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OIL PRICE SHOCKS AND MACROECONOMIC ACTIVITY:

AN APPLICATION OF HIDDEN COINTEGRATION

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BING LI

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Oil Price Shocks and Macroeconomic Activity: an Application of Hidden Cointegration" submitted by Bing Li in partial fulfillment of the requirements for the degree of Master of Arts.

Chairman, Dr. Frank J. Atkins
Department of Economics

Dr. Daniel V. Gordon
Department of Economics

Dr. Michael Robinson
Haskayne School of Business

May 27, 2003

Abstract

In this paper we apply the hidden cointegration technique proposed by Granger and Yoon (2002) to examine the oil price-macroeconomy relationship in Canada by selecting real Canadian GDP level and the total Canadian unemployment rate as macroeconomic indicators.

Our empirical results indicate that there are hidden cointegrations among components of these variables, although they themselves are not cointegrated. Our results are consistent with two previous findings, that is, a negative correlation between oil price movements and macroeconomic activity and an asymmetric effect on the macroeconomy of oil price changes. However, our findings are somewhat different from previous studies. We found that the reduction in oil price exert a positive influence on the unemployment rate and oil prices increases will be harmful to Canadian GDP growth. We present a few explanations for this kind of asymmetry. The uncertainty on Canada's role in oil production is one of the sources of asymmetry. Different responses of the central bank to oil price movements may be a possible explanation. Finally, we also argue that adjustment cost to changing oil prices could account for asymmetry.

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Dedication

To all my family members

Table of Contents

Abstract--iii

Acknowledgements---iv

Dedication---v

Table of Contents---vi

List of Tables---vii

List of Figures---viii

Section 1: Introduction--1

Section 2: Literature Review--6

2.1 Cointegration and its evolution--6

2.2 Oil price-Macroeconomy Relationship--12

2.2.1 Oil price movements and gross---12

domestic/national production fluctuation

2.2.2 Oil price and unemployment rate---16

Section 3: Hidden Cointegration Methodology--18

3.1 Hidden Cointegration--18

3.2 Crouching Error Correction Models --21

Section 4: Empirical Regressions and Results--23

4.1 Data Description--23

4.2 Unit Root Tests--24

4.3 Cointegration Tests--27

4.4 Hidden Cointegration Tests---29

4.4.1 Data Manipulation--29

4.4.2 Hidden Cointegration Tests---30

4.5 Crouching Error Correction Models --31

Section 5: Conclusion---36

References---38

List of Tables

Table1	ADF Unit Root Tests	45
Table 1.1	ADF Unit Root Tests (for differenced data)	46
Table 2	KPSS Unit Root Tests	47
Table 2.1	KPSS Unit Root Tests (for differenced data)	48
Table 3	Engle-Granger Cointegration Tests	49
Table 4	Hidden Cointegration Tests	51

List of Figures

Figure 1	Oil Prices versus Unemployment Rates	53
Figure 2	Oil Prices versus GDP	54
Figure 3	Components of Unemployment Rate and Oil Price	55
Figure 4	Components of GDP and Oil Price	56

Section 1

Introduction

Time series data is frequently and intensively used in empirical research. The Classical econometrics theory typically assumes that observed time series data comes from a stationary process. An intuitive idea of stationarity is very simple although its strict academic definition is complicated. A time series or realization generated by a stochastic process is said to be stationary if its mean and variance are constant over time. However, when we take a glance at graphs of most economic time series such as GDP, personal disposable income, and government revenues and expenditures, we would find that nonstationarity seems a natural feature of economic life since economies evolve, grow, and change over time and legislative changes often induce structural breaks.

Should one distinguish between stationary and nonstationary time series? Generally speaking, if we neglect the presence of nonstationarity when we conduct modeling test, 'nonsense regression' problems as Udny Yule (1926) pointed out would be yielded. The 'nonsense regression' problem, often called spurious regression, means there are often extremely high correlations found between variables for which there is no ready causal explanation. Other fundamental differences between a stationary and a nonstationary time series include that a stationary series has a mean and there is a tendency for the series to return to that mean, whereas an integrated (nonstationary) series tends to wander widely; stationary series tend to exhibit smooth behavior, whereas nonstationary series tend to be erratic; a stationary series has a finite variance, shocks are transitory, and its autocorrelations fade out as the time difference grows, whereas a nonstationary series has an infinite variance, shocks are permanent, and its autocorrelations tend to one. These differences suggest that economic forecasts based on nonstationary data are often wrong although that should occur relatively infrequently in a stationary process, which makes the traditional time series analysis become less attractive because the traditional time series analysis was primarily utilized to forecast the time path of a certain variable.

Due to the severe problems of nonstationarity, it has become customary to investigate the existence of the stationarity at first before conducting formal inference. A test of stationarity that is common is known as the unit root test. Suppose we have a time series y_t, which is allowed to be a first order autoregressive process:

$$y_t = \rho y_{t-1} + \varepsilon_t \tag{1}$$

ε_t is assumed to be white noise. Using the lag operator L, $y_{t-1} = Ly_t$. Then, (1) can be written as:

$$y_t = \rho L y_t + \varepsilon_t \tag{2}$$

or:

$$y_t = \frac{\varepsilon_t}{1-\rho L} \tag{3}$$

Interpreted as a polynomial in L, (3) has a factor of $1-\rho L$, which has a root of $1/\rho$: when $\rho = 1$, (2) is called a unit root process. Obviously, the unit root test is to investigate whether the value of ρ is equal to unity or not. However, the distinction between a unit root process and *near* unit root process need not be crucial for practical modeling. Even though a time series is stationary, but with a root close to unity (say, $\rho > 0.95$), it is often a good idea to act as if there are unit roots to obtain robust statistical inference.

Unit root nonstationarity can be transformed to stationarity by differencing and cointegration transformations. However, by differencing data we may lose a valuable long run relationship among those variables that is given by the levels of those variables. Most economic theory is stated as a long run relationship among variables in level form and not in difference form. Cointegration analysis is designed to remove unit roots and find linear combinations of variables in level form. The idea of cointegration is that economic data share common stochastic trends, which are eliminated by cointegrating linear combinations. Therefore, although variables are individually nonstationary, the linear combinations of them may be stationary. Such linear relationships are often called 'long-run equilibrium', since it can be proved that they act as 'attractors' towards which convergence occurs whenever there are departures (Granger, 1986).

However, as Granger and Yoon (2002) pointed out, cointegration is indeed a special phenomenon. Economic data are cointegrated because they respond to stochastic shocks together. What if they respond together only to a certain kind of shocks? For instance, some series would move together with others to positive shocks, while they would respond differently to negative shocks. Granger and Yoon (2002) in their discussion paper introduced the hidden cointegration technique to solve the preceding problem. The economic series are said to "have hidden cointegration, when the components are cointegrated." "While such data series are not cointegrated, there might be useful information hidden in their components to help understand their dynamic relationship." With hidden cointegration, it becomes possible to investigate long-run relationship among non-cointegrated nonstationary data series.

One of the objectives of this paper is to trace cointegration and review the hidden cointegration developed by Granger and Yoon (2002). More importantly, we will apply the hidden cointegration technique to investigate the oil price-macroeconomic relationship. We chose the real Canadian GDP and the total unemployment rate in Canada as macroeconomic indicators. We examine the hidden cointegration in following data sets: real crude oil prices and real Canadian GDP, and real crude oil prices and total unemployment rate.

