in pattern and significance to the effect using the 1974 sample.

Figure 5.8.2 shows the impulse response functions for the different sample periods when the price shocks are treated asymmetrically. Again, as with the variance decompositions, because the correlations between the positive and negative price shocks were greater than 0.2 the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {Positive Price Shock- Negative Price Shock-CPI-IPI} ordering is shown. Part A of this figure shows the response of the four variables to a positive price shock when the full sample is used. The response of the CPI to a positive price shock seems to be positive, although it only appears to be significant at about the one-year mark. The IPI shows a mainly negative response that seems to be significant only at about the fourteenth month. Part B of this figure indicates that the CPI responds negatively to a negative price shock, although the effect does not seem to be significant at all during the sixty months shown. The response of the IPI to a negative price shock seems to be predominantly negative and significant at about the six-month mark. The difference in the responses to positive and negative price shocks when the full sample is considered adds support to the hypothesis of asymmetric price effects on the IPI. Although the magnitude and significance of the responses of the CPI may suggest asymmetry, the direction and general pattern of the responses may actually suggest a symmetric response to positive and negative price shocks.

The impulse response functions when the 1974 sub-sample is considered are shown in Parts C and D of Figure 5.8.2. As Part C indicates, the response of the CPI to a positive price shock is again positive and only seems to be significant in the twelfth month. The response of the IPI suggests a negative effect following a positive price shock that appears to be significant in the second and fourth months. Part D indicates that the response of the CPI to innovations in the negative price shocks when the 1974 sample is used is similar to the full sample response. The response of the IPI to a negative price shock is again predominantly negative and seems to be significant only at the sixth month.

As Parts E and F of Figure 5.8.2 shows, the impulse response functions generated when the sub-sample beginning in 1981 is used are again similar in the patterns. According to Part E, the response of the CPI to a positive price shock is positive and appears to be significant in the third and sixth months. The response of the IPI to an positive price shock is initially negative and appears to be significant at the second and fourth months. The response of the CPI to an innovation in the negative price shock is negative but does not appear to be significant. The response of the IPI to a negative price shock appears to oscillate between positive and negative, although again only seems to be significant at the six-month mark. There still seems to be some indication of asymmetric effects on both the CPI and the IPI.

5.9 Multi-Equation Results from the Mexican Data

Only two sets of analyses were performed on the data for Mexico. As suggested in the previous analysis, because the full sample begins in April 1972, there did not seem to be enough data in the pre 1974 sub-sample to warrant performing the analyses on the sub-sample beginning in 1975.

5.9.1 Granger Causality Tests

Table 5.9.1 shows the results of the Granger causality tests for the Mexican data when the two different samples are used. According to this table, the p-values indicate that the null hypothesis that the change in the unanticipated shock in the oil price does not Granger cause the change in the CPI can be rejected only for the full sample. As well, the null hypothesis that the unanticipated shock in the oil price does not Granger cause the IPI cannot be rejected in either of the samples. Finally, the null hypotheses that either the IPI or the CPI do not Granger cause the unanticipated shock in the oil price are rejected for both samples. As Table 5.9.2 indicates, the null hypotheses of no Granger causality cannot be rejected in any of the cases when the unanticipated price shocks are separated into positive and negative shocks.

5.9.2 Variance Decomposition

The correlation matrices for the error terms from the VAR on the Mexican data, assuming symmetric effects, for the two different sample periods are presented in Table 5.9.3 (only the lower triangular part of each matrix is presented due to the symmetry of the matrices). This table indicates that the correlation between the unanticipated price shock and the CPI exceeds 0.2 for both samples, suggesting that the ordering may matter when calculating the variance decompositions in all three samples. Table 5.9.4 shows the correlations between the error terms when the effects of price shocks are assumed to be asymmetric. As this table indicates, the correlation between the positive price shock and the negative price shock, as well as the correlation between the positive price shock and the CPI exceed 0.2 for both samples, indicating again that the ordering may matter.

Table 5.9.5 shows the variance decomposition for the Mexican data at five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months when the effects of price shocks are assumed to be symmetric. Although the correlation coefficients between the unanticipated price shock and the CPI were above 0.2, using different orderings of the variables produced no significant difference in the variance decompositions. Therefore, only the variance decomposition for the {Unanticipated Price Shock-CPI-IPI} ordering is shown for the two different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The unanticipated price shock explains the bulk of the forecast variance in the CPI growth rate that is not explained by the CPI. The CPI tends to dominate the unanticipated price shock in explaining the forecast variance of the IPI.

Part B of Table 5.9.5 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1981 is considered. The results are almost identical to the decompositions found using the full sample: the unanticipated price shock dominates the IPI in explaining the forecast variance of the CPI, while the CPI dominates the unanticipated price shock in explaining the forecast variance of the IPI.

Table 5.9.6 shows the variance decomposition for the Mexican data at five different time horizons: twelve months, twenty-four months, thirty-six months, forty-eight months and sixty months when the effects of price shocks are assumed to be asymmetric. Given the correlation coefficients between positive and negative price and shocks and between the positive price shock and the CPI were above 0.2, different orderings of the variables were used to generate the variance decompositions. However, because these different orderings did not show any significant difference, only the variance decomposition for the {Positive Price Shock-Negative Price Shock-CPI-IPI} ordering is shown for the two different sample periods. Part A of this table indicates that when the full sample is considered, each variable explains the majority of its own forecast variance for every time horizon. The positive price shock dominates the negative price shock and IPI in explaining the portion of the forecast variance in the CPI growth rate that is not explained by the CPI. The CPI dominates both the positive and negative price shocks in explaining the forecast variance of the IPI. Part B of Table 5.9.6 shows the variance decomposition at the different time horizons when the sub-sample beginning in 1981 is considered. The results are almost identical to those from the full sample.

As with the U.S. and the Canadian data, in both of the samples for the Mexican data the majority of the change in the forecast variances seems to occur within the first year, regardless of whether the price shocks are treated symmetrically or asymmetrically.

5.9.3 Impulse Response Functions

Figure 5.9.1 shows the impulse response functions for the different sample periods when the price shocks are treated symmetrically. As with the variance decompositions, different orderings produced no significant differences in the results and therefore only the {Unanticipated Price Shock-CPI-IPI} ordering is shown. Part A of this figure shows the response of the three variables to an unanticipated price shock when the full sample is used. The response of the CPI to an unanticipated price shock seems to be positive and seems to be significant for the first year. The IPI shows a mainly negative response that seems to be significant only at about the third month.

The impulse response functions are similar when the 1981 sub-sample is considered, as Part B of Figure 5.9.1 shows. The response of the CPI to an unanticipated price shock is again positive and appears to be significant through the first year. The response of the IPI is again predominantly negative and does not appear to be significant except in the third month.

Figure 5.9.2 shows the impulse response functions for the different sample periods when the price shocks are treated asymmetrically. Again, as with the variance decompositions, because the correlations between the positive and negative price shocks were greater than 0.2 the impulse response functions were generated using the different orderings of the variables. Because there was very little difference in the impulse response functions, only the {Positive Price Shock- Negative Price Shock -CPI-IPI} ordering is shown. Part A of this figure shows the response of the four variables to a positive price shock when the full sample is used. The response of the CPI to a positive price shock seems to be positive and appears to be significant at about the one-year mark. The IPI shows a mainly negative response that does not seem to be significant throughout the sixty-month period. Part B of this figure indicates that the CPI responds negatively to a negative price shock, although the effect does not seem to be significant at all during the sixty months shown. The response of the IPI to a negative price shock, as with the response to a positive price shock, seems to be predominantly negative although does not appear to be significant. The difference in the responses to positive and negative price shocks when the full sample is considered adds support to the hypothesis of asymmetric price effects on both the CPI and the IPI.

The impulse response functions when the 1981 sub-sample is considered, as shown in Parts C and D of Figure 5.9.2, are almost identical to the responses when the full sample is considered. As Part C indicates, the response of the CPI to a positive price shock is again positive and only seems to be significant for the majority of the first year. The response of the IPI suggests a negative effect following a positive price shock that appears to be significant only in the third month. Part D indicates that the response of the CPI to innovations in the negative price shocks is negative but does not appear to be significant. The response of the IPI to a negative price shock is again predominantly negative although it does not seem to be significant.

5.10 Conclusion

The question of whether the volatility of oil prices has any effect on the growth rate of the CPI and the IPI was studied in this chapter. A GARCH(1,1) model was used to calculate the anticipated and unanticipated volatility of oil prices. The unanticipated price shocks were also separated into positive and negative shocks in order to test for asymmetry in the macroeconomic effects. A single equation approach and a multi-equation approach similar to the previous chapter were used in this analysis. The same three samples were again used for the U.S. and Canadian data. The analysis was again run only twice for the Mexican data, on the full sample and the 1981 sub-sample.

The single equation approach entailed estimating regressions in which the growth rate of either the CPI or the IPI was the dependent variable and the anticipated and unanticipated volatility measures were the independent variables. The regressions were first run assuming symmetric price effects. A second set of regressions was run which relaxed the assumption of symmetry. Tests for Granger causality from the anticipated and unanticipated volatility to the growth rate of the macroeconomic variables were performed, as were tests for symmetry between the anticipated and unanticipated volatility and between the positive and negative price shocks. The results of the single equation analysis on the U.S. data tended to suggest that the anticipated volatility shows a significant effect on the IPI while the unanticipated volatility has a significant impact on the CPI when the positive and negative price shocks are treated symmetrically. When the price shocks are treated asymmetrically, the results tend to suggest that the negative price shocks have a significant effect on the CPI. There is also some suggestion that the price effects are in fact asymmetric, at least in the 1981 sample. There is, however, considerable ambiguity in the results. The results for the Canadian data seem to suggest that the volatility, whether anticipated or unanticipated, has little effect on the growth rates of the CPI and IPI. There is also little suggestion in the single equation results of any asymmetry between the positive and negative price shocks. The results for Mexico suggest that the anticipated volatility has some effect on the CPI, although there is also some suggestion that the positive price shocks affect both the CPI and the IPI.

For the multi-equation approach, Granger causality tests were performed on a model that included the unanticipated price shocks, the CPI and the IPI. Vector autoregressions were run on the variables to generate the impulse response functions and the variance decompositions. Similar to the single equation approach, the VAR's were run first assuming symmetric price effects and again with the assumption of symmetry relaxed. The results tended to vary based on the country and the sample used. Although the results for the U.S. assuming symmetric price effects tended to indicated that the oil price shocks Granger caused the CPI, any causality all but disappeared with the relaxation of the symmetry assumption. Very little causality was suggested by either the Canadian or the Mexican data. The results did tend to suggest that the oil price affects all three economies more through prices than through production and more through positive oil price shocks than through negative oil price shock, indicating some level of asymmetry on both the CPI and the IPI.

Table 5.3.1: GARCH(1,1) Estimates for the U.S. Data

$$\Delta P_t = b_0 + \sum_{i=1}^{n} b_i \Delta P_{t-i} + \varepsilon_t ; \sigma_t^2 = \omega_0 + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$$

Full Sample (n=1)

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0031	0.0019	1.6591	0.0976
b_1	0.3843	0.0589	6.5284	0.0000
ω_0	0.0001	0.0000	8.3670	0.0000
α	0.6098	0.0641	9.5132	0.0000
β	0.7018	0.0164	42.8222	0.0000
log L	1144.9240			

1974 Sample (n=1)

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0043	0.0029	1.5030	0.1340
b_1	0.2122	0.0588	3.6099	0.0004
ω_0	0.0011	0.0002	5.9353	0.0000
α	0.6077	1.0175	5.9727	0.0000
β	0.2140	0.0746	2.8698	0.0044
log L	406.7039			

1981 Sample (n=2)

	Coefficient	S.E.	t-statistic	p-value
b_0	-0.0008	0.0034	-0.2285	0.8195
b_1	0.2883	0.0690	4.1770	0.0000
b_2	-0.1934	0.0675	-2.8655	0.0046
ω_0	0.0004	0.0002	2.2384	0.0264
α	0.4423	0.0792	5.5817	0.0000
β	0.5534	0.0907	6.1013	0.0000
log L	271.3675			

Table 5.3.2: Results of the Single Equation Regressions for the U.S. Data (Symmetric Price Effects) - $\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \varepsilon_{t-i}/\sigma_{t-i} + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0015	0.0004	3.3585	**0.0008**
β_1	0.3544	0.0406	8.7212	**0.0000**
β_2	0.1014	0.0417	2.4313	**0.0153**
β_3	0.0332	0.0409	0.8130	0.4166
β_4	0.0075	0.0386	0.1955	0.8451
γ_1	0.0000	0.0004	-0.0949	0.9245
γ_2	-0.0008	0.0005	-1.5734	0.1161
γ_3	-0.0003	0.0005	-0.5938	0.5529
γ_4	-0.0008	0.0005	-1.5930	0.1117
π_1	0.0298	0.0243	1.2293	0.2194
π_2	-0.0356	0.0318	-1.1171	0.2644
π_3	0.0540	0.0318	1.6998	0.0897
π_4	-0.0566	0.0231	-2.4535	**0.0144**

D. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0008	0.0002	4.6102	**0.0000**
β_1	0.3608	0.0421	8.5705	**0.0000**
β_2	0.1889	0.0441	4.2823	**0.0000**
β_3	0.0968	0.0428	2.2592	**0.0242**
β_4	0.0850	0.0404	2.1068	**0.0356**
γ_1	0.0002	0.0001	1.4489	0.1479
γ_2	0.0001	0.0001	0.6575	0.5111
γ_3	0.0000	0.0001	0.0985	0.9216
γ_4	0.0000	0.0001	0.1299	0.8967
π_1	0.0005	0.0070	0.0782	0.9377
π_2	-0.0046	0.0092	-0.4962	0.6200
π_3	0.0114	0.0091	1.2470	0.2129
π_4	-0.0017	0.0067	-0.2535	0.8000

B. Y=IPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0011	0.0006	1.8780	0.0615
β_1	0.3228	0.0614	5.2555	**0.0000**
β_2	0.1504	0.0642	2.3437	**0.0198**
β_3	0.0709	0.0638	1.1114	0.2674
β_4	-0.0215	0.0610	-0.3530	0.7244
γ_1	-0.0003	0.0005	-0.6472	0.5181
γ_2	-0.0007	0.0005	-1.6282	0.1047
γ_3	-0.0001	0.0005	-0.3241	0.7462
γ_4	-0.0006	0.0005	-1.3030	0.1937
π_1	0.0193	0.0588	0.3290	0.7424
π_2	-0.0867	0.0624	-1.3896	0.1658
π_3	0.0515	0.0241	2.1431	**0.0330**
π_4	-0.0176	0.0166	-1.0576	0.2912