The correlation between oil price movements and GDP fluctuation has been the subject of a large number of studies since the 1980s. In an influential paper, Hamilton (1983) observed within a vector autoregression (VAR) framework that oil price change has a strong causal and negative correlation with real U.S. GNP growth from 1948 to 1980. Subsequent empirical work (Burbidge and Harrison 1984, Gisser and Goodwin 1986 and Tatom 1988) supported Hamilton's finding by using alternative data and estimation procedures. Mork (1989) proposed further that this kind of negative correlation is not symmetric, that is, oil price increases have had a significantly negative impact on GNP growth while oil price decreases did not lead to increased output growth.

In this thesis, we also test the relation between oil prices and Canadian unemployment rates. The real oil price has such a significant effect on the unemployment rate that some researchers (Nickell, 1997, 1998, Blanchard and Wolfers, 1999) arguethat oil price has become one of the primary determinants of unemployment level. Carruth *et. al.* (1998) pointed out that the main movements in US postwar unemployment are well explained in the context of an efficiency-wage model in which input prices affect the equilibrium rate.

Our empirical results indicate that we do not observe the regular cointegration relation in both data sets across different sample periods although all variables are integrated of order 1. We then apply the hidden cointegration procedure to both data sets and find there are hidden cointegrations in both data sets. The reduction in oil price has a positive effect on the unemployment rate while oil prices increases is harmful to Canadian real GDP growth. The information hidden in the long run cointegration relationship reflects an asymmetric effect of oil price movements on the Canadian macroeconomy. We also find that oil price increases have no significant effect on aggregate employment in Canada, which is somewhat different from previous studies.

The remainder of this paper is structured as follows. In section 2, we trace the development of the cointegration technique, and review past literature on oil price-macroeconomy relationship. Section 3 will briefly introduce the hidden cointegration methodology developed by Granger and Yoon (2002). In section 4, the empirical results are given and section 5 summarizes the conclusion.

Section 2

Literature Review

This section entails two categories of literature review. First, we start with the concept of cointegration and then trace the cointegration technique. We introduce several extensions of Engle and Granger basic cointegration model. Next, we will review the literature on oil price-macroeconomy relation. Specifically, we review how oil price movements influence the GDP fluctuation and unemployment rates and what findings have been observed.

2.1 Cointegration and its evolution

The concept of cointegration was introduced by Granger (1981) and extended in Engle and Granger (1987), Engle and Yoo (1987), Phillips and Ouliaris (1990), Phillips (1991), and Johansen (1988, 1991). The literature on this subject is extensive. Therefore, it is useful to begin by defining the concept of cointegration. Suppose x_t is a vector of economic variables, all of which are I (d), they may be said to be in equilibrium when the specific linear constraint $\alpha' x_t = 0$ occurs. In most time periods, x_t will not be in equilibrium and the univariate quantity $z_t = \alpha' x_t$ is called the equilibrium error. The components of the vector x_t are said to be cointegrated, if z_t is I (d-b) ($b \leq d$), where α is know as the cointegration vector. A particular case of interest to economists, illustrated in Engle and Granger (1987) is the following: suppose that the vector x_t contains two variables y_t and w_t, all of which are I (1). y_t and w_t are said to be cointegrated, if there exists a linear combination:

$$z_t = y_t - \beta w_t, z_t \sim I(0) \tag{4}$$

such that z_t is I (0), where $(1,-\beta)$ is the cointegrating vector.

Rather than differencing nonstationary time series and using only differenced variables, which leads to the loss of the long-run equilibrium properties of the data, cointegration technique provides a formal framework for testing for and estimating long-run relationships among economic variables. Before cointegration was proposed by Granger (1981), Error Correction Mechanisms (denoted ECMs) had the similar function in that they allow long-run components of variables to obey equilibrium constraints, while short-run components have a flexible dynamic specification. The idea of ECMs is the proportion of the disequilibrium from one period is corrected in the next period through the equilibrium error. A distinctive feature of ECM models is that the long-run equilibrium position is not embodied in an explicit associated set of simultaneous equations, but instead is captured by one or more error-correction terms. For a two variable system a typical ECM model would relate the change in one variable to past equilibrium errors, as well as to past changes in both variables.

Engle and Granger (1987) proved that ECM and cointegration were actually two names for the same thing. The existence of cointegration between a set of economic variables provides a statistical foundation for the use of ECM models. Conversely, if an ECM model provides an adequate representation of the variables under consideration, then they must be cointegrated. In the above case, when y_t and w_t are cointegrated, the ECM model for the two variables may be given as:

$$\begin{aligned} \Delta y_t &= A(L)\Delta y_{t-1} + B(L)\Delta w_{t-1} - \gamma_1 z_{t-1} + \varepsilon_{1t} \\ \Delta w_t &= A(L)\Delta y_{t-1} + B(L)\Delta w_{t-1} - \gamma_2 z_{t-1} + \varepsilon_{2t} \end{aligned} \tag{5}$$

where A and B are lag operators, ε_{1t} and ε_{2t} are assumed to be white noises.

The appearance of cointegration implies that differencing is not the only means of eliminating unit roots. If the data are found to have unit roots, in order to eliminate the nonstationarity of data researcher might test for cointegration first; if a cointegrating relationship can be found, this should be exploited by undertaking estimation in an ECM framework.

The attractive features of cointegration motivate the research on cointegration techniques. Besides the hidden cointegration model, there are numerous extensions of the basic cointegration model.

Some econometricians focus on the assumption of a linear and symmetric adjustment mechanism implied by Engle and Granger (1987). Recall the Engle-Granger two-stage methodology. In the simplest case, the first stage entails using OLS to estimate the long-run equilibrium relationship as

$$X_{1t} = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_n X_{nt} + \mu_t \tag{6}$$

where X_{it} is an I (1) variable, β_i is the estimated parameter, and μ_t is the disturbance term that may be serially correlated. The second stage tests whether the residuals from the first stage are white noise in the linear regression equation: $\Delta\mu_t = \rho\mu_{t-1} + \varepsilon_t$. If the null hypothesis of no cointegration is rejected, there exists an error correction representation by the Granger representation theorem. However, when adjustment is asymmetric, cointegration tests are misspecified. If we employ the Engle-Granger procedure to test the cointegration in the presence of asymmetric adjustment, Pippenger and Goering (1993), Balke and Fomby (1997), and Enders and Granger (1998) showed that tests have low power.

To overcome the limitation of Engle-Granger cointegration model, Balke and Fomby (1997) proposed the threshold cointegration tests based on the concept of a discrete adjustment. They considered that the movement toward the long-run equilibrium might not be continuous as the Engle-Granger model implied. For example, "the presence of fixed costs of adjustment maybe prevent economic agent from adjusting continuously." They presented a model in which the cointegrating relationship turns on and off. They modeled "this on and off behavior explicitly as a threshold model in which the series are cointegrated if they move too far away from the equilibrium relationship but are not cointegrated as long as they are relatively close to the equilibrium." It should be pointed out that although they extended the basic model and developed the threshold cointegration model, they still employed the Engle-Granger two-step approach to test threshold cointegration.

Enders and Granger (1998) extended the Engle-Granger model by allowing for either threshold autoregressive (TAR) or momentum- TAR adjustment toward a cointegrating vector. Enders and Siklos (2001) proved that the power of the test for TAR adjustment is poor compared to that of the Engle-Granger test, while the M-TAR test can be many times that of the Engle-Granger test for a plausible range of the adjustment parameters.

Another important extension of the basic cointegration model is called the nonlinear cointegrating model. Suppose we have two I (1) variables X_t and Y_t. They are said to be linear cointegrated if there exists α such that $z_t = [Y_t - \alpha X_t] \sim I(0)$. Nonlinear cointegration states that if there exists β such that $w_t = [f(Y_t) - \beta g(X_t)] \sim I(0)$ for certain nonlinear function *f* and *g*, X_t and Y_t are called to be nonlinearly cointegrated. Seemingly, the form of *f* and *g* is the center of the problem. However, the problem is not that easy. Granger (1995) pointed out "the opportunities for misspecification are greatly enhanced when one is dealing with nonlinear functions of variables having a nonstationary property." He emphasized that the conventional definition of unit root has no meaning and therefore gave the theoretical and practical definition of I (0). Granger (1995) listed a few different nonlinear cointegration models given different functional forms. Granger and Swanson (1996) stated that the definition of cointegration becomes relaxed by allowing for generalizations of I (0), I (1), and I (d) variables to be utilized by using time-varying parameter and nonlinear in mean generating mechanisms. Park and Phillips (2001) developed some new technology that makes possible the analysis of nonlinear regressions with unit root nonstationary time series.

The hidden cointegration model proposed by Granger and Yoon (2002) is a special case of the nonlinear cointegration model indeed. In the hidden cointegration framework,

$f(Y_t)$ and $g(X_t)$ are either $\sum_{i=1}^{t}\max(\Delta Y_i, d_Y)$, $\sum_{i=1}^{t}\max(\Delta X_i, d_X)$ or $\sum_{i=1}^{t}\min(\Delta Y_i, d_Y)$, $\sum_{i=1}^{t}\min(\Delta X_i, d_X)$. Time series are said to have the hidden cointegration if there are cointegrating relationships among the nonstationary components of them. The reason that this kind of cointegration is called the hidden cointegration is that although such time series are not cointegrated, there might be useful information *hidden* in their components to help understand their dynamic relationship.

A vector of time series variables is called fractionally cointegrated if the variables are integrated of order d>0.5 and there exists a linear combination of the variables with a smaller degree of integration d-b. The properties of fractionally cointegrated systems are analyzed by Cheung and Lai (1993), Jeganathan (1999), Marinucci and Robinson (2001), and Tsay (2000).

The stochastic cointegration model was discussed in D. Harris *et. al.* (2002). A stochastic cointegrating regression, allowing some or all of the variables to be conventionally or heteroscedastically integrated, encompassed heteroscedastic cointegration model proposed by Hansen (1992), and the conventional model of Engle and Granger (1987). The concept of cointegration in the stochastic cointegration modelling framework is much weaker than that of Engle-Granger cointegration because it require only that I (1) behaviour is absent, rather than requiring the presence of I (0) stationarity. As in Hansen's model, the concept of cointegration in the stochastic cointegration model is nonlinear and this generalizes Hansen's (1992) heteroscedastic cointegrating regression model, where the dependent variable is heteroscedastically integrated, but all the regressor variables are restricted to being conventionally integrated. In contrast to conventional and heteroscedastic cointegrating regression, ordinary least-squares (OLS) estimation is shown to be inconsistent, in general, in a stochastically cointegrating regression. As a solution, a new instrumental variables (IV) estimator is proposed and is shown to be consistent. Under a suitable exogeneity assumption, standard asymptotic inference on the stochastic cointegrating vector can be carried out based on the IV estimator.

2.2 Oil price- Macroeconomy Relationship

The oil price-macroeconomy relationship has been the subject of a larger number of studies since the energy crisis of the 1970s. Empirically, most previous studies have focused on the effects of oil price change on GDP/GNP fluctuations and aggregate employment.

2.2.1 Oil price movement and gross domestic/national production fluctuation

There are two significant findings about the effect of oil price changes on GDP or GNP fluctuations on the basis of the U.S. data. One is the negative linear relation between oil prices and output proposed by Hamilton (1983) and the other is the asymmetric relation based on oil price increases alone advocated by Mork (1989).

In an influential paper, Hamilton (1983) found within a vector autoregression (VAR) framework that oil price change has a strong causal and negative correlation with real U.S. GNP growth from 1948 to 1980. Hamilton (1983) demonstrated both the significance and the robustness of this finding on U.S. data both before and after the "oil crisis" of the 1970s. The view expressed by Hamilton (1983, 1988) is that oil shocks affect the macroeconomy primarily by depressing demand for key consumption and investment goods. Gisser and Goodwin (1986) and Tatom (1988), used alternative data and estimation procedures to demonstrate that Hamilton's basic findings held up. They have convincingly argued that oil prices were significant determinants of U.S. economic activity.

Burbidge and Harrison (1984) used international data and found significant impacts of oil shocks on real activity for five industrial countries. They determined the influence on five OECD economies including Canada of the large oil price increases in the 1970s. They estimated a seven-variable VAR model that is similar to that which Hamilton (1983) exploited. They found that the response of the Canadian and U.S. Consumer Product Index to the oil price increases was substantial. For the Industrial Production, the oil price exerts a sizable influence in the U.S. and U.K., but quite small in Canada.

Hamilton's (1983) finding focused on the period in which all oil price movements were upward. The oil price declines since 1985 have provided the data needed to test whether the macroeconomic effects of oil price increases and decreases are symmetric, that is, whether oil price declines are as beneficial as oil price increases of the same magnitude are detrimental to economic activity.

Mork (1989) based his investigation on a six-variable VAR model that extended the sample period to 1988:2. He pointed out that until the oil price collapse of late 1985, the major oil shocks since 1948 had been price increases. The correlation becomes only marginally significant, and more importantly, there is an asymmetry in effects: GNP growth has a definite negative correlation with oil price increases and a statistically insignificant correlation with oil prices decreases.

In order to examine the possibility of asymmetric persistence in GNP, Beaudry and Koop (1992) extended the standard ARMA representations of output growth by including the current depth of a recession (denoted CDR). They pointed out that negative innovations to GNP were observed to be much less persistent than positive ones: the effects of negative shocks would be mainly temporary while the effects of positive shocks would be very persistent. Therefore, they came to the conclusion that theories about temporary changes in output may be relevant for understanding contractions and recoveries, while theories about permanent changes in output may be more relevant for expansions.

Mory (1993) showed that increases and decreases in real oil prices have asymmetric effects on output and other macro-variables from 1951 to 1990 by using annual data.

Mork, Olsen and Mysen (1994) investigated the correlation between oil-price movements and GDP fluctuations for seven OECD countries. They considered the bivariate correlations as well as partial correlations within a reduced-form macroeconomic model. The bivariate results show a general pattern of negative correlations between GDP growth and real oil price increases. This correlation is significant at the 10% level for all countries except Canada. Furthermore, Norway shows a significantly positive correlation given the large relative magnitude of the oil sector in the Norwegian economy. In their paper, they also found some evidence of asymmetric effects. Furthermore, the results differ somewhat from country to country.