E. Y=CPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0008	0.0003	3.0223	**0.0028**
β_1	0.5362	0.0630	8.5049	**0.0000**
β_2	0.1003	0.0698	1.4366	0.1520
β_3	0.1275	0.0693	1.8410	0.0667
β_4	0.0540	0.0588	0.9179	0.3595
γ_1	0.0006	0.0001	4.4915	**0.0000**
γ_2	-0.0001	0.0001	-0.4166	0.6773
γ_3	-0.0001	0.0001	-0.8120	0.4175
γ_4	-0.0001	0.0001	-1.0548	0.2925
π_1	-0.0161	0.0159	-1.0101	0.3134
π_2	0.0019	0.0169	0.1124	0.9106
π_3	0.0098	0.0065	1.5070	0.1330
π_4	-0.0042	0.0045	-0.9289	0.3538

C. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0012	0.0007	1.7744	0.0777
β_1	0.1099	0.0742	1.4819	0.1401
β_2	0.1546	0.0743	2.0808	**0.0389**
β_3	0.1294	0.0746	1.7354	0.0844
β_4	0.1210	0.0743	1.6280	0.1053
γ_1	0.0001	0.0005	0.2020	0.8401
γ_2	-0.0004	0.0005	-0.8234	0.4114
γ_3	0.0000	0.0005	-0.0594	0.9527
γ_4	-0.0007	0.0005	-1.5716	0.1178
π_1	0.0071	0.0744	0.0952	0.9243
π_2	-0.0900	0.0880	-1.0225	0.3079
π_3	0.0574	0.0879	0.6532	0.5145
π_4	-0.0038	0.0713	-0.0532	0.9576

F. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0014	0.0003	4.1207	**0.0001**
β_1	0.4178	0.0773	5.4074	**0.0000**
β_2	0.0644	0.0830	0.7754	0.4391
β_3	0.1029	0.0829	1.2421	0.2158
β_4	-0.0163	0.0701	-0.2323	0.8166
γ_1	0.0006	0.0001	4.5597	**0.0000**
γ_2	0.0001	0.0001	0.5094	0.6111
γ_3	-0.0003	0.0001	-2.0054	**0.0464**
γ_4	-0.0002	0.0001	-1.2332	0.2191
π_1	-0.0198	0.0213	-0.9264	0.3555
π_2	0.0156	0.0250	0.6242	0.5333
π_3	0.0179	0.0249	0.7204	0.4722
π_4	-0.0264	0.0205	-1.2885	0.1992

Table 5.3.3: Results of the Single Equation Regressions for the U.S. Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4}\beta_i \Delta Y_{t-i} + \sum_{i=1}^{4}\gamma_i pos\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\lambda_i neg\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\pi_i \sigma_{t-i}^2$$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0024	0.0007	3.4533	**0.0006**
β_1	0.3462	0.0409	8.4568	**0.0000**
β_2	0.0757	0.0433	1.7462	0.0813
β_3	0.0567	0.0434	1.3077	0.1915
β_4	0.0058	0.0407	0.1420	0.8871
γ_1	-0.0002	0.0005	-0.4148	0.6784
γ_2	-0.0013	0.0006	-2.1357	**0.0331**
γ_3	-0.0005	0.0006	-0.8207	0.4121
γ_4	-0.0011	0.0006	-1.7597	0.0790
λ_1	0.0005	0.0012	0.3839	0.7012
λ_2	0.0006	0.0012	0.4839	0.6286
λ_3	0.0005	0.0012	0.3793	0.7046
λ_4	-0.0002	0.0012	-0.1672	0.8672
π_1	0.0452	0.0264	1.7101	0.0878
π_2	-0.0409	0.0348	-1.1760	0.2401
π_3	0.0571	0.0347	1.6456	0.1004
π_4	-0.0647	0.0245	-2.6347	**0.0086**

D. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0009	0.0002	3.9818	**0.0001**
β_1	0.3628	0.0423	8.5707	**0.0000**
β_2	0.1947	0.0444	4.3877	**0.0000**
β_3	0.0984	0.0431	2.2805	**0.0229**
β_4	0.0800	0.0405	1.9751	**0.0487**
γ_1	0.0000	0.0001	0.1393	0.8893
γ_2	0.0000	0.0002	0.2654	0.7908
γ_3	0.0001	0.0002	0.5310	0.5956
γ_4	0.0001	0.0002	0.6009	0.5481
λ_1	0.0009	0.0003	2.5809	**0.0101**
λ_2	0.0003	0.0003	0.8356	0.4037
λ_3	-0.0002	0.0004	-0.6902	0.4904
λ_4	-0.0003	0.0004	-0.7708	0.4412
π_1	0.0020	0.0076	0.2621	0.7933
π_2	-0.0084	0.0100	-0.8380	0.4024
π_3	0.0105	0.0100	1.0523	0.2931
π_4	0.0002	0.0071	0.0271	0.9784

B. Y=IPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0024	0.0010	2.4103	**0.0166**
β_1	0.3172	0.0616	5.1531	**0.0000**
β_2	0.1636	0.0644	2.5397	**0.0117**
β_3	0.0758	0.0640	1.1831	0.2378
β_4	-0.0445	0.0615	-0.7233	0.4701
γ_1	-0.0012	0.0007	-1.7160	0.0874
γ_2	-0.0021	0.0009	-2.5210	**0.0123**
γ_3	0.0003	0.0009	0.3209	0.7486
γ_4	-0.0005	0.0007	-0.7214	0.4713
λ_1	0.0008	0.0009	0.9578	0.3390
λ_2	0.0009	0.0010	0.9238	0.3564
λ_3	-0.0008	0.0010	-0.8207	0.4126
λ_4	-0.0003	0.0009	-0.2889	0.7729
π_1	0.1076	0.0762	1.4123	0.1590
π_2	-0.1529	0.0773	-1.9783	**0.0489**
π_3	0.0609	0.0266	2.2871	**0.0230**
π_4	-0.0196	0.0169	-1.1631	0.2459

E. Y=CPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0012	0.0004	3.0840	**0.0023**
β_1	0.5316	0.0632	8.4188	**0.0000**
β_2	0.0993	0.0700	1.4193	0.1570
β_3	0.1252	0.0695	1.8001	0.0730
β_4	0.0383	0.0595	0.6432	0.5207
γ_1	0.0003	0.0002	1.5533	0.1216
γ_2	-0.0002	0.0002	-0.6690	0.5041
γ_3	-0.0002	0.0002	-0.9030	0.3674
γ_4	-0.0001	0.0002	-0.6971	0.4864
λ_1	0.0009	0.0002	3.7676	**0.0002**
λ_2	0.0000	0.0003	0.1655	0.8687
λ_3	0.0000	0.0003	0.1080	0.9141
λ_4	-0.0001	0.0003	-0.2811	0.7788
π_1	-0.0094	0.0209	-0.4482	0.6544
π_2	0.0043	0.0209	0.2052	0.8376
π_3	0.0086	0.0072	1.1925	0.2342
π_4	-0.0045	0.0046	-0.9858	0.3251

C. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0018	0.0015	1.2447	0.2149
β_1	0.1031	0.0752	1.3709	0.1721
β_2	0.1757	0.0763	2.3039	**0.0224**
β_3	0.1325	0.0760	1.7441	0.0829
β_4	0.0897	0.0773	1.1603	0.2475
γ_1	-0.0008	0.0008	-0.9353	0.3509
γ_2	-0.0012	0.0011	-1.1593	0.2479
γ_3	0.0007	0.0011	0.6260	0.5321
γ_4	-0.0003	0.0011	-0.3071	0.7591
λ_1	0.0011	0.0009	1.2463	0.2143
λ_2	0.0005	0.0011	0.4543	0.6501
λ_3	-0.0009	0.0010	-0.8255	0.4102
λ_4	-0.0009	0.0011	-0.7945	0.4280
π_1	0.0570	0.1052	0.5419	0.5886
π_2	-0.1852	0.1168	-1.5860	0.1145
π_3	0.0630	0.1160	0.5434	0.5876
π_4	0.0248	0.0918	0.2700	0.7875

F. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0015	0.0005	2.8157	**0.0054**
β_1	0.4193	0.0789	5.3118	**0.0000**
β_2	0.0686	0.0840	0.8169	0.4151
β_3	0.1076	0.0839	1.2823	0.2014
β_4	-0.0264	0.0729	-0.3626	0.7174
γ_1	0.0005	0.0002	2.0884	**0.0382**
γ_2	0.0002	0.0003	0.7133	0.4766
γ_3	-0.0005	0.0003	-1.5003	0.1353
γ_4	-0.0003	0.0003	-0.9493	0.3437
λ_1	0.0007	0.0002	2.7672	**0.0063**
λ_2	-0.0001	0.0003	-0.3558	0.7225
λ_3	-0.0001	0.0003	-0.3243	0.7461
λ_4	-0.0001	0.0003	-0.2071	0.8362
π_1	-0.0282	0.0314	-0.8988	0.3700
π_2	0.0358	0.0335	1.0692	0.2865
π_3	0.0162	0.0332	0.4874	0.6266
π_4	-0.0336	0.0267	-1.2553	0.2110

Table 5.3.4: p-values for Selected Tests on Parameters of the Single Equation Regressions for the U.S. Data (Symmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \, {\varepsilon_{t-i}}/{\sigma_{t-i}} + \sum_{i=1}^{4} \pi_i \sigma^2_{t-i}$$

	$\gamma_i = 0$; $i = 1$ to 4	$\pi_i = 0$; $i = 1$ to 4	$\gamma_i = \pi_i$; $i = 1$ to 4
Y=IPI (Full Sample)	0.2727	0.1089	0.1144
Y=CPI (Full Sample)	0.6556	0.5306	0.5520
Y=IPI (1974 Sample)	0.2807	0.3320	0.3274
Y=CPI (1974 Sample)	**0.0002**	0.3078	0.2901
Y=IPI (1981 Sample)	0.5511	0.8414	0.8439
Y=CPI (1981 Sample)	**0.0000**	0.6132	0.6068

Table 5.3.5: p-values for Selected Tests on Parameters of the Single Equation Regressions for the U.S. Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \, pos\left({\varepsilon_{t-i}}/{\sigma_{t-i}}\right) + \sum_{i=1}^{4} \lambda_i \, neg\left({\varepsilon_{t-i}}/{\sigma_{t-i}}\right) + \sum_{i=1}^{4} \pi_i \sigma^2_{t-i}$$

	$\gamma_i = 0$; $i = 1$ to 4	$\lambda_i = 0$; $i = 1$ to 4	$\gamma_i = \lambda_i$; $i = 1$ to 4
Y=IPI (Full Sample)	0.0790	0.9555	0.4881
Y=CPI (Full Sample)	0.9497	0.0694	0.1435
Y=IPI (1974 Sample)	**0.0405**	0.6403	0.1580
Y=CPI (1974 Sample)	0.4284	**0.0066**	0.4595
Y=IPI (1981 Sample)	0.5996	0.5530	0.5338
Y=CPI (1981 Sample)	0.0764	0.0993	**0.0001**

Table 5.4.1: GARCH(1,1) Estimates for the Canadian Data

$$\Delta P_t = b_0 + \sum_{i=1}^{n} b_i \Delta P_{t-i} + \varepsilon_t; \sigma_t^2 = \omega_0 + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

Full Sample (n=1)

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0031	0.0022	1.4342	0.1523
b_1	0.3869	0.0582	6.6478	0.0000
ω_o	0.0001	0.0000	7.6462	0.0000
α	0.5281	0.0744	7.0991	0.0000
β	0.7030	0.0276	25.5074	0.0000
log L	700.5794			

1974 Sample (n=2)

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0055	0.0028	1.9609	0.0509
b_1	0.2606	0.0595	4.3824	0.0000
b_2	-0.1145	0.0608	-1.8837	0.0607
ω_o	0.0005	0.0001	5.7410	0.0000
α	0.5140	0.0712	7.2220	0.0000
β	0.4454	0.0448	9.9373	0.0000
log L	409.4584			

1981 Sample (n=2)

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0002	0.0033	0.0675	0.9463
b_1	0.3009	0.0679	4.4307	0.0000
b_2	-0.1746	0.0653	-2.6741	0.0081
ω_o	0.0003	0.0001	2.5613	0.0112
α	0.5673	0.1029	5.5152	0.0000
β	0.5010	0.0818	6.1230	0.0000
log L	273.5079			

Table 5.4.2: Results of the Single Equation Regressions for the Canadian Data (Symmetric Price Effects) - $\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \varepsilon_{t-i} / \sigma_{t-i} + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0022	0.0006	3.5625	**0.0004**
β_1	-0.1302	0.0483	-2.6977	**0.0073**
β_2	0.1213	0.0472	2.5717	**0.0105**
β_3	0.2432	0.0470	5.1707	**0.0000**
β_4	0.1410	0.0480	2.9350	**0.0035**
γ_1	-0.0007	0.0005	-1.2631	0.2073
γ_2	0.0005	0.0006	0.7917	0.4290
γ_3	0.0002	0.0006	0.3312	0.7406
γ_4	0.0000	0.0006	0.0002	0.9999
π_1	-0.0152	0.0327	-0.4654	0.6419
π_2	-0.0631	0.0436	-1.4484	0.1483
π_3	0.0853	0.0435	1.9596	***0.0507***
π_4	-0.0556	0.0311	-1.7912	0.0740

D. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0012	0.0003	4.1836	**0.0000**
β_1	0.0784	0.0474	1.6545	0.0988
β_2	0.1523	0.0462	3.2990	**0.0011**
β_3	0.2033	0.0461	4.4136	**0.0000**
β_4	0.2502	0.0468	5.3423	**0.0000**
γ_1	0.0003	0.0002	1.8552	0.0643
γ_2	0.0001	0.0002	0.6433	0.5204
γ_3	0.0003	0.0002	1.5843	0.1139
γ_4	0.0001	0.0002	0.5547	0.5794
π_1	0.0014	0.0104	0.1296	0.8969
π_2	-0.0067	0.0139	-0.4804	0.6312
π_3	0.0259	0.0139	1.8680	0.0625
π_4	-0.0123	0.0100	-1.2379	0.2165