Lee *et. al.* (1995) argued that an oil price change is likely to have a greater impact on real GNP (and unemployment) in an environment where oil prices have been stable than in an environment where oil price movement has been frequent and erratic. An oil price shock variable is constructed and found to be highly significant in explaining economic growth across different sample periods. They found that positive normalized shocks have a powerful effect on growth while negative normalized shocks do not.

There are several channels proposed to account for the negative correlation between oil prices and economic activity. The most popular explanation posits that oil price increases lead to inflation that lowers the quantity of real balances in the system. Lower real balances produce recessions through familiar channels. Some (Darby (1982) and Bohi (1991)) also argued that counter-inflationary monetary policy responses to oil price increases are responsible for the real output losses associated with these shocks. A supply-side explanation focuses on the relation between oil and capital. If oil and capital are complements in the production process, then oil price increases lead to a decline in the economy's productive capacity as agents respond to higher oil prices by reducing their utilization of both oil and capital. In this way, oil price increases lead to negative output growth as the economy moves to a new steady-state equilibrium growth path.

2.2.2 Oil price and Unemployment Rate

Unemployment is significant in the study of macroeconomics. The literature on unemployment suggests that real oil prices and real interest rates are the primary determinants of unemployment.

Carruth *et. al.* (1998) developed an efficiency-wage model in which input prices affect the equilibrium rate of unemployment. Their results provided strong evidence that real oil prices cause unemployment across different sample periods. Also, they found the coefficient on real oil prices and interest rates in the cointegrating regression to be positive and the cointegration relationship is supported. They proved that the equilibrium unemployment rate depended upon firms' input prices, in particular, the real price of energy and the real cost of borrowing. Moreover, oil prices play a stronger and more significant role than real interest rates. The real oil price and real interest rate can explain the main postwar movements in the rate of U.S. joblessness.

Gil-Alana (2002) examines the relationship between unemployment, real oil price and real interest rates in Canada. Although these three variables are I (1), he argues that the discrete options I (1) and I(0) offered by classical cointegration analysis are rather restrictive. Instead of following the classical approach based on I (0) stationarity or I (1) cointegrating relationships, he used fractional cointegration techniques. That means that adjustment to equilibrium might take a longer time than suggested by standard cointegration tests.

Section 3

Hidden Cointegration Methodology

This section briefly reviews the hidden cointegration methodology first introduced by Granger and Yoon (2002) and crouching error correction models implied by hidden cointegration.

3.1 Hidden Cointegration

Consider the following two random walks without drifts;

$$X_t = X_{t-1} + \varepsilon_t = X_0 + \sum_{i=1}^{t} \varepsilon_i \tag{7}$$

and

$$Y_t = Y_{t-1} + \eta_t = Y_0 + \sum_{i=1}^{t} \eta_i \tag{8}$$

where t = 1, 2, …, and X_0 and Y_0 denote initial values. ε_i and η_i are white noises with zero means. Define new variables;

$$\varepsilon_t^+ = \max(\varepsilon_t, 0) \quad \text{and} \quad \varepsilon_t^- = \min(\varepsilon_t, 0) \tag{9}$$

Now, ε_t can be written as;

$$\varepsilon_t = \varepsilon_t^+ + \varepsilon_t^- \tag{10}$$

The summation of ε_t is;

$$\sum_{i=1}^{t} \varepsilon_i = \sum_{i=1}^{t} \varepsilon_i^+ + \sum_{i=1}^{t} \varepsilon_i^- \tag{11}$$

Setting $X_t^+ = \sum_{i=1}^{t} \varepsilon_i^+$ and $X_t^- = \sum_{i=1}^{t} \varepsilon_i^-$. Therefore, X_t can be decomposed as follows;

$$X_t = X_0 + X_t^+ + X_t^- \tag{12}$$

X_t^+ and X_t^- can be interpreted respectively as the cumulative sums of the positive and negative shocks. Note that $\Delta X_t^+ = \varepsilon_t^+$ and $\Delta X_t^- = \varepsilon_t^-$. In a similar fashion, Y_t can be decomposed as; $Y_t = Y_0 + Y_t^+ + Y_t^-$.

Schorderet (2002) characterizes the properties of X_t^+ and X_t^-. The main properties of X_t^+ and X_t^- include:

1) X_t^+ (respectively X_t^-) are non-decreasing (non-increasing) series in the sense that $X_t^+ \geq X_{t-1}^+$ and $X_t^- \leq X_{t-1}^-$.

2) X_t^+ and X_t^- are nonstationary series as a deterministic and a stochastic trend characterize their second order properties.

3) Cov $(\Delta X_t^-; \Delta X_t^+)$ = E (ΔX_t^-)E (ΔX_t^+)<0, which emphasizes that ΔX_t^- and ΔX_t^+ are strongly dependent.

For X and Y, Granger and Yoon (2002) are assumed to be non cointegrated. The definition of the hidden cointegration says that X and Y have hidden cointegration if their components are cointegrated each other. By definition, if any pair in $\{X_t^+, Y_t^+\}$, $\{X_t^+, Y_t^-\}$,$\{X_t^-, Y_t^+\}$ and $\{X_t^-, Y_t^-\}$ is cointegrated, X and Y have the hidden cointegration. For instance, if only $\{X_t^+, Y_t^+\}$ are found to be cointegrated which means that both X and Y are subject to common positive shocks. Even though X and Y are still not cointegrated, there is still some useful information hidden in the positive components.

Granger and Yoon (2002) explain in which case the hidden cointegration might exist. For convenience, they implicitly assume that neither $\{X_t^+, Y_t^-\}$ or $\{X_t^-, Y_t^+\}$ are cointegrated while they test for possible cointegration between them in empirical implementation. Four cases are discussed.

- Case 1: Neither $\{X_t^+, Y_t^+\}$ nor $\{X_t^-, Y_t^-\}$ are cointegrated.
- Case 2: Either $\{X_t^+, Y_t^+\}$ or $\{X_t^-, Y_t^-\}$ are cointegrated.
- Case 3: Both $\{X_t^+, Y_t^+\}$ and $\{X_t^-, Y_t^-\}$ are cointegrated, but with different cointegrating vectors.
- Case 4: Both $\{X_t^+, Y_t^+\}$ and $\{X_t^-, Y_t^-\}$ are cointegrated with same cointegrating vectors.

In case 1, X and Y have neither cointegration nor hidden cointegration. They are subject to positive and negative shocks, which have their own separate stochastic trends. In case 2, X and Y have either common positive or common negative shocks. Even though X and Y are still not cointegrated, they have more structure than available in the case 1. There is some valuable information hidden in the components. In case 3, X and Y have common positive and negative shocks. However, the common shocks are not cointegrated. X and Y are not cointegrated. Only in case 4, when the positive and negative shocks are cointegrated with the same cointegrating vectors at the same time, X and Y are cointegrated. Therefore, they conclude that cointegration is said to be a special phenomenon.