B. Y=IPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0013	0.0008	1.7099	**0.0885**
β_1	-0.0971	0.0618	-1.5696	0.1177
β_2	0.1750	0.0596	2.9382	**0.0036**
β_3	0.2881	0.0588	4.8986	**0.0000**
β_4	0.0753	0.0601	1.2521	0.2116
γ_1	-0.0011	0.0006	-1.7788	0.0764
γ_2	0.0005	0.0006	0.7953	0.4272
γ_3	-0.0010	0.0006	-1.5176	0.1303
γ_4	0.0001	0.0006	0.1480	0.8825
π_1	0.0108	0.1014	0.1062	0.9155
π_2	-0.1777	0.1176	-1.5111	0.1320
π_3	0.1295	0.0621	2.0863	**0.0379**
π_4	-0.0445	0.0290	-1.5370	0.1255

E. Y=CPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0011	0.0004	2.7291	**0.0068**
β_1	0.0403	0.0597	0.6759	0.4997
β_2	0.1975	0.0572	3.4539	**0.0006**
β_3	0.2470	0.0577	4.2817	**0.0000**
β_4	0.2517	0.0591	4.2563	**0.0000**
γ_1	0.0002	0.0002	1.1107	0.2677
γ_2	0.0004	0.0002	1.9742	**0.0494**
γ_3	0.0003	0.0002	1.2377	0.2169
γ_4	0.0000	0.0002	-0.0851	0.9322
π_1	0.0005	0.0327	0.0160	0.9873
π_2	-0.0124	0.0385	-0.3221	0.7476
π_3	0.0263	0.0201	1.3119	0.1907
π_4	-0.0020	0.0095	-0.2101	0.8338

C. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0002	0.0009	0.2197	0.8263
β_1	-0.0700	0.0746	-0.9382	0.3494
β_2	0.1241	0.0685	1.8121	0.0717
β_3	0.4411	0.0684	6.4464	**0.0000**
β_4	0.0778	0.0749	1.0378	0.3008
γ_1	-0.0005	0.0007	-0.6899	0.4912
γ_2	0.0006	0.0007	0.8560	0.3931
γ_3	-0.0010	0.0007	-1.4215	0.1569
γ_4	0.0003	0.0007	0.4380	0.6619
π_1	-0.0116	0.0888	-0.1311	0.8958
π_2	-0.1098	0.1023	-1.0739	0.2843
π_3	0.1857	0.1023	1.8163	0.0710
π_4	0.0042	0.0853	0.0497	0.9605

F. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0008	0.0004	1.9855	**0.0486**
β_1	0.0016	0.0709	0.0228	0.9819
β_2	0.1769	0.0686	2.5775	**0.0108**
β_3	0.2387	0.0697	3.4245	**0.0008**
β_4	0.2344	0.0711	3.2954	**0.0012**
γ_1	0.0001	0.0002	0.4793	0.6323
γ_2	0.0004	0.0002	1.6241	0.1061
γ_3	0.0001	0.0002	0.4946	0.6215
γ_4	-0.0002	0.0002	-0.9780	0.3294
π_1	-0.0030	0.0301	-0.1007	0.9199
π_2	-0.0020	0.0356	-0.0572	0.9544
π_3	-0.0329	0.0348	-0.9445	0.3462
π_4	0.0749	0.0288	2.6060	**0.0099**

Table 5.4.3: Results of the Single Equation Regressions for the Canadian Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4}\beta_i \Delta Y_{t-i} + \sum_{i=1}^{4}\gamma_i pos\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\lambda_i neg\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\pi_i\sigma^2_{t-i}$$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0032	0.0011	3.0620	**0.0023**
β_1	-0.1354	0.0490	-2.7663	**0.0059**
β_2	0.1138	0.0482	2.3628	**0.0186**
β_3	0.2342	0.0478	4.8979	**0.0000**
β_4	0.1388	0.0487	2.8514	**0.0046**
γ_1	-0.0011	0.0006	-1.7865	0.0748
γ_2	0.0003	0.0009	0.3142	0.7536
γ_3	0.0001	0.0009	0.0651	0.9481
γ_4	-0.0003	0.0009	-0.3083	0.7580
λ_1	0.0011	0.0013	0.8029	0.4225
λ_2	0.0009	0.0014	0.6249	0.5324
λ_3	0.0002	0.0014	0.1475	0.8828
λ_4	0.0005	0.0014	0.3751	0.7078
π_1	-0.0072	0.0384	-0.1864	0.8522
π_2	-0.0674	0.0513	-1.3146	0.1894
π_3	0.0903	0.0512	1.7642	0.0784
π_4	-0.0637	0.0354	-1.8022	0.0722

B. Y=IPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0025	0.0016	1.5840	0.1144
β_1	-0.1088	0.0619	-1.7578	0.0800
β_2	0.1752	0.0594	2.9501	**0.0035**
β_3	0.2885	0.0589	4.8960	**0.0000**
β_4	0.0813	0.0601	1.3517	0.1776
γ_1	-0.0029	0.0010	-2.8296	**0.0050**
γ_2	-0.0004	0.0013	-0.2903	0.7718
γ_3	-0.0005	0.0012	-0.4177	0.6765
γ_4	0.0009	0.0011	0.8490	0.3967
λ_1	0.0010	0.0012	0.8232	0.4111
λ_2	0.0013	0.0014	0.9457	0.3452
λ_3	-0.0015	0.0014	-1.1132	0.2667
λ_4	-0.0007	0.0013	-0.5490	0.5835
π_1	0.0427	0.1299	0.3287	0.7426
π_2	-0.2550	0.1453	-1.7555	0.0804
π_3	0.1504	0.0729	2.0632	**0.0401**
π_4	-0.0417	0.0299	-1.3956	0.1640

C. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0003	0.0025	0.1074	0.9146
β_1	-0.1068	0.0753	-1.4186	0.1578
β_2	0.1349	0.0680	1.9832	**0.0489**
β_3	0.4427	0.0683	6.4804	**0.0000**
β_4	0.0859	0.0744	1.1540	0.2501
γ_1	-0.0029	0.0013	-2.2519	**0.0256**
γ_2	-0.0005	0.0016	-0.2947	0.7686
γ_3	0.0009	0.0016	0.5323	0.5952
γ_4	0.0025	0.0016	1.5652	0.1193
λ_1	0.0021	0.0013	1.6458	0.1016
λ_2	0.0015	0.0016	0.9436	0.3467
λ_3	-0.0030	0.0016	-1.9051	0.0584
λ_4	-0.0016	0.0016	-0.9669	0.3349
π_1	-0.0128	0.1170	-0.1098	0.9127
π_2	-0.2396	0.1301	-1.8421	0.0672
π_3	0.1401	0.1303	1.0752	0.2838
π_4	0.1234	0.1061	1.1632	0.2463

D. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0015	0.0004	4.0111	**0.0001**
β_1	0.0733	0.0478	1.5336	0.1259
β_2	0.1499	0.0466	3.2148	**0.0014**
β_3	0.2077	0.0464	4.4721	**0.0000**
β_4	0.2557	0.0474	5.3928	**0.0000**
γ_1	0.0004	0.0002	1.7724	0.0771
γ_2	-0.0001	0.0003	-0.3095	0.7571
γ_3	0.0002	0.0003	0.6385	0.5235
γ_4	-0.0001	0.0003	-0.3550	0.7228
λ_1	0.0001	0.0004	0.1973	0.8437
λ_2	0.0005	0.0004	1.1569	0.2480
λ_3	0.0006	0.0004	1.2649	0.2066
λ_4	0.0005	0.0004	1.1085	0.2683
π_1	0.0081	0.0122	0.6631	0.5077
π_2	-0.0081	0.0163	-0.4938	0.6217
π_3	0.0294	0.0163	1.8080	0.0713
π_4	-0.0180	0.0113	-1.5980	0.1108

E. Y=CPI (1974 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0017	0.0007	2.3806	**0.0180**
β_1	0.0364	0.0598	0.6083	0.5436
β_2	0.1953	0.0575	3.3969	**0.0008**
β_3	0.2395	0.0587	4.0767	**0.0001**
β_4	0.2439	0.0602	4.0496	**0.0001**
γ_1	0.0003	0.0003	0.9092	0.3641
γ_2	0.0004	0.0004	0.9548	0.3405
γ_3	-0.0002	0.0004	-0.5116	0.6094
γ_4	-0.0005	0.0004	-1.2924	0.1974
λ_1	0.0001	0.0004	0.3164	0.7520
λ_2	0.0004	0.0005	0.7647	0.4452
λ_3	0.0007	0.0005	1.6390	0.1024
λ_4	0.0005	0.0004	1.1811	0.2386
π_1	0.0114	0.0425	0.2672	0.7895
π_2	0.0167	0.0475	0.3528	0.7245
π_3	0.0129	0.0236	0.5445	0.5866
π_4	-0.0049	0.0097	-0.4991	0.6181

F. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	-0.0001	0.0009	-0.1467	0.8835
β_1	0.0013	0.0713	0.0185	0.9852
β_2	0.1543	0.0707	2.1820	**0.0304**
β_3	0.2457	0.0707	3.4773	**0.0006**
β_4	0.2634	0.0732	3.6003	**0.0004**
γ_1	0.0007	0.0005	1.4924	0.1374
γ_2	0.0009	0.0006	1.5631	0.1198
γ_3	-0.0001	0.0006	-0.1549	0.8771
γ_4	0.0002	0.0006	0.3032	0.7621
λ_1	-0.0004	0.0005	-0.9515	0.3427
λ_2	0.0000	0.0005	-0.0660	0.9475
λ_3	0.0004	0.0005	0.7769	0.4383
λ_4	-0.0007	0.0006	-1.2810	0.2019
π_1	-0.0295	0.0406	-0.7270	0.4682
π_2	0.0304	0.0451	0.6752	0.5004
π_3	-0.0572	0.0447	-1.2796	0.2024
π_4	0.0878	0.0359	2.4458	**0.0154**

Table 5.4.4: p-values for Selected Tests on Parameters of the Single Equation Regressions for the Canadian Data (Symmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \, {}^{\varepsilon_{t-i}}\!/_{\sigma_{t-i}} + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$$

	$\gamma_i = 0$; i = 1 to 4	$\pi_i = 0$; i = 1 to 4	$\gamma_i = \pi_i$; i = 1 to 4
Y=IPI (Full Sample)	0.6560	0.0628	0.0654
Y=CPI (Full Sample)	0.1946	0.2829	0.3221
Y=IPI (1974 Sample)	0.2336	0.3175	0.3123
Y=CPI (1974 Sample)	0.1257	0.0725	0.0874
Y=IPI (1981 Sample)	0.5564	0.3150	0.3113
Y=CPI (1981 Sample)	0.3654	0.1293	0.1280

Table 5.4.5: p-values for Selected Tests on Parameters of the Single Equation Regressions for the Canadian Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i pos\left({}^{\varepsilon_{t-i}}\!/_{\sigma_{t-i}}\right) + \sum_{i=1}^{4} \lambda_i neg\left({}^{\varepsilon_{t-i}}\!/_{\sigma_{t-i}}\right) + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$$

	$\gamma_i = 0$; i = 1 to 4	$\lambda_i = 0$; i = 1 to 4	$\gamma_i = \lambda_i$; i = 1 to 4
Y=IPI (Full Sample)	0.4908	0.8444	0.6611
Y=CPI (Full Sample)	0.4463	0.2519	0.5541
Y=IPI (1974 Sample)	0.0715	0.5235	0.2023
Y=CPI (1974 Sample)	0.4612	0.3144	0.4599
Y=IPI (1981 Sample)	0.0968	0.0940	0.0596
Y=CPI (1981 Sample)	0.3452	0.5440	0.4660

Table 5.5.1: GARCH(1,1) Estimates for the Mexican Data

$$\Delta P_t = b_0 + \varepsilon_t ; \sigma_t^2 = \omega_0 + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$$

Full Sample

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0294	0.0084	3.5185	0.0005
ω_0	0.0029	0.0006	5.0395	0.0000
α	0.1252	0.0657	1.9067	0.0576
β	0.6023	0.0777	7.7524	0.0000
log L	241.1868			

1981 Sample

	Coefficient	S.E.	t-statistic	p-value
b_0	0.0289	0.0088	3.2674	0.0013
ω_0	0.0016	0.0004	3.6838	0.0003
α	0.1681	0.0822	2.0445	0.0423
β	0.7229	0.0773	9.3563	0.0000
log L	164.0733			

Table 5.5.2: Results of the Single Equation Regressions for the Mexican Data

(Symmetric Price Effects) - $\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i \varepsilon_{t-i} / \sigma_{t-i} + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0070	0.0042	1.6652	0.0971
β_1	-0.4941	0.0619	-7.9856	**0.0000**
β_2	-0.1648	0.0695	-2.3711	**0.0185**
β_3	-0.0009	0.0690	-0.0130	0.9897
β_4	-0.1198	0.0614	-1.9494	0.0523
γ_1	-0.0001	0.0023	-0.0248	0.9803
γ_2	-0.0042	0.0032	-1.3293	0.1849
γ_3	0.0001	0.0032	0.0341	0.9728
γ_4	-0.0052	0.0028	-1.8815	0.0610
π_1	-0.1604	0.6103	-0.2627	0.7930
π_2	-0.2989	0.8294	-0.3604	0.7188
π_3	0.6386	0.6358	1.0045	0.3161
π_4	-0.3688	0.3444	-1.0711	0.2851

C. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0041	0.0017	2.4481	**0.0150**
β_1	0.7599	0.0645	11.7745	**0.0000**
β_2	-0.1162	0.0804	-1.4462	0.1493
β_3	0.1482	0.0802	1.8486	0.0656
β_4	0.0551	0.0634	0.8698	0.3852
γ_1	0.0009	0.0008	1.1008	0.2720
γ_2	0.0008	0.0011	0.7144	0.4756
γ_3	0.0011	0.0011	0.9825	0.3268
γ_4	0.0006	0.0010	0.5960	0.5517
π_1	0.0626	0.2106	0.2971	0.7666
π_2	-0.1202	0.2887	-0.4165	0.6774
π_3	0.3106	0.2177	1.4267	0.1549
π_4	-0.2311	0.1180	-1.9575	0.0514

B. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0051	0.0042	1.2259	0.2219
β_1	-0.4122	0.0759	-5.4289	0.0000
β_2	-0.1137	0.0814	-1.3977	**0.1640**
β_3	-0.0050	0.0798	-0.0627	0.9501
β_4	-0.1096	0.0747	-1.4681	0.1439
γ_1	0.0012	0.0025	0.4699	0.6390
γ_2	-0.0048	0.0033	-1.4518	0.1484
γ_3	-0.0015	0.0034	-0.4493	0.6537
γ_4	-0.0020	0.0031	-0.6229	0.5341
π_1	-0.0482	0.4435	-0.1086	0.9137
π_2	0.2217	0.6565	0.3378	0.7359
π_3	-0.4171	0.6520	-0.6398	0.5232
π_4	0.0426	0.4120	0.1035	0.9177

D. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0039	0.0019	2.0688	**0.0400**
β_1	0.8315	0.0776	10.7198	**0.0000**
β_2	-0.1850	0.1005	-1.8401	0.0674
β_3	0.2029	0.1010	2.0096	**0.0460**
β_4	0.0023	0.0764	0.0299	0.9762
γ_1	-0.0001	0.0010	-0.1428	0.8866
γ_2	0.0011	0.0013	0.8560	0.3931
γ_3	0.0025	0.0013	1.8745	0.0625
γ_4	-0.0010	0.0012	-0.7849	0.4336
π_1	0.0204	0.1734	0.1177	0.9065
π_2	-0.1330	0.2587	-0.5140	0.6079
π_3	0.7535	0.2570	2.9315	**0.0038**
π_4	-0.5746	0.1664	-3.4531	**0.0007**

Table 5.5.3: Results of the Single Equation Regressions for the Mexican Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4}\beta_i \Delta Y_{t-i} + \sum_{i=1}^{4}\gamma_i pos\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\lambda_i neg\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4}\pi_i \sigma^2_{t-i}$$

A. Y=IPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0129	0.0056	2.3192	**0.0212**
β_1	-0.4839	0.0626	-7.7333	**0.0000**
β_2	-0.1684	0.0699	-2.4105	**0.0166**
β_3	-0.0078	0.0698	-0.1122	0.9107
β_4	-0.1403	0.0622	-2.2538	**0.0251**
γ_1	-0.0034	0.0029	-1.1824	0.2382
γ_2	-0.0178	0.0072	-2.4865	**0.0135**
γ_3	0.0065	0.0074	0.8766	0.3816
γ_4	-0.0054	0.0072	-0.7493	0.4544
λ_1	0.0097	0.0058	1.6718	0.0958
λ_2	0.0072	0.0073	0.9888	0.3237
λ_3	-0.0087	0.0074	-1.1699	0.2431
λ_4	0.0002	0.0072	0.0287	0.9771
π_1	1.8092	1.0828	1.6709	0.0960
π_2	-2.5702	1.4934	-1.7211	0.0865
π_3	1.0800	1.4754	0.7320	0.4649
π_4	-0.2317	0.7770	-0.2983	0.7658

C. Y=CPI (Full Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0040	0.0019	2.1046	**0.0363**
β_1	0.7975	0.0646	12.3352	**0.0000**
β_2	-0.1797	0.0811	-2.2172	**0.0275**
β_3	0.2228	0.0812	2.7438	**0.0065**
β_4	0.0116	0.0629	0.1850	0.8534
γ_1	0.0007	0.0010	0.6743	0.5008
γ_2	-0.0030	0.0025	-1.2184	0.2242
γ_3	0.0047	0.0025	1.8752	0.0619
γ_4	-0.0063	0.0024	-2.6045	**0.0097**
λ_1	0.0015	0.0020	0.7626	0.4464
λ_2	0.0039	0.0025	1.5608	0.1198
λ_3	-0.0008	0.0025	-0.3100	0.7568
λ_4	0.0045	0.0024	1.8338	0.0679
π_1	0.6240	0.3700	1.6863	0.0930
π_2	-1.1263	0.5148	-2.1876	**0.0296**
π_3	2.0159	0.5049	3.9926	**0.0001**
π_4	-1.1188	0.2650	-4.2216	**0.0000**

B. Y=IPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0093	0.0063	1.4767	0.1416
β_1	-0.3807	0.0770	-4.9417	**0.0000**
β_2	-0.1002	0.0812	-1.2348	0.2186
β_3	-0.0054	0.0796	-0.0679	0.9460
β_4	-0.1158	0.0742	-1.5597	0.1207
γ_1	-0.0016	0.0033	-0.4646	0.6428
γ_2	-0.0189	0.0068	-2.7877	**0.0059**
γ_3	0.0088	0.0070	1.2582	0.2100
γ_4	-0.0018	0.0068	-0.2687	0.7885
λ_1	0.0064	0.0058	1.1188	0.2648
λ_2	0.0081	0.0069	1.1760	0.2412
λ_3	-0.0122	0.0069	-1.7621	0.0798
λ_4	-0.0005	0.0068	-0.0744	0.9408
π_1	1.2903	0.6941	1.8589	0.0648
π_2	-1.8914	1.0124	-1.8682	0.0634
π_3	0.4990	1.0123	0.4929	0.6227
π_4	-0.0415	0.6046	-0.0687	0.9453

D. Y=CPI (1981 Sample)

	Coefficient	S.E.	t-Stat	p-value
α	0.0075	0.0026	2.8341	**0.0051**
β_1	0.8684	0.0782	11.1031	**0.0000**
β_2	-0.2537	0.1033	-2.4562	**0.0150**
β_3	0.2770	0.1035	2.6777	**0.0081**
β_4	-0.0413	0.0768	-0.5377	0.5915
γ_1	-0.0009	0.0014	-0.6285	0.5305
γ_2	-0.0026	0.0026	-0.9839	0.3266
γ_3	0.0053	0.0027	1.9637	0.0512
γ_4	-0.0068	0.0026	-2.5662	**0.0111**
λ_1	0.0012	0.0022	0.5209	0.6031
λ_2	0.0048	0.0027	1.7322	0.0850
λ_3	-0.0010	0.0028	-0.3463	0.7295
λ_4	0.0052	0.0027	1.9513	0.0527
π_1	0.3917	0.2746	1.4267	0.1555
π_2	-0.7656	0.4042	-1.8941	0.0599
π_3	1.5729	0.4007	3.9258	**0.0001**
π_4	-1.0339	0.2407	-4.2945	**0.0000**

Table 5.5.4: p-values for Selected Tests on Parameters of the Single Equation Regressions for the Mexican Data (Symmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4}\beta_i \Delta Y_{t-i} + \sum_{i=1}^{4}\gamma_i \,\varepsilon_{t-i}/\sigma_{t-i} + \sum_{i=1}^{4}\pi_i \sigma^2_{t-i}$$

	$\gamma_i = 0$; i = 1 to 4	$\pi_i = 0$; i = 1 to 4	$\gamma_i = \pi_i$; i = 1 to 4
Y=IPI (Full Sample)	0.1973	0.8187	0.8259
Y=CPI (Full Sample)	0.3748	0.4214	0.4147
Y=IPI (1981 Sample)	0.4254	0.8608	0.8712
Y=CPI (1981 Sample)	0.2144	**0.0051**	**0.0053**

Table 5.5.5: p-values for Selected Tests on Parameters of the Single Equation Regressions for the Mexican Data (Asymmetric Price Effects) -

$$\Delta Y_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{4} \gamma_i pos\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4} \lambda_i neg\left(\varepsilon_{t-i}/\sigma_{t-i}\right) + \sum_{i=1}^{4} \pi_i \sigma_{t-i}^2$$

	$\gamma_i = 0$; i = 1 to 4	$\lambda_i = 0$; i = 1 to 4	$\gamma_i = \lambda_i$; i = 1 to 4
Y=IPI (Full Sample)	0.0775	0.2378	0.0813
Y=CPI (Full Sample)	**0.0465**	0.1319	0.0715
Y=IPI (1981 Sample)	0.0740	0.2035	0.0752
Y=CPI (1981 Sample)	**0.0425**	0.1308	0.0543

Table 5.7.1: p-values for Multi-Equation Granger Causality Test on the U.S. Data Assuming Symmetric Price Effects

Full Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.1922	0.4018
IPI	0.4124	0.6217

1974 Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	**0.0009**	0.6073
IPI	0.9827	0.9327

1981 Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	**0.0001**	0.7881
IPI	0.8210	0.9659

Table 5.7.2: p-values for Multi-Equation Granger Causality Test on the U.S. Data Assuming Asymmetric Price Effects

Full Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.2442	0.1126	0.2435	0.9966
IPI	0.1649	0.2886	0.9943	0.8466

1974 Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.5319	0.7066	0.0940	0.7097
IPI	0.3506	0.9605	0.1257	0.4117

1981 Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.1654	0.7910	**0.0259**	0.7892
IPI	0.2451	0.8303	0.3432	0.0867

Table 5.7.3: Residual Correlation Matrix from the VAR on the U.S. Data Assuming Symmetric Price Effects

Full Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	**0.2147**	1.0000	
IPI	0.0016	0.0642	1.0000

1974 Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	**0.2245**	1.0000	
IPI	0.0271	0.1444	1.0000

1981 Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	**0.2515**	1.0000	
IPI	0.0115	0.0305	1.0000

Table 5.7.4: Residual Correlation Matrix from the VAR on the U.S. Data Assuming Asymmetric Price Effects

Full Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	-0.1766	1.0000		
CPI	**0.2246**	-0.0540	1.0000	
IPI	0.0039	-0.0060	0.0645	1.0000

1974 Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.3094**	1.0000		
CPI	0.1968	-0.1482	1.0000	
IPI	-0.0278	-0.0620	0.1182	1.0000

1981 Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.4147**	1.0000		
CPI	**0.2791**	-0.2528	1.0000	
IPI	-0.0937	-0.0762	0.0947	1.0000

Table 5.7.5: Variance Decomposition for the U.S. Data Assuming Symmetric Price Effects {Unanticipated Price Shock-CPI-IPI}

A. Full Sample

12 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	96.47	9.90	2.76
CPI	2.12	84.84	1.78
IPI	1.41	5.26	95.46

24 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	95.94	11.94	3.69
CPI	2.38	82.42	3.68
IPI	1.68	5.64	92.63

36 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	95.91	12.19	3.71
CPI	2.41	82.20	3.75
IPI	1.69	5.61	92.54

48 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	95.90	12.25	3.74
CPI	2.41	82.14	3.77
IPI	1.69	5.62	92.48

60 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	95.90	12.26	3.74
CPI	2.41	82.13	3.78
IPI	1.69	5.62	92.48

B. 1974 Sub-Sample

12 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	95.28	20.44	2.04
CPI	3.49	67.36	5.66
IPI	1.23	12.20	92.30

24 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	94.96	13.35	5.81
CPI	2.48	81.24	3.91
IPI	2.56	5.41	90.28

36 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	93.83	18.99	2.41
CPI	3.77	61.35	6.59
IPI	2.40	19.66	91.00

48 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	93.82	18.93	2.44
CPI	3.78	60.99	6.72
IPI	2.40	20.08	90.85

60 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	93.81	18.89	2.46
CPI	3.78	60.78	6.78
IPI	2.40	20.33	90.76

C. 1981 Sub-Sample

12 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	94.29	29.79	6.84
CPI	3.71	62.38	5.08
IPI	2.01	7.83	88.09

24 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	92.57	30.38	8.14
CPI	4.19	60.50	5.75
IPI	3.24	9.12	86.11

36 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	92.37	30.40	8.25
CPI	4.30	60.38	5.76
IPI	3.33	9.23	86.00

48 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	92.34	30.39	8.25
CPI	4.32	60.36	5.78
IPI	3.34	9.25	85.97

60 Month Horizon (Forecast Variable)

Unanticipated	Unanticipated Price Shock	CPI	IPI
Price Shock	92.34	30.39	8.25
CPI	4.32	60.36	5.78
IPI	3.34	9.25	85.97

Table 5.7.6: Variance Decomposition for the U.S. Data .{Positive Price Shock, Negative Price Shock, CPI, IPI}

A. Full Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	93.66	4.93	8.94	3.60
Negative Price Shock	1.73	93.76	2.04	0.66
CPI	2.71	0.43	82.98	1.80
IPI	1.89	0.89	6.04	93.95

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	92.93	4.94	11.17	4.64
Negative Price Shock	1.78	93.09	1.94	0.69
CPI	3.10	0.49	80.46	3.84
IPI	2.18	1.48	6.43	90.83

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	92.83	4.95	11.31	4.75
Negative Price Shock	1.80	93.02	1.99	0.71
CPI	3.16	0.53	80.32	3.90
IPI	2.21	1.50	6.38	90.64

48 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	92.81	4.95	11.33	4.81
Negative Price Shock	1.80	93.00	2.02	0.72
CPI	3.18	0.55	80.26	3.95
IPI	2.21	1.50	6.39	90.51

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	92.80	4.95	11.33	4.81
Negative Price Shock	1.80	92.99	2.03	0.72
CPI	3.19	0.56	80.25	3.97
IPI	2.21	1.50	6.38	90.50

B. 1974 Sub-Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	90.35	11.53	9.65	5.25
Negative Price Shock	5.50	82.35	12.96	6.47
CPI	2.29	2.55	66.53	8.79
IPI	1.86	3.56	10.86	79.49

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.81	11.19	8.03	5.38
Negative Price Shock	6.29	80.54	17.91	6.84
CPI	2.50	2.78	58.12	9.94
IPI	2.40	5.49	15.93	77.83

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.57	11.15	7.42	5.39
Negative Price Shock	6.34	80.45	21.31	7.15
CPI	2.56	2.85	54.94	10.17
IPI	2.53	5.56	16.32	77.29

48 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.50	11.12	7.14	5.37
Negative Price Shock	6.37	80.42	22.94	7.39
CPI	2.57	2.88	53.62	10.29
IPI	2.55	5.57	16.30	76.95

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.48	11.11	7.01	5.36
Negative Price Shock	6.38	80.40	23.71	7.54
CPI	2.58	2.90	52.97	10.33
IPI	2.56	5.58	16.31	76.76

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	87.91	18.97	20.76	13.07
Negative Price Shock	5.41	71.80	11.35	6.58
CPI	3.30	3.18	59.16	6.75
IPI	3.38	6.05	8.73	73.61

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.71	18.57	21.44	14.39
Negative Price Shock	5.87	68.98	12.71	8.06
CPI	3.52	3.33	56.80	7.78
IPI	3.90	9.12	9.05	69.76

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.54	18.61	21.32	14.54
Negative Price Shock	5.90	68.71	12.79	8.10
CPI	3.60	3.45	56.72	7.81
IPI	3.97	9.23	9.17	69.54