Granger and Yoon (2002) also showed that hidden cointegration is a simple example of nonlinear cointegration. For I (1) variables {X_t} and {Y_t}, they are linearly cointegrated if there exists α such that {$Y_t - \alpha X_t$} ~ I (0). Further, they are nonlinearly cointegrated if there is β such that {f (Y_t) $- \beta g$ (X_t)} ~ I (0) for certain nonlinear functions f and g. In the hidden cointegration framework, f (Y_t) like the function for g, is taken to be either $\sum_{i=1}^{t} \max(\Delta Y_t, 0)$ or $\sum_{i=1}^{t} \min(\Delta Y_t, 0)$ with a zero threshold.

3.2 Crouching Error Correction Models

If the data is cointegrated, error correction models (ECMs) are estimated; otherwise, VAR models are estimated in a first difference form. In order to correspond to the hidden cointegration, Granger and Yoon introduced a crouching ECM. Crouching ECMs are standard ECMs, except for the fact that they show long-run equilibrium relationship and short-run dynamics of nonstationary components of data series, rather than the data themselves.

In case 2, $\{X_t^+, Y_t^+\}$ are cointegrated with a cointegrating vector of (1, -1). They have the following the crouching ECM;

$$\Delta X_t^+ = \gamma_0 + \gamma_1 \left(X_{t-1}^+ - Y_{t-1}^+ \right) + \text{lags}(\Delta X_{t-1}^+, \Delta Y_{t-1}^+) + \xi_t \tag{13}$$

$$\Delta Y_t^+ = \gamma_0 + \gamma_1 \left(X_{t-1}^+ - Y_{t-1}^+ \right) + \text{lags}(\Delta X_{t-1}^+, \Delta Y_{t-1}^+) + \zeta_t \tag{14}$$

where $\text{lags}(\Delta X_{t-1}^+, \Delta Y_{t-1}^+)$ indicates additional terms with various lags of ΔX_{t-1}^+ and ΔY_{t-1}^+. ζ_t and ξ_t are white noises as usual.

In case 3, $\{X_t^-, Y_t^-\}$ are cointegrated as well, with a different cointegration vector of

(1, -*k*), k≠1. The crouching ECMs are as follow;

$$\Delta X_t^+ = \gamma_0 + \gamma_1\left(X_{t-1}^+ - Y_{t-1}^+\right) + \gamma_2\left(X_{t-1}^- - kY_{t-1}^-\right) + \text{lags}(\Delta X_{t-1}^+, \Delta Y_{t-1}^+, \Delta X_{t-1}^-, \Delta Y_{t-1}^-) + \xi_t \quad (15)$$

and

$$\Delta Y_t^+ = \delta_0 + \delta_1\left(X_{t-1}^+ - Y_{t-1}^+\right) + \delta_2\left(X_{t-1}^- - kY_{t-1}^-\right) + \text{lags}(\Delta X_{t-1}^+, \Delta Y_{t-1}^+, \Delta X_{t-1}^-, \Delta Y_{t-1}^-) + \zeta_t \quad (16)$$

Finally for case 4, assume that (1, -1) is a common cointegrating vector and that X and Y has the following standard error correction models:

$$\Delta X_t = \gamma_0 + \gamma\left(X_{t-1} - Y_{t-1}\right) + \text{lags}(\Delta X_{t-1}, \Delta Y_{t-1}) + \xi_t \quad (17)$$

and

$$\Delta Y_t = \delta_0 + \delta\left(X_{t-1} - Y_{t-1}\right) + \text{lags}(\Delta X_{t-1}, \Delta Y_{t-1}) + \zeta_t \quad (18)$$

By rewriting equation (2) as follows:

$$\Delta X_t = \gamma_0 + \gamma\left(X_{t-1}^+ - Y_{t-1}^+\right) + \gamma\left(X_{t-1}^- - Y_{t-1}^-\right) + \text{lags}(\Delta X_{t-1}^+ + \Delta X_{t-1}^-, \Delta Y_{t-1}^+ + \Delta Y_{t-1}^-) + \xi_t \quad (19)$$

Therefore, $\gamma_1 = \gamma_2 = \gamma$ and the coefficients associated with ΔX_{t-k}^+ and ΔX_{t-k}^-, k=1,2... should be the same. Similarly for ΔY_{t-k}^+ and ΔY_{t-k}^-. Here we can see that the crouching ECMs are more general than the conventional ECMs because they put fewer restrictions on their coefficients.

Section 4

Empirical Regressions and Results

In section 4.1, we describe the two pairs of data used. The Augmented Dickey-Fuller (ADF) and KPSS tests are applied to investigate the existence of unit root in both pairs of data. In section 4.3, cointegration is tested through the two-step Eagle-Granger procedure. As cointegration relationship is not found in both data sets, the hidden cointegration technique is utilized in the section 4.4. The hidden cointegration relationships are found although they are not strong. Finally, crouching ECMs are discussed in section 4.5.

4.1 Data Description

There are two sets of data used. For the first set, we studied monthly data on the real crude oil prices and the total unemployment rate in Canada over the period from January 1961 to December 2000. Because of the availability of data, the real Canadian GDP and real crude oil price data are on the quarterly basis from 1st quarter of 1961 to 4th quarter of 2000.

We used the West Texas Intermediate (WTI) spot price for crude oil price, obtained on the monthly basis from the Federal Reserve Economics Data II (FREDII) bulletin board of the Federal Reserve Bank of St. Louis. This price is generally thought of as the benchmark price for crude oil in North America. From 1961 to 1981, the WTI crude oil price was adjusted on a quarterly basis by the Texas Railroad Commission (TRC) and it has been a market-based price since 1982. Therefore, we will investigate the data both in the full sample and subsample from 1982 to 2000. The WTI spot prices are transformed into the real term deflating by CPI Index. Quarterly real oil price data is derived from the average of the monthly data.

The real Canadian GDP data are derived from CANSIM II on a quarterly basis. The real GDP data are transformed into log. The total Canadian unemployment rates are in % and derived from two databases. Prior to 1976, the data are obtained from the hard copies of Statistics Canada saved in the form of the Microfiche. The unemployment rate data after 1976 are from CANSIM II.

The pattern of the monthly real oil price (OIL) and the monthly total unemployment rate (UR) is shown in Figure 1. Figure 2 illustrates the quarterly real Canadian GDP (GDP) and the quarterly real crude oil price (OIL).

4.2. Unit Root Tests

It is natural to investigate unit roots in the data set before we make any inference due to the 'nonsense regression' problems caused by the presence of nonstationarity. A wide variety of unit root tests have been developed in the last two decades but a common major problem of these tests is that none is very powerful. Moreover, most tests require the use of special critical values, even when the test statistic itself takes a familiar form. In this paper, we select two unit root tests: Augmented Dickey-Fuller test and KPSS test.

The ADF test seems to be the most popular unit root test. In the ADF test, the following regression is estimated by OLS:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \rho y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta y_{t-j} + \varepsilon_t \tag{20}$$

The ADF unit root "t-tests" are computed. The null of hypothesis of a single unit root is rejected if ρ is negative and significantly different from zero. For these tests, one adds lagged difference of the series until the residuals ε_t are white noise. Although the appropriate number of lagged difference *p* is rarely know, RATS 5.02 provides five methods based on information criteria to determine it. They are AIC, BIC, Ljung-Box tests, LM tests and the general to simple selection methods. In general, the BIC, Ljung-Box tests, and LM tests pick out the same optimal lag length for the ADF regression (plus or minus one). The AIC and the general to simple selection methods will generally pick out the same lag length (plus or minus one), which will always be at least as large as the lag length BIC, LB, and LM tests. The BIC, LB and LM give a more parsimonious lag structure.