48 Month Horizon

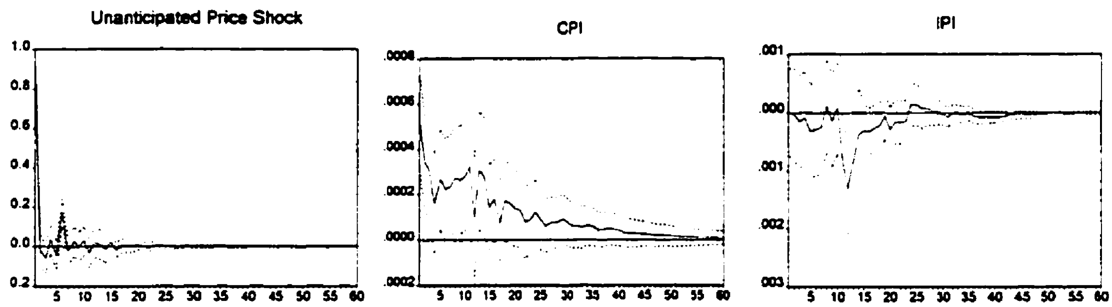
	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.50	18.62	21.30	14.58
Negative Price Shock	5.92	68.69	12.80	8.10
CPI	3.61	3.45	56.69	7.86
IPI	3.97	9.24	9.21	69.46

60 Month Horizon

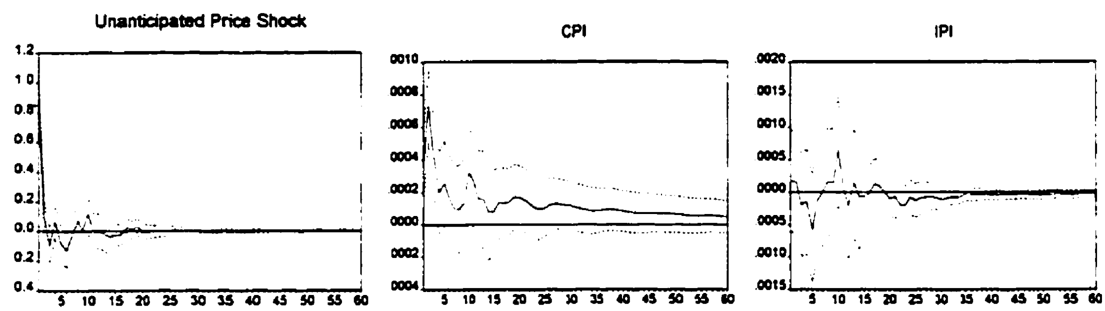
	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.50	18.62	21.30	14.58
Negative Price Shock	5.92	68.69	12.80	8.10
CPI	3.61	3.45	56.69	7.86
IPI	3.97	9.24	9.21	69.46

Figure 5.7.1: Response to Unanticipated Price Shock for U.S. Data Assuming Symmetric Price Effects {Unanticipated Price Shock - CPI - IPI}

A. Full Sample



B. 1974 Sample



C. 1981 Sample

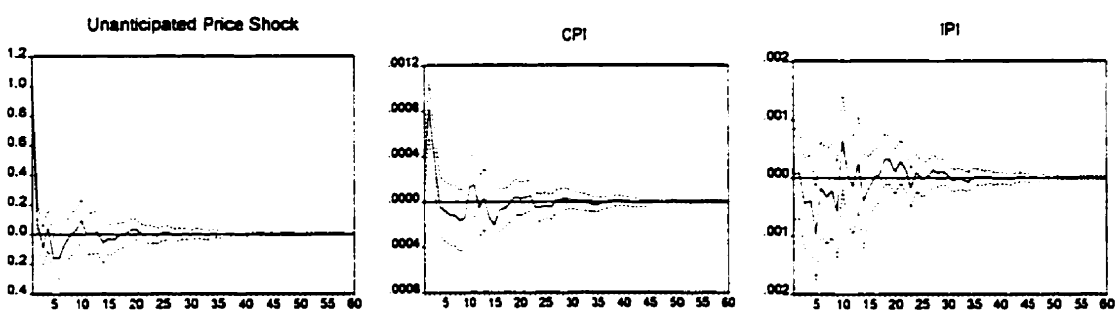
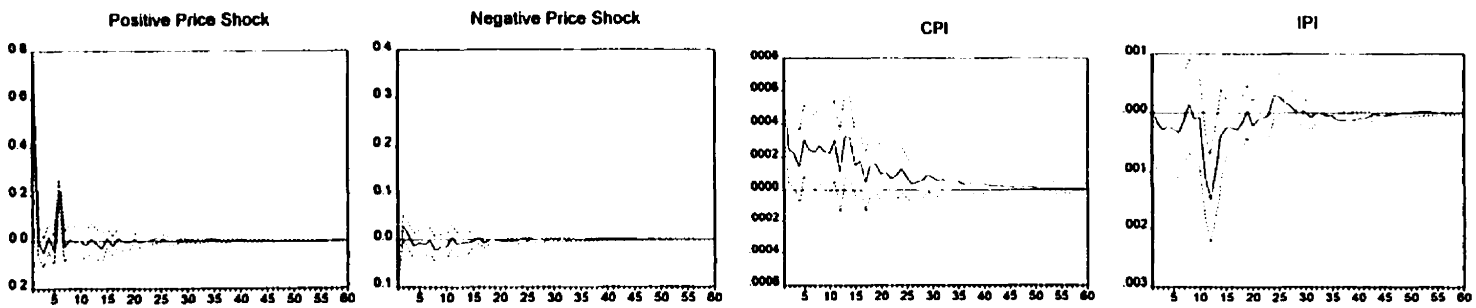


Figure 5.7.2: Response to Price Shocks for U.S. Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

A. Response to Positive Price Shock (Full Sample)



B. Response to Negative Price Shock (Full Sample)

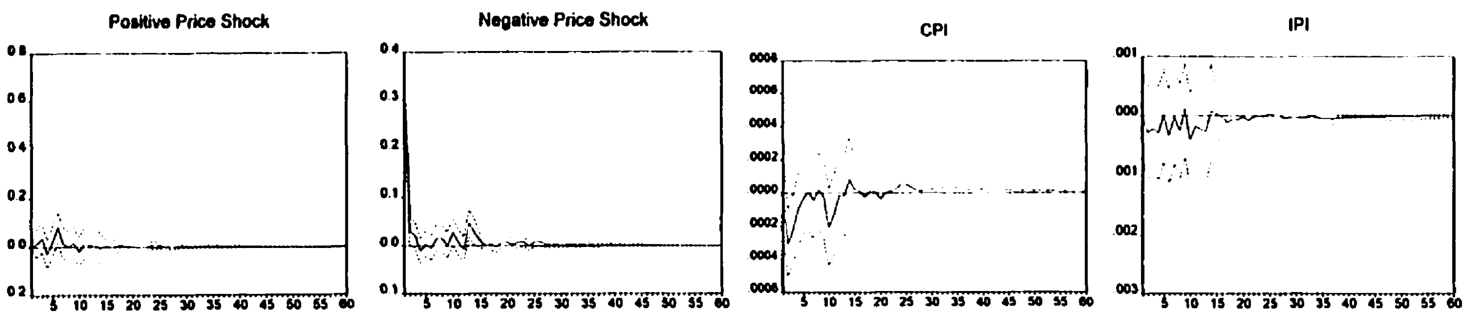
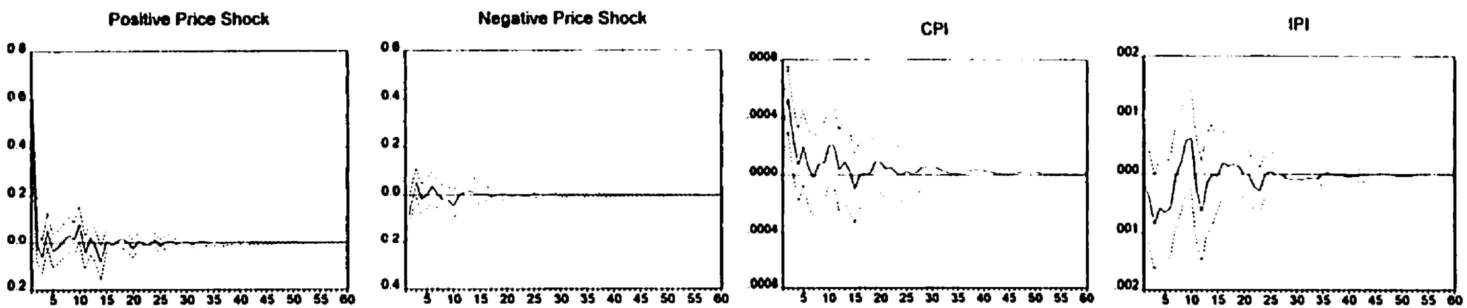


Figure 5.7.2 (continued): Response to Price Shocks for U.S. Data Assuming Asymmetric Price Effects
{Positive Price Shock - Negative Price Shock - CPI - IPI}

C. Response to Positive Price Shock (1974 Sample)



D. Response to Negative Price Shock (1974 Sample)

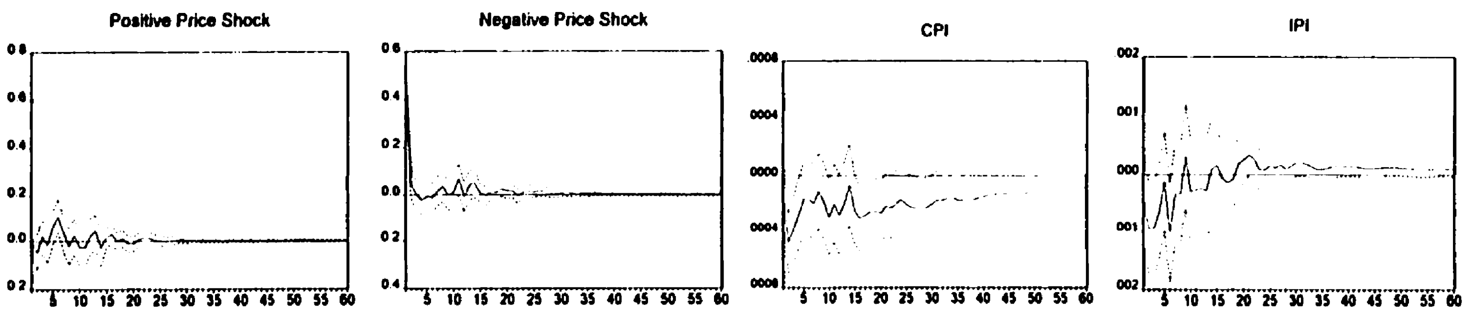
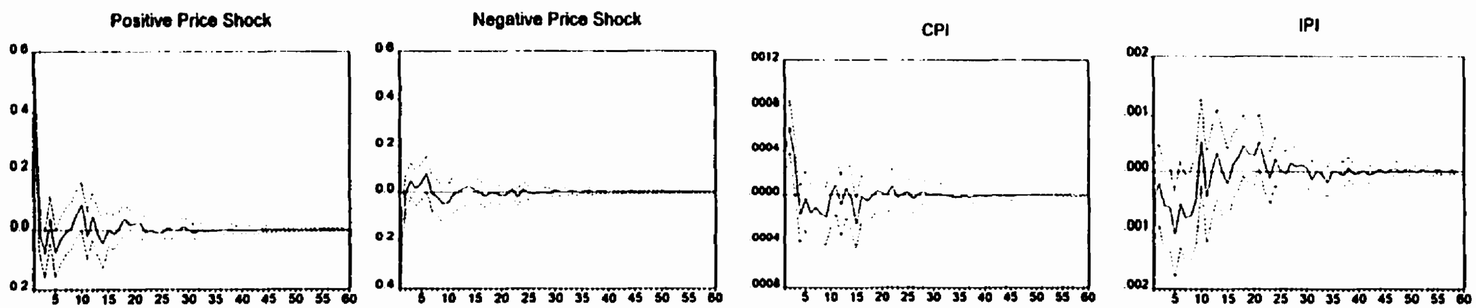


Figure 5.7.2 (continued): Response to Price Shocks for U.S. Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

E. Response to Positive Price Shock (1981 Sample)



F. Response to Negative Price Shock (1981 Sample)

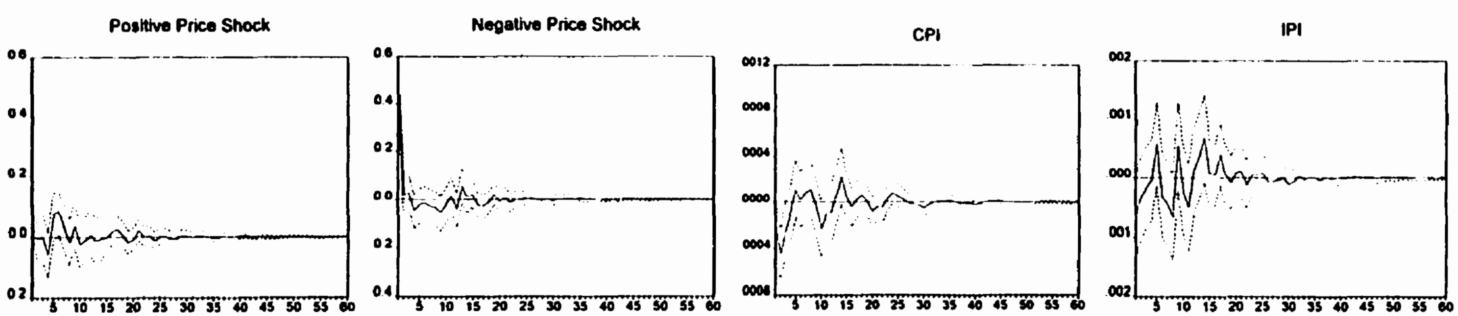


Table 5.8.1: p-values for Multi-Equation Granger Causality Test on the Canadian Data Assuming Symmetric Price Effects

Full Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.0610	0.2826
IPI	0.3316	0.3983

1974 Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.1818	0.8548
IPI	0.5126	0.9529

1981 Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.2048	0.3672
IPI	0.6687	0.7667

Table 5.8.2: p-values for Multi-Equation Granger Causality Test on the Canadian Data Assuming Asymmetric Price Effects

Full Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.1473	0.1656	0.7659	0.6994
IPI	0.2119	0.1460	0.7960	0.6273

1974 Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.5765	0.7929	0.8661	0.5634
IPI	0.2069	0.9316	0.6922	0.8280

1981 Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.3579	0.1971	0.8679	0.3814
IPI	0.1460	0.7218	0.2140	0.6761

Table 5.8.3: Residual Correlation Matrix from the VAR on the Canadian Data Assuming Symmetric Price Effects

Full Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	-0.0115	1.0000	
IPI	0.0091	-0.0915	1.0000

1974 Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	-0.0345	1.0000	
IPI	0.0246	-0.0888	1.0000

1981 Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	0.0398	1.0000	
IPI	-0.0018	-0.1404	1.0000

Table 5.8.3: Residual Correlation Matrix from the VAR on the Canadian Data Assuming Symmetric Price Effects

Full Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.2059**	1.0000		
CPI	-0.0070	0.0443	1.0000	
IPI	-0.0156	-0.0851	-0.0865	1.0000

1974 Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.3835**	1.0000		
CPI	-0.0292	0.0308	1.0000	
IPI	0.0060	-0.0701	-0.0530	1.0000

1981 Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.4703**	1.0000		
CPI	0.0212	-0.0023	1.0000	
IPI	-0.1258	-0.0382	-0.0599	1.0000

Table 5.8.5: Variance Decomposition for the Canadian Data {Unanticipated Price Shock-CPI-IPI} - Symmetric Price Effects

A. Full Sample

12 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	93.57	7.00	2.30
CPI	3.27	89.60	2.79
IPI	3.16	3.40	94.90

24 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	92.63	7.91	4.65
CPI	3.85	86.16	3.82
IPI	3.52	5.94	91.52

36 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	92.53	8.21	4.65
CPI	3.95	85.02	4.23
IPI	3.52	6.77	91.12

48 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	92.49	8.48	4.67
CPI	3.99	84.34	4.41
IPI	3.53	7.18	90.92

60 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	92.45	8.66	4.70
CPI	4.01	83.86	4.52
IPI	3.53	7.47	90.78

B. 1974 Sub-Sample

12 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	95.55	9.54	5.14
CPI	2.26	86.46	3.70
IPI	2.19	4.01	91.16

24 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	94.96	13.35	5.81
CPI	2.48	81.24	3.91
IPI	2.56	5.41	90.28

36 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	94.88	15.12	5.86
CPI	2.51	79.58	4.06
IPI	2.61	5.30	90.07

48 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	94.87	16.10	5.90
CPI	2.52	78.63	4.13
IPI	2.61	5.27	89.97

60 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	94.86	16.64	5.93
CPI	2.52	78.09	4.15
IPI	2.61	5.27	89.92

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	93.55	8.52	5.66
CPI	2.95	86.40	11.32
IPI	3.51	5.08	83.01

24 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	91.62	8.80	7.70
CPI	4.07	84.24	11.08
IPI	4.31	6.96	81.22

36 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	91.27	9.22	7.85
CPI	4.30	83.82	11.27
IPI	4.43	6.96	80.89

48 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	91.21	9.28	7.85
CPI	4.36	83.74	11.28
IPI	4.43	6.98	80.87

60 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	91.19	9.30	7.85
CPI	4.37	83.73	11.29
IPI	4.44	6.98	80.86

Table 5.8.6: Variance Decomposition for the Canadian Data (Positive Price Shock, Negative Price Shock, CPI, IPI) - Asymmetric Price Effects

A. Full Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	91.29	5.66	5.76	2.14
Negative Price Shock	1.83	90.30	2.12	3.35
CPI	2.79	1.75	89.00	2.58
IPI	4.09	2.29	3.13	91.93

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.96	5.77	5.99	4.60
Negative Price Shock	2.56	89.52	3.34	3.28
CPI	3.61	2.30	85.59	3.55
IPI	4.87	2.41	5.08	88.57

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.71	5.79	6.07	4.67
Negative Price Shock	2.62	89.41	4.33	3.43
CPI	3.79	2.39	84.07	4.13
IPI	4.88	2.41	5.53	87.77

48 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.62	5.79	6.31	4.73
Negative Price Shock	2.63	89.40	4.86	3.50
CPI	3.86	2.40	83.08	4.38
IPI	4.89	2.41	5.75	87.40

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.56	5.79	6.45	4.78
Negative Price Shock	2.64	89.40	5.17	3.52
CPI	3.90	2.40	82.43	4.52
IPI	4.90	2.41	5.95	87.18

B. 1974 Sub-Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	93.01	14.79	8.77	6.30
Negative Price Shock	3.17	79.16	2.79	4.44
CPI	2.25	3.09	84.64	4.33
IPI	1.56	2.95	3.80	84.93

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	91.88	14.77	10.13	7.62
Negative Price Shock	3.46	78.07	5.41	4.76
CPI	2.53	3.96	78.36	4.57
IPI	2.13	3.20	6.10	83.05

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	91.63	14.82	11.05	7.69
Negative Price Shock	3.50	77.77	6.50	4.80
CPI	2.62	4.12	76.31	4.77
IPI	2.25	3.30	6.14	82.74

48 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	91.58	14.83	11.68	7.76
Negative Price Shock	3.51	77.69	7.09	4.82
CPI	2.66	4.18	75.00	4.89
IPI	2.25	3.31	6.23	82.53

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	91.55	14.84	12.03	7.78
Negative Price Shock	3.51	77.64	7.48	4.85
CPI	2.68	4.21	74.19	4.95
IPI	2.26	3.31	6.30	82.42

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.17	22.55	8.89	10.28
Negative Price Shock	4.95	68.83	3.14	7.41
CPI	5.43	5.63	85.48	8.00
IPI	3.45	2.99	2.49	74.31

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	84.36	22.04	8.98	10.95
Negative Price Shock	5.24	65.98	3.90	8.71
CPI	5.98	8.11	83.28	9.00
IPI	4.43	3.86	3.84	71.33

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	84.02	22.04	9.12	11.15
Negative Price Shock	5.26	65.68	4.03	8.77
CPI	6.20	8.40	82.96	9.06
IPI	4.51	3.88	3.90	71.03

48 Month Horizon

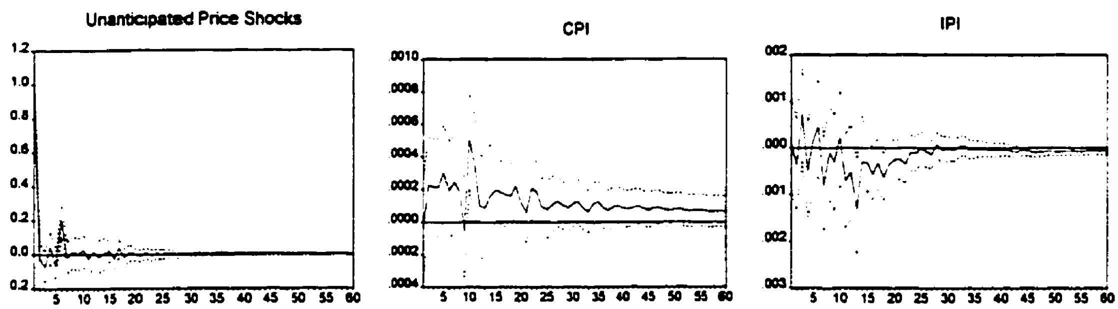
	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	83.95	22.03	9.11	11.17
Negative Price Shock	5.27	65.64	4.06	8.78
CPI	6.25	8.44	82.94	9.09
IPI	4.52	3.89	3.89	70.96

60 Month Horizon

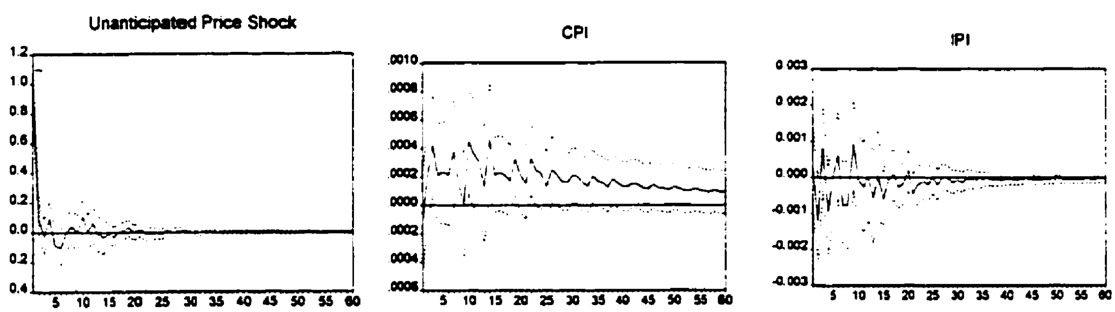
	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	83.93	22.03	9.10	11.17
Negative Price Shock	5.27	65.63	4.07	8.78
CPI	6.27	8.45	82.95	9.10
IPI	4.52	3.89	3.88	70.95

Figure 5.8.1: Response to Unanticipated Price Shock for Canadian Data Assuming Symmetric Price Effects {Unanticipated Price Shock - CPI - IPI}

A. Full Sample



B. 1974 Sample



C. 1981 Sample

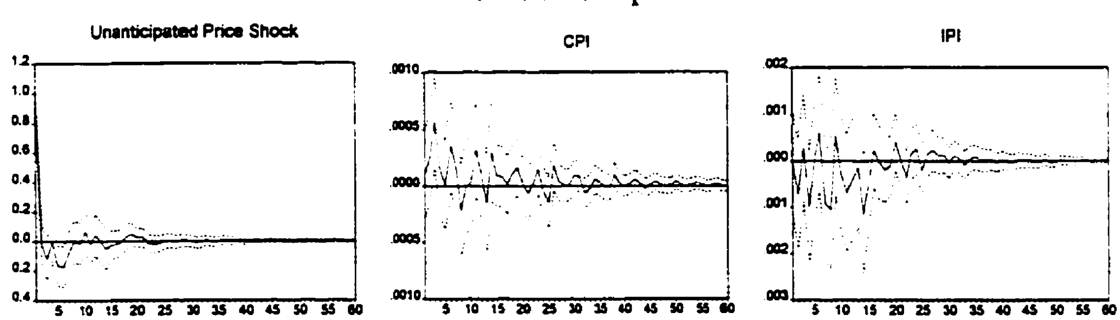
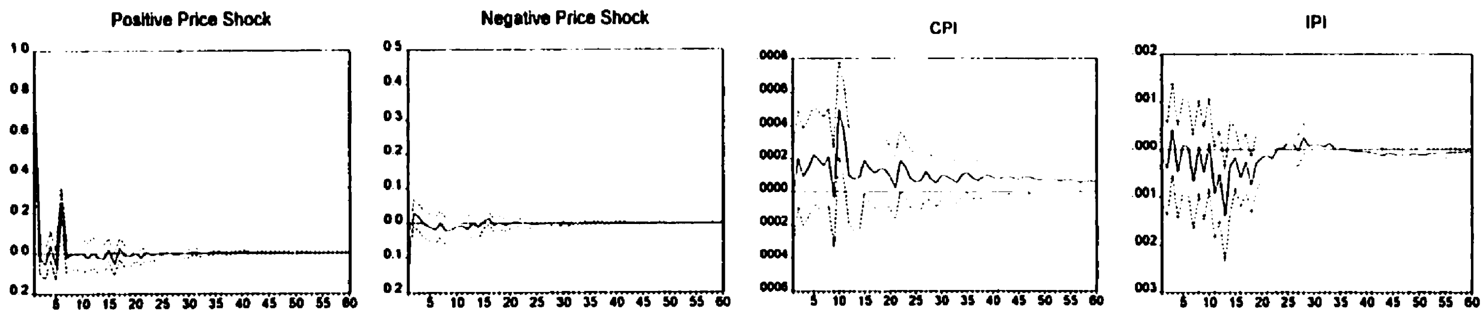


Figure 5.8.2: Response to Price Shocks for Canadian Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

A. Response to Positive Price Shock (Full Sample)



B. Response to Negative Price Shock (Full Sample)

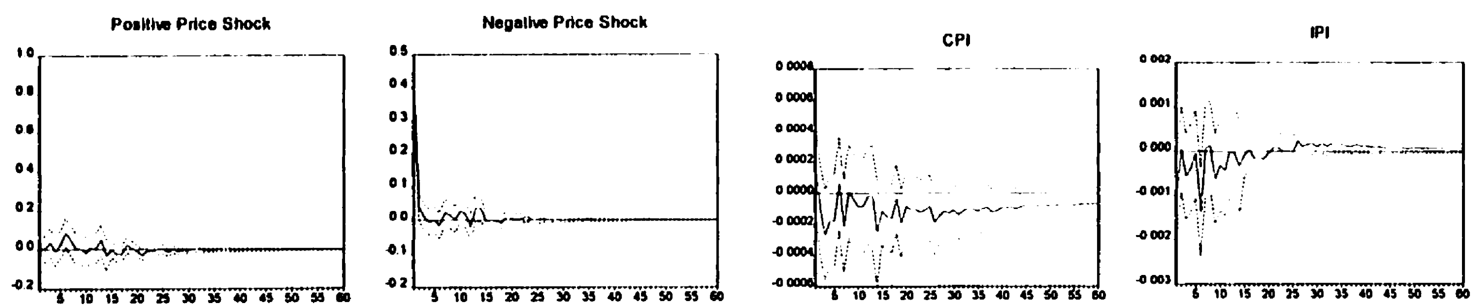
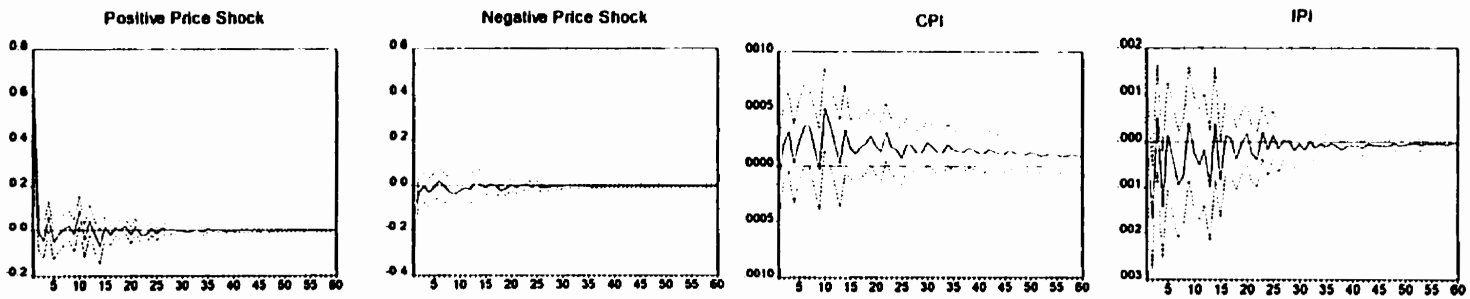


Figure 5.8.2 (continued): Response to Price Shocks for Canadian Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