The vast majority of unit root tests have non-stationarity, that is, a unit root, as the null hypothesis. It is because the traditional classical testing methodology accepts the null hypothesis unless there is strong evidence against it. Unit root tests usually conclude that there is a unit root. This problem is exacerbated by the fact that unit root tests generally have low power. KPSS test introduced by Kwiatkowski *et. al.* (1992) suggested tests for a null hypothesis of stationarity against the alternative of existing unit root. Kwiatkowski *et. al.* (1992) do this by modeling a time series as a sum of deterministic trend, a random walk and a stationary error. A test for the random walk having zero variance is then carried out. KPSS procedure calculates ETA (mu) and ETA (tau) statistics. With ETA (mu), testing H_0: {X (t)} is stationary around a level. With ETA (tau), testing H_0: {X (t)} is trend stationary.

The results of ADF test and KPSS test by RATS 5.02 are reported in Table 1 and Table 2 respectively.

In Table 1, we investigated unit root in these four variables in two cases subject to the inclusion of time trend: 1) with constant and no trend and, 2) with constant and with trend. We also test the unit root in the subsample from 1982 to 2000. Critical values at the 5 percent significant level are computed through RATS 5.02 where there is a routine called EGCRTVAL.SRC designed to calculate the exact critical value. The results in Table 1 show that all the ADF test values except for one are smaller than the critical value at the 5% significant level so we do not reject the null hypothesis that a unit root exists. In the second case, with constant and with trend, the ADF test value for the quarterly real GDP exceeds the critical value absolute term and this indicates that the time series may be trend stationarity. However, the KPSS results in Table 2 show that we reject the hypothesis of trend stationarity.

In Table 2, we investigate the unit root in both cases: 1) the stationarity with drift and, 2) the stationary trend. KPSS tests reject the stationarity of each series in both cases. Based on the results from the ADF tests and KPSS tests, we conclude that unit roots do exist in each series.

In order to verify whether these time series are integrated of order one, Table 1.1 and Table 2.1 present the results of unit root test on the first differenced data. Since the first differenced data of each series are uniformly stationary, we conclude that each time series is integrated of order one, I (1).

4.3 Cointegration Tests

Since these time series have the same integrated order, the existence of cointegration relationship among them is tested for. There are two popularly used methodologies to test the cointegration. One that we have known is the two-stage Engle-Granger procedure that is a residual-based test for cointegration. In the first stage, OLS is applied to conduct the regression and produce the regression residuals. In the second stage, ADF test is employed to find a unit root in the residuals. If there exists the unit root in the residuals, no cointegration is concluded. Otherwise, if the residuals are white noise we should reject the null hypothesis of no cointegration.

The other methodology to test for cointegration is known as the Johansen Maximum Likelihood procedure. Compared to the Engle-Granger procedure, the Johansen method has few advantages such as dealing automatically with the problem of choosing normalization, increasing the efficiency of estimation and allowing testing of restrictions on the cointegrating vectors.

For residual based tests for cointegration, one of the advantages is its simplification. Moreover, Hansen and Phillips (1990) showed Johansen Maximum Likelihood procedure have much lower power than residual based tests, especially as the number of variables increases. As well, Haug (1993, 1996) in his Monte Carlo studies found that the ADF test is relatively powerful compared to other tests. Therefore, we follow Granger and Yoon (2002) work and adopted the traditional Engle-Granger procedure to test for cointegration.

One of the main objectives of this paper is to find and verify how the change in real oil price influences macroeconomy. We therefore have the real oil price as an independent variable, the unemployment rate and the real Canadian GDP as a dependent respectively. Again, we will discuss two cases subject to the inclusion of time trend when we investigate unit roots.

Table 3 presents the OLS regressions in the stage 1 and the ADF test values for the residuals in the stage 2. The critical values are generated through RATS 5.02. For the first data set, the unemployment and the real oil price, we run OLS and collect the regression residuals. The values in the parenthesis are t-statistic. Now we find there is a seemingly positive relationship between the real oil price and the unemployment rate. However, the robustness of this conclusion highly relies on the existence of cointegration. If no cointegration is found, the above regression obtained by OLS is spurious. Therefore, in the second stage of Engle-Granger procedure, we apply the ADF test to the *resid1* and investigate whether it is stationary. In the table 3, the ADF t-test values are lower than the critical value at the 5 percent significant level, which means that we do not reject the null hypothesis of no cointegration. We cannot find the cointegration relationship although both the unemployment and the real oil price are integrated order of one.

For the second data set, the signs on the coefficient of the real oil prices in the full sample are opposite to those in the subsample from 1982:01 to 2000:04. As well, the ADF results both in the full sample and subsample show that there are no cointegration relationship between the real GDP and the real oil prices. Therefore, we do not conclude whether the correlation between oil price movements and real GDP fluctuation is positive or negative. Some information is hidden in these series and further investigation is needed.

4.4 Hidden Cointegration Tests

Although we cannot find cointegration in both data sets, there is some useful information *hidden* in these data sets that help us to study how real oil prices affect macroeconomy. The hidden cointegration says that when the components of those time series are cointegrated, that cointegration relationship would tell us what information is hidden. Therefore, what we do next is to determine the cointegration among data components.

4.4.1 Data Manipulation

Following the methodology in Part III, we choose zero as the threshold and divided a variable into three components:

$$X_t = X_0 + X_t^+ + X_t^- \tag{21}$$

X_t^+ (or X_t^-) represents the cumulative sums of positive (or negative) shocks. Specifically, in the two data sets: the unemployment rate (UR) and the real oil price (OIL_M) and the real Canadian GDP (GDP) and the real oil price (OIL_Q), we differenced those four variables at first and then calculate cumulative sums of positive and negative shocks. Eight new variables were generated.

	X_t^+	X_t^-
UR	$UR_t^+ = \sum_{i=1961:01}^{t} \Delta UR_i^+$	$UR_t^- = \sum_{i=1961:01}^{t} \Delta UR_i^-$
OIL_M	$OIL\_M_t^+ = \sum_{i=1961:01}^{t} \Delta OIL\_M_i^+$	$OIL\_M_t^- = \sum_{i=1961:01}^{t} \Delta OIL\_M_i^-$
GDP	$GDP_t^+ = \sum_{i=1961:01}^{t} \Delta GDP_i^+$	$GDP_t^- = \sum_{i=1961:01}^{t} \Delta GDP_i^-$
OIL_Q	$OIL\_Q_t^+ = \sum_{i=1961:01}^{t} \Delta OIL\_Q_i^+$	$OIL\_Q_t^- = \sum_{i=1961:01}^{t} \Delta OIL\_Q_i^-$

One of the important properties of $X_t^+ (X_t^-)$ given by Granger and Yoon (2002) is that $X_t^+ (X_t^-)$ is a random walk with drift. Figure 3 and 4 illustrate these four variables.

4.4.2 Hidden Cointegration test

Our objective is to investigate the existence of cointegration among components of non-cointegrated nonstationary series. For each pair of data, we have four combinations of cumulative sums of positive or negative shocks to test: $\{X_t^+, Y_t^+\}$, $\{X_t^+, Y_t^-\}$, $\{X_t^-, Y_t^+\}$ and $\{X_t^-, Y_t^-\}$.