C. Response to Positive Price Shock (1974 Sample)



D. Response to Negative Price Shock (1974 Sample)

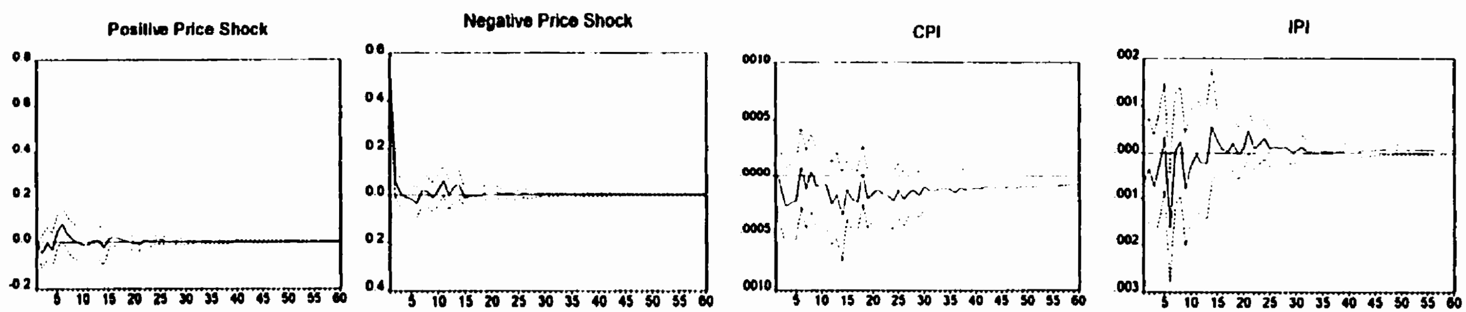
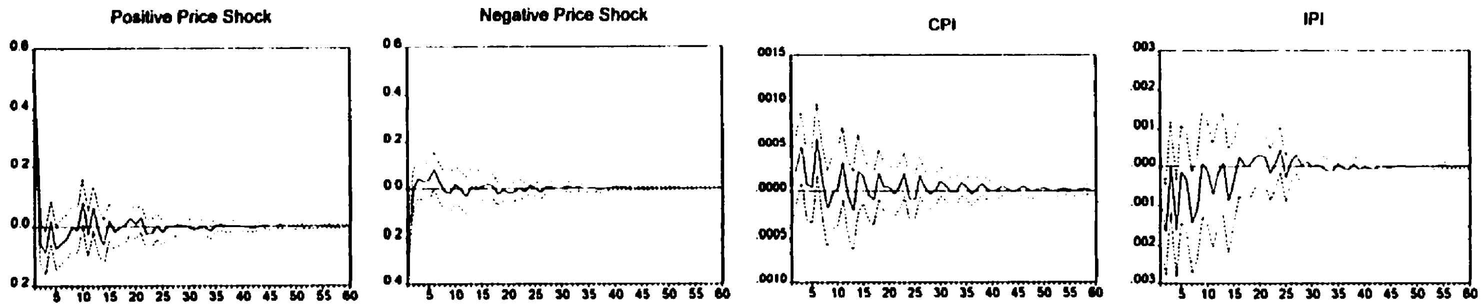


Figure 5.8.2 (continued): Response to Price Shocks for Canadian Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

E. Response to Positive Price Shock (1981 Sample)



F. Response to Negative Price Shock (1981 Sample)

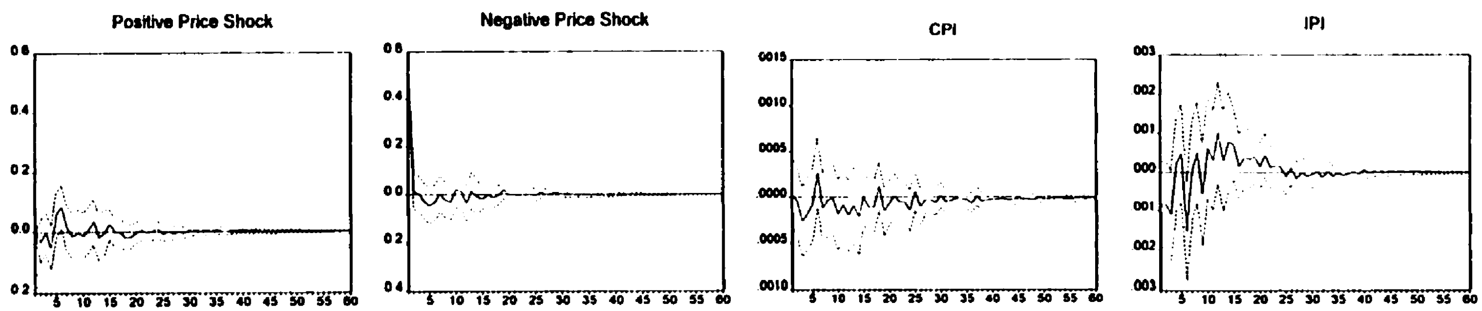


Table 5.9.1: p-values for Multi-Equation Granger Causality Test on the Mexican Data Assuming Symmetric Price Effects

Full Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.0333	0.1216
IPI	0.2676	0.8592

1981 Sample

Y	Unanticipated Price Shock Granger Causes Y	Y Granger Causes Unanticipated Shock
CPI	0.0862	0.0753
IPI	0.2743	0.8638

Table 5.9.2: p-values for Multi-Equation Granger Causality Test on the Mexican Data Assuming Asymmetric Price Effects

Full Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.0918	0.1592	0.9788	0.4948
IPI	0.4156	0.7787	0.3940	0.7493

1981 Sample

Y	Positive Price Shock Granger Causes Y	Y Granger Causes Positive Shock	Negative Price Shock Granger Causes Y	Y Granger Causes Negative Shock
CPI	0.0600	0.1546	0.9442	0.4074
IPI	0.6064	0.8467	0.5011	0.8290

Table 5.9.3: Residual Correlation Matrix from the VAR on the Mexican Data Assuming Symmetric Price Effects

Full Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	**0.3374**	1.0000	
IPI	-0.0406	-0.0381	1.0000

1981 Sample

	Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	1.0000		
CPI	**0.3087**	1.0000	
IPI	-0.0245	-0.0306	1.0000

Table 5.9.4: Residual Correlation Matrix from the VAR on the Mexican Data Assuming Asymmetric Price Effects

Full Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.2683**	1.0000		
CPI	**0.3373**	-0.1349	1.0000	
IPI	-0.0746	0.0091	-0.0733	1.0000

1981 Sample

	Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	1.0000			
Negative Price Shock	**-0.2720**	1.0000		
CPI	**0.2735**	-0.1493	1.0000	
IPI	-0.0235	0.0436	-0.0160	1.0000

Table 5.9.5: Variance Decomposition for the Mexican Data Assuming Symmetric Price Effects {Unanticipated Price Shock-CPI-IPI}

A. Full Sample

12 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	92.69	34.58	5.06
CPI	4.63	63.68	11.24
IPI	2.68	1.74	83.69

24 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	91.16	33.55	5.13
CPI	5.51	63.59	12.60
IPI	3.33	2.86	82.27

36 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	90.84	33.49	5.18
CPI	5.55	63.22	12.97
IPI	3.61	3.29	81.84

48 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	90.77	33.49	5.20
CPI	5.57	63.13	13.07
IPI	3.66	3.39	81.73

60 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	90.76	33.48	5.20
CPI	5.57	63.11	13.10
IPI	3.67	3.41	81.70

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	89.91	37.36	8.18
CPI	6.53	60.89	8.03
IPI	3.56	1.75	83.79

24 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	87.44	36.97	7.82
CPI	8.14	60.97	10.40
IPI	4.41	2.06	81.78

36 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	87.20	36.89	7.89
CPI	8.18	60.87	10.92
IPI	4.62	2.25	81.18

48 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	87.15	36.87	7.91
CPI	8.19	60.85	11.04
IPI	4.66	2.29	81.05

60 Month Horizon

	Forecast Variable: Unanticipated Price Shock	CPI	IPI
Unanticipated Price Shock	87.14	36.87	7.92
CPI	8.20	60.84	11.07
IPI	4.66	2.30	81.01

Table 5.9.6: Variance Decomposition for the Mexican Data Assuming Asymmetric Price Effects {Positive Price Shock- Negative Price Shock-CPI-IPI}

A. Full Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	88.64	10.61	31.93	4.43
Negative Price Shock	2.97	84.34	3.78	4.69
CPI	5.68	2.40	62.79	10.82
IPI	2.71	2.65	1.50	80.06

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.57	10.65	30.69	4.58
Negative Price Shock	3.58	82.73	3.76	4.55
CPI	6.58	3.29	63.16	12.66
IPI	3.27	3.33	2.39	78.21

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.25	10.65	30.58	4.67
Negative Price Shock	3.60	82.48	3.81	4.46
CPI	6.63	3.36	62.88	13.23
IPI	3.53	3.51	2.72	77.65

48 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.18	3.60	6.65	4.69
Negative Price Shock	10.65	82.44	3.37	4.43
CPI	30.59	3.81	62.80	13.39
IPI	4.69	4.43	13.39	77.49

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	86.17	10.65	30.59	4.69
Negative Price Shock	3.60	82.43	3.81	4.43
CPI	6.65	3.37	62.78	13.44
IPI	3.59	3.55	2.82	77.44

C. 1981 Sub-Sample

12 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	84.51	13.36	32.53	5.32
Negative Price Shock	5.70	78.82	5.00	7.15
CPI	7.03	4.17	60.94	8.14
IPI	2.77	3.65	1.53	79.39

24 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	80.82	13.82	31.36	5.44
Negative Price Shock	7.18	76.33	4.72	6.77
CPI	8.45	5.11	61.82	10.68
IPI	3.56	4.73	2.09	77.11

36 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	80.44	13.83	31.04	5.58
Negative Price Shock	7.28	75.99	4.79	6.72
CPI	8.45	5.17	61.69	11.18
IPI	3.83	5.01	2.48	76.53

48 Month Horizon

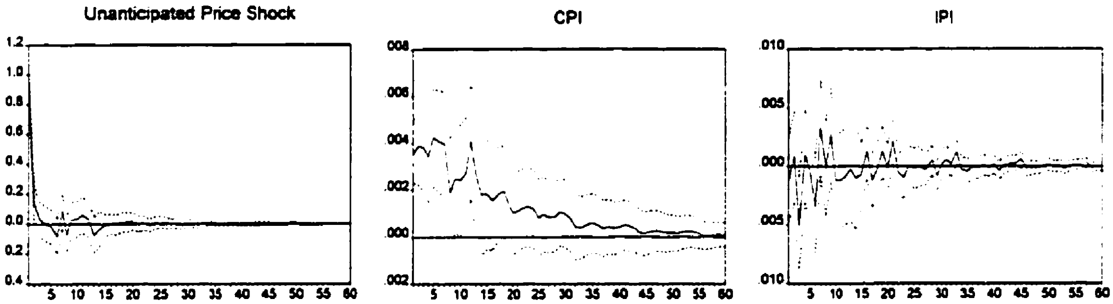
	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	80.34	13.84	31.00	5.60
Negative Price Shock	7.28	75.90	4.79	6.70
CPI	8.46	5.19	61.61	11.30
IPI	3.92	5.07	2.60	76.40

60 Month Horizon

	Forecast Variable: Positive Price Shock	Negative Price Shock	CPI	IPI
Positive Price Shock	80.32	13.84	30.99	5.60
Negative Price Shock	7.28	75.88	4.79	6.70
CPI	8.47	5.19	61.59	11.34
IPI	3.94	5.08	2.63	76.36

Figure 5.9.1: Response to Unanticipated Price Shock for Mexican Data Assuming Symmetric Price Effects {Unanticipated Price Shock - CPI - IPI}

A. Full Sample



B. 1981 Sample

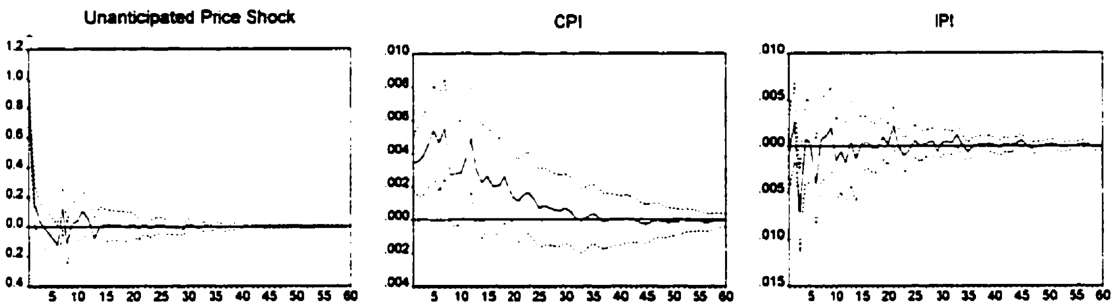
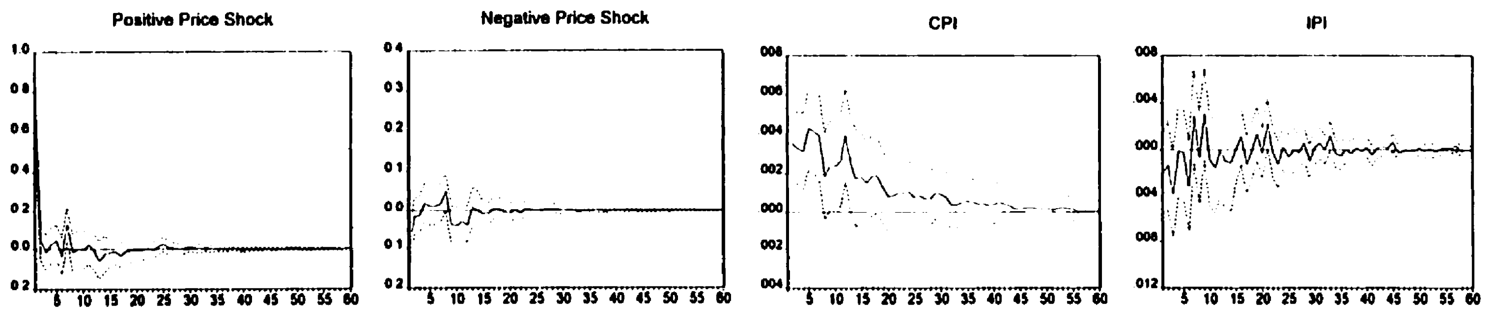


Figure 5.9.2: Response to Price Shocks for Mexican Data Assuming Asymmetric Price Effects
{Positive Price Shock - Negative Price Shock - CPI - IPI}

A. Response to Positive Price Shock (Full Sample)



B. Response to Negative Price Shock (Full Sample)

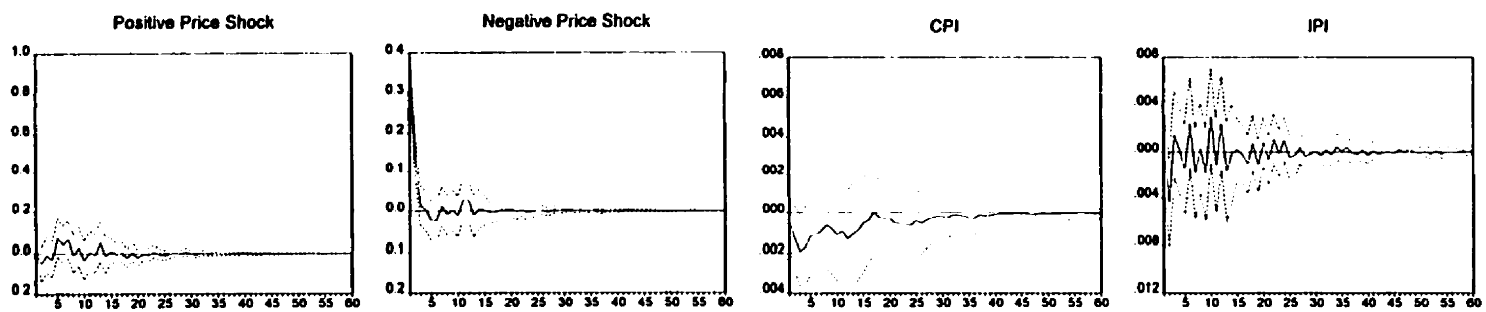
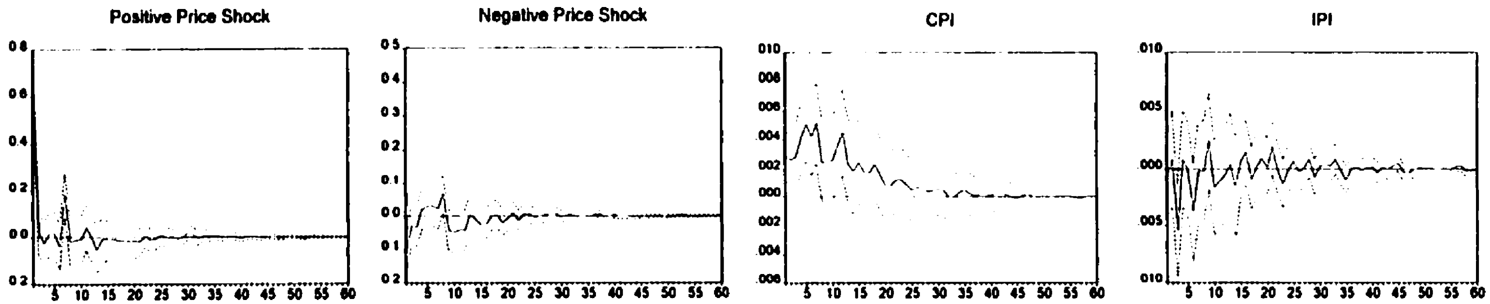
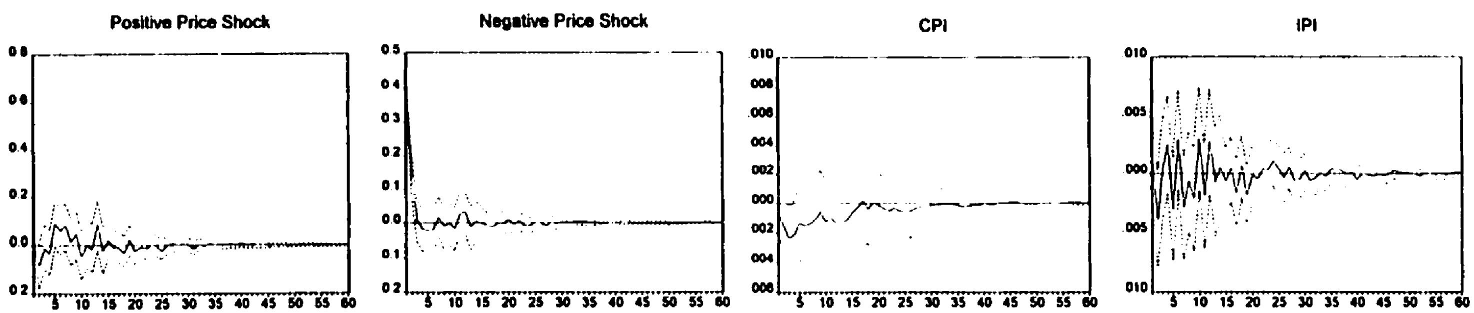


Figure 5.9.2 (continued): Response to Price Shocks for Mexican Data Assuming Asymmetric Price Effects {Positive Price Shock - Negative Price Shock - CPI - IPI}

A. Response to Positive Price Shock (1981 Sample)



B. Response to Negative Price Shock (1981 Sample)



Chapter 6: Conclusion

This study has attempted to analyze the effects of oil price shocks on the Consumer's Price Index and Industrial Production Index in the United States, Canada and Mexico. It was argued that the policy implications with regards to responses to oil price shocks depend on the mechanisms through which these shocks affect the economy. An attempt was made in this study to separate the effects into price and production effects. The analysis was performed on monthly data for the three North American economies using the West Texas Intermediate (WTI) price as the oil price. The WTI is generally accepted to be the benchmark oil price for North America.

The analysis was performed using three samples of the data for the U.S. and Canada, once using the full sample, extending back to 1947 for the U.S. and 1961 for Canada, once using a sub-sample beginning in 1974 and once using a sub-sample beginning in 1981. 1974 was chosen as the beginning date for the second sample because this represents the first major oil price shock. 1981 was chosen as the beginning of the third sample because this represented the beginning of the active trading of the WTI futures contract and therefore represents the beginning of a purely market-based price, rather than a price set by the Texas Railroad Commission. The analysis was performed only twice for Mexico. The 1974 sub-sample was excluded because the full sample began only in 1972.

This study used both a single equation approach and a multi-equation approach in order to analyze the effects of oil price shocks. The single equation approach was a simple bivariate model including the oil price as the independent variable and either the IPI or the CPI as the dependent variable. Given that the data were all found to contain a single unit root, these models were first tested for cointegration. In those instances where the variables were found to cointegrate, an error correction model was constructed. For those cases where there was no indication of cointegration, the data was analyzed in first differences. The multi-equation model involved the use of a vector autoregression (VAR). Despite the unit roots present, the data were analyzed in levels rather than first differences, following Sims (1980) and Doan (1992). The models were tested for Granger causality between the oil price and the macroeconomic variables. The VAR's were then used to generate the variance decompositions and the impulse response functions. Only disturbances to the oil price were considered, as this was the focus of the study.

The results for both the single equation approach and the multi-equation approach, when no account is taken for oil price volatility, tend to suggest that there is a significant relationship between the oil price and the CPI in the United States and Canada, regardless of the size of the sample used in the analysis, although there is more variation in the results across samples for the multi-equation approach than for the single equation approach. Although the single equation approach does not seem to suggest much of a significant relationship between the oil price and the CPI for the Mexican data, the multi-equation approach does suggest that such a relationship exists. For all three countries, both the single equation and the multi-equation approaches suggest that the relationship between the oil price and the IPI is weak and insignificant. While there does not seem to be much difference in the direction of the effect of an oil price shock across samples, the effect does appear to diminish with the sample size. This could be an indication that the economies have adapted quicker to sudden oil price changes with the implementation of a monthly market-based price and have adapted to volatile prices.

The question of volatility was also raised in this study. Specifically, the question of what effect volatility in oil prices has on the economy and whether it matters if the volatility is anticipated or unanticipated. A second question raised in this part of the study is whether unanticipated price shocks, when corrected for volatility, have asymmetric effects. The method used to generate the measures of anticipated and unanticipated volatility was a GARCH(1,1) model. As with the previous analysis, the volatility measures were used in both a single equation and a multi-equation framework, although the multi-equation approach considered only the unanticipated price shocks normalized by the volatility. The single equation approach produced some very ambiguous results that tended to vary across country and sample, although for the most part, there did not appear to be a significant relationship between the oil price volatility and the macroeconomic variables.

The multi-equation results also tended to be ambiguous. While the Granger causality results did not appear, in general, to be very significant, the impulse response functions and variance decompositions tended to suggest that unanticipated oil price shocks have a significant impact on the CPI and an insignificant impact on the IPI. There is also some evidence of asymmetric price effects on both the CPI and IPI, although the results for the CPI tend to be more ambiguous and the significance of the results for the

IPI is questionable. The results appear to be strongest for the Mexican economy and weakest for the Canadian economy. One interesting result is that when volatility is accounted for, there appears to be less of a discrepancy in the results generated from the different samples.

The results of the above analysis, although diverse and ambiguous, tend to suggest that shocks in the oil price tend to affect the economy through prices rather than productive activity. This would, on the surface, suggest that any policy initiatives in response to a sudden change be directed at the price level. Any asymmetry in the results tends to further suggest that any policy response be directed at increases in the oil price but perhaps not at decreases in the oil price. That is, according to the results of this study, an increase in oil prices may suggest that the central bank tighten monetary policy, especially if the central bank has moved toward an anti-inflation policy. The magnitude and significance of the results, however, leaves some room for debate about whether or not a policy initiative is necessary, at least in the United States and Canada. The Mexican economy definitely seems to be more sensitive to oil price shocks, although the lines of causality are much less clear. The differences in the responses of the different economies may be the result of differences in the importance to the economy of the oil industries. Therefore, as the Mexican oil industry further develops, the economy may respond more to oil price changes rather than the reverse.

The results of this analysis, however, must be interpreted very carefully. The use of the WTI oil price as a representative for the oil price in Canada and Mexico was a matter of convenience. The actual oil price in Canada, however, was regulated between

1973 and 1984. The Mexican oil price is still subject to government regulation. While regulators in both countries used the WTI as one benchmark in determining the regulated price and represented the price domestic producers could receive for exports from these countries, the actual domestic price of oil was rarely, if ever, accurately reflected by the WTI. As a result, the macroeconomic responses to changes in the WTI price may not accurately reflect the response to changes in the domestic oil price in Canada and Mexico. A further consideration in this analysis is the level of economic development in Mexico. While the United States and Canada are both developed, industrialized countries, Mexico represents a developing economy and has, over the past three decades experienced, among other things, several currency crises and policy reforms. These factors tend to mask the true macroeconomic effects of oil price shocks for the Mexican economy, especially the effects on the CPI.

There is a great deal of potential for research in this subject. Although there has been significant research already, the ambiguity of the results prevents a clear understanding (if one exists) of the oil - economy relationship. As more developing countries industrialize, pushing up world wide demand, it follows that there is at least the potential for more volatile price movements, especially when one considers that the OPEC countries still control a large proportion of the world wide production. This suggests that if there is a significant relationship between oil prices and the economy, policy responses to oil price shock will play a major role. This study has suggested that such a relationship exists between oil price shocks and the CPI in the three North American economies. However, this study has also suggested that the effects show some significant differences across countries, indicating that the policy response appropriate for one country may not be appropriate for another. This argument can most likely be extended to the intra-national regional level. The responsiveness of an economy to oil price shocks will undoubtedly change from one region to another. One direction for future study is to look at the regional responses.

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IMAGE EVALUATION
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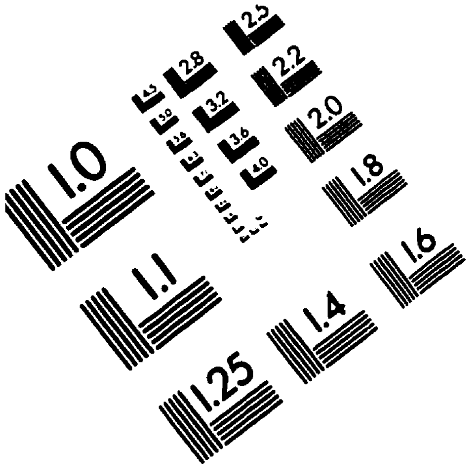

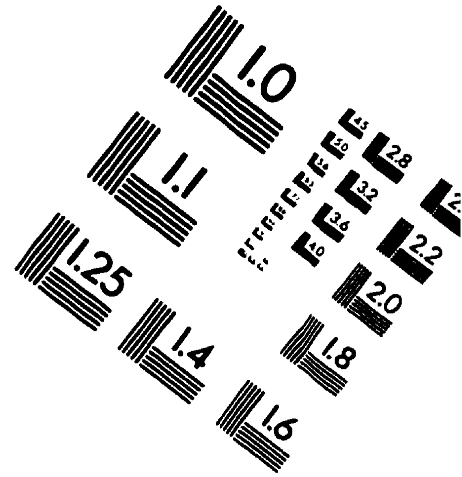

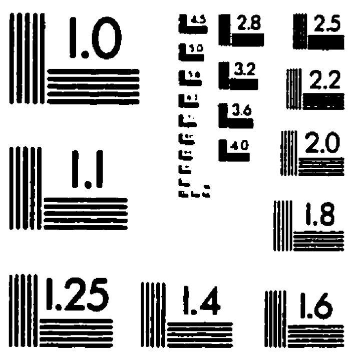

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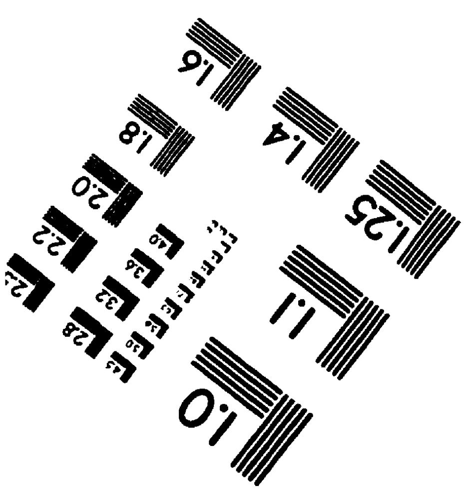

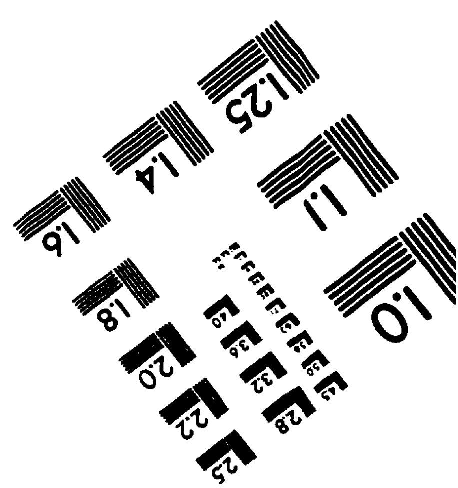

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