Table 4 and 5 present the results of hidden cointegration tests. As we can see from the Table 4, we find the hidden cointegration in the data set of UR_t^- and OIL_t^-, which implies that falling real oil price would reduce unemployment in the long run although unemployment and real oil price do not share a common stochastic trend. The following hidden cointegration regression in the full sample is estimated with OLS;

$$UR_t^- = \underset{(-42.73)}{-13.41} + \underset{(53.09)}{0.15} \times OIL_t^- + residual_t \tag{22}$$

where t-values are reported in the parentheses. In the subsample, the OLS regression is;

$$UR_t^- = \underset{(-60.06)}{-17.06} + \underset{(70.78)}{0.13} \times OIL_t^- + residual_t \tag{23}$$

where t-values are reported in the parentheses. We found a positive correlation between oil price decreases and unemployment rate declines, but we did not find how the increase in oil price influences the unemployment rate movement.

In Table 5, we cannot find the hidden cointegration between GDP and oil price in the full sample data. In the subsample data, the following hidden cointegrating regression was found; the increase in the oil price will have a negative impact on Canadian economy.

$$GDP_t^- = \underset{(-49.18)}{-1.42} - \underset{(-37.92)}{0.29} \times OIL_t^+ + residual_t \tag{24}$$

4.5 Crouching Error Correction Models

As Engle and Granger (1987) pointed out that the existence of cointegration between a set of economic variables provides a statistical foundation for the use of ECM models. Granger and Yoon (2002) named an ECM implied by hidden cointegration as a crouching error correction model (CECM). We give the following CECMs after eliminating insignificant terms.

$$\begin{aligned}
\Delta GDP_t^- &= -\underset{(-3.42)}{0.02} - \underset{(-2.27)}{0.07} \times resid_{t-1} + \underset{(2.75)}{0.04} \times \Delta OIL_Q_{t-5}^+ + \underset{(7.56)}{0.92} \times \Delta GDP_{t-4}^- \\
&- \underset{(-2.98)}{0.36} \times \Delta GDP_{t-7}^+ \qquad (25) \\
\overline{R}^2 &= 0.87
\end{aligned}$$

In the full sample data, we obtain the following CECM after eliminating insignificant terms;

$$\begin{aligned}
\Delta UR_t^- &= -\underset{(-3.75)}{0.26} - \underset{(-2.31)}{0.004} \times resid_{t-1} - \underset{(-2.58)}{1.50} \times \Delta OIL_M_{t-6}^- + \underset{(4.02)}{2.36} \times \Delta OIL_M_{t-7}^- \\
&- \underset{(-2.33)}{0.14} \times \Delta UR_{t-5}^- - \underset{(-2.38)}{0.15} \times \Delta UR_{t-6}^- - \underset{(-2.16)}{0.13} \times \Delta UR_{t-10}^- + \underset{(8.85)}{0.52} \times \Delta UR_{t-12}^- \qquad (26) \\
\overline{R}^2 &= 0.32
\end{aligned}$$

For the subsample from 1982:02 to 2000:12, the CECM is;

$$\begin{aligned}
\Delta UR_t^- &= -\underset{(-3.07)}{0.54} - \underset{(-2.24)}{1.87} \times \Delta OIL_M_{t-6}^- + \underset{(3.52)}{2.99} \times \Delta OIL_M_{t-7}^- - \underset{(-2.11)}{0.30} \times \Delta UR_{t-6}^- \\
&+ \underset{(2.20)}{0.31} \times \Delta UR_{t-12}^- \\
\overline{R}^2 &= 0.15
\end{aligned}$$

(27)

T-values are reported in the parentheses. The error correcting term is not significant in the subsample UR equation. Note that the $\overline{R}^2$ in the subsample is only half of that in the full sample.

These CECMs appear to support two findings mentioned in the literature review. First of all, we observe the negative correlation between oil prices and Canadian macroeconomic activity since a positive relation between oil price and unemployment rate implies the negative correlation between oil price and *employment.*

Secondly, the hidden cointegration relationships in two different data sets reflect an asymmetric effect of the oil price movements on macroeconomy. On the one hand, the decrease in the oil price would lead to the reduction in the unemployment rate in the long run while we do not observe the evidence that oil price increases have negative impacts on unemployment level. On the other hand, the Canadian gross domestic production does not benefit from the reduction in oil prices but is harmed from the increase in oil prices.

Our empirical results indicate that although we do not observe the regular cointegration in both data sets, we do find the hidden cointegration. The hidden cointegration reveals a long run relation between the oil price and macro indicators in Canada like GDP and unemployment rate. The information hidden in these two data sets is similar to that expressed by two findings we mentioned in part II, but somewhat different from them. Previous study (Mork *et. al.* 1994) shows that oil price increases have a negative effect on both GDP growth and aggregate employment in Canada. Our results however, indicates that the oil price increases have an adverse impact on GDP, but not on unemployment rate while the reduction in real oil prices will lead to the unemployment rate decline and GDP growth however is not beneficial from it. Besides, our results are also partially consistent with conclusions made by Beaudry and Koop (1992). Beaudry and Koop (1992) applied an extended ARMA representation to examine the possibility of asymmetric persistence in GNP. They observed that negative innovations to GNP are much less persistent than positive ones. In our paper, we do observe positive innovations are more persistent that negative ones in the data set of real GDP and real oil prices. We only long run hidden cointegration in the correlation between negative GDP accumulative shocks (GDP_t^-) and positive oil price accumulative shocks (OIL_t^+). However, in the case of aggregate employment we do not support their findings. Our empirical results show that negative innovations of oil prices have persistent effects on aggregate employment. What we support in this paper is the asymmetric effect of oil price movements on macroeconomic indicators such as real GDP and unemployment rate. This kind of asymmetry is different across various macroeconomic variables and may be varied across different countries.

We try to give explanations for where this kind of asymmetry originates. First of all, the change of Canada's role in oil production may be one of the sources of asymmetry. Since the 1970s, Canada has moved back and forth between a position of net oil importer and a position of net oil exporter over time. The position of net oil exporter causes a positive correlation between oil price and economic performance. As Mork *et. al.* (1994) showed that the correlation with oil-price increases is positive and significant for Norway, whose oil-producing sector is large relative to the economy as a whole. On the other hand, a position of net oil importer will result in a negative correlation as many previous studies observed in the U.S. and Japan cases. The uncertainty of Canada's role in oil production might cause this sort of asymmetry. Secondly, the monetary policy's response to oil price movements may account for asymmetry. From the Bank of Canada's point view, it may adopt the contradictionary monetary policy to mitigate the negative effect of oil price increase on economic activity while it may do nothing in response for the oil price decline. The different response of the monetary policy leads to that the negative effect of oil price increase on macroeconomy is more significant than the positive effect of oil price decline. The third possible explanation is about adjustment costs to changing oil prices. Falling oil price stimulates economic activity and rising oil price retards economic activity. However, the adjustment cost to changing oil prices also retards economic activity. Combining these elements, we see that rising oil price would present both negative effects on economic activity. Falling oil price would present both a positive and a negative effect that would be offsetting. Asymmetry could be the result of adjustment costs to changing oil prices.

Section 5

Conclusion

The oil price-macroeconomy relationship has been the subject of a larger number of studies since the energy crisis of the 1970s. Most previous studies have focused on the effects of oil price changes on GDP fluctuations and aggregate employment using vector autoregression models. In this paper however, we do not follow previous studies' methodology, but instead used the hidden cointegration technique proposed by Granger and Yoon (2002) to examine the oil price-macroeconomy relationship in Canada. As Granger and Yoon (2002) pointed out, cointegration is actually a special phenomenon of hidden cointegration. The hidden cointegration methodology is developed to reveal the long run relationship among non-cointegrating time series since although these series are not cointegrated, there may be some useful information *hidden* in them.

Two macroeconomic indicators, the real Canadian GDP and the total Canadian unemployment rate, were studied. We investigate two pairs of data: the real oil price and the unemployment rate, and the real oil price and Canadian real GDP from 1961 to 2000 and also examine the subsample data from 1982 to 2000 considering the existence of oil price breaks. The Engle-Granger two-stage cointegration procedure is applied to perform cointegration and hidden cointegration test due to its simplicity and greater power (Hansen and Phillips, 1990).

Our empirical results do not support regular cointegration relation in both data sets across different sample periods although all variables are integrated of order 1, I (1). We then apply the hidden cointegration procedure to both data sets and found that there exist hidden cointegrations in both data sets. A reduction in oil price has a positive effect on the unemployment rate while oil prices increases will be harmful to Canadian real GDP growth.

Our study is somewhat different from previous studies that show oil price increases have negative effects on both GDP growth and aggregate employment in Canada. Our results indicate that the oil price increases only have adverse impact on GDP, but not on the unemployment rate. As well, our results are partially consistent with conclusions made by Beaudry and Koop (1992). In the case of real GDP, we support their findings that negative innovations to GNP are much less persistent than positive ones. In the case of aggregate employment however, we found that negative innovations of oil prices had a persistent effect on aggregate employment.

The information hidden in the long run cointegration relationship reflects an asymmetric effect of the oil price movements on the Canadian macroeconomy. We present a few explanations for the asymmetry. The uncertainty on Canada's role in oil production is one of the sources of asymmetry. Different responses of the central bank to oil price movements may be another possible explanation. Finally, we also argue that adjustment cost to changing oil prices could also account for asymmetry.

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Table 1. ADF Unit Root Tests

	With drift No trend		With drift With trend	
	1982:01-2000:12	Full sample	1982:01-2000:12	Full sample
Unemployment Rate (monthly)	-2.66[1]	-1.29[0]	-2.91[1]	-1.53[0]
Real Oil Price (monthly)	-0.55[0]	-1.95[1]	-1.69[0]	-1.92 [1]
Critical Value (5%)	-2.87	-2.87	-3.43	-3.42
	1982:01-2000:04	Full sample	1982:01-2000:04	Full sample
Real GDP (quarterly)	-1.46[4]	-1.79[4]	-3.55[4]*	-2.27[4]
Real Oil Price (quarterly)	-2.70[3]	-1.65[0]	-2.47[3]	-1.65[0]
Critical Value (5%)	-2.90	-2.88	-3.47	-3.44

Note:
Numbers in the square parentheses determined by the BIC criterion are lag orders used in the ADF tests.
The critical values are calculated through EGCRTVAL.SRC in RATS 5.02.
*: indicates that value is greater than the corresponding critical value.

Table 1.1 ADF Unit Root Tests (For Differenced Data)

	With drift No trend		With drift With trend	
	1982:01- 2000:12	Full sample	1982:01- 2000:12	Full sample
Unemployment Rate (monthly)	-11.97[0]	-22.36[0]	-12.06[0]	-22.24[0]
Real Oil Price (monthly)	-10.78[1]	-16.41[0]	-10.80[1]	-16.40[0]
Critical Value (5%)	-2.87	-2.87	-3.43	-3.42
	1982:02- 2000:04	Full sample	1982:02- 2000:04	Full sample
Real GDP (quarterly)	-3.14[4]	-4.86[6]	-3.14[4]*	-5.54[6]
Real Oil Price (quarterly)	-7.37[0]	-10.79[0]	-7.55[0]	-10.75[0]
Critical Value (5%)	-2.90	-2.88	-3.47	-3.44

Note:
Numbers in the square parentheses determined by the BIC criterion are lag orders used in the ADF tests.
The critical values are calculated through EGCRTVAL.SRC in RATS 5.02.
*: indicates that value is not statistically significant.

Table 2. KPSS Unit Root Tests

	Stationarity with drift ETA (mu) Values		Trend stationary ETA (tau) Values	
	1982:1-2000:12	Full Sample	1982:1-2000:12	Full Sample
Unemployment Rate	2.61	5.59	0.67	0.82
Real Oil Price	1.21	1.61	0.41	1.47
Critical Value (5%)	0.463	0.463	0.146	0.146
	1982:01-2000:04	Full Sample	1982:1-2000:04	Full Sample
Real Oil Price	0.98	0.69	0.22	0.56
Real GDP	1.53	3.27	0.18	0.71
Critical Value (5%)	0.463	0.463	0.146	0.146

Table 2.1 KPSS Unit Root Tests (for the differenced data)

	Stationarity with drift ETA (mu) Values		Trend stationarity ETA (tau) Values	
	1982:01-2000:12	Full Sample	1982:01-2000:12	Full Sample
Unemployment Rate	0.25	0.15	0.12	0.143
Real Oil Price	0.23	0.09	0.02	0.07
Critical Value (5%)	0.463	0.463	0.146	0.146
	1982:01-2000:04	Full Sample	1982:01-2000:04	Full Sample
Real Oil Price	0.21	0.08	0.04	0.07
Real GDP	0.08	0.25	0.08	0.05
Critical Value (5%)	0.463	0.463	0.146	0.146

Table 3. Engle-Granger Cointegration Tests

Stage 1:

Full Sample

Without Trend: $UR_t = \underset{(31.74)}{6.36} + \underset{(7.71)}{0.05} \cdot OIL_t + RESID1_t$

With Trend: $UR_t = \underset{(22.56)}{4.10} + \underset{(20.79)}{0.01} \cdot TREND + \underset{(7.97)}{0.04} \cdot OIL_t + RESID1_t$

Without Trend: $GDP_t = \underset{(54.34)}{10.95} + \underset{(3.97)}{0.25} \cdot OIL_t + RESID2_t$

With Trend: $GDP_t = \underset{(303.78)}{10.80} + \underset{(70.27)}{0.01} \cdot TREND + \underset{(7.61)}{0.08} \cdot OIL_t + RESID2_t$

Subsample

Without Trend: $UR_t = \underset{(17.99)}{4.35} + \underset{(7.89)}{0.08} \cdot OIL_t + RESID1_t$

With Trend: $UR_t = \underset{(17.38)}{4.17} + \underset{(1.85)}{0.005} \cdot TREND + \underset{(3.81)}{0.06} \cdot OIL_t + RESID1_t$

Without Trend: $GDP_t = \underset{(119.62)}{12.98} - \underset{(-8.38)}{0.28} \cdot OIL_t + RESID2_t$

With Trend: $GDP_t = \underset{(176.38)}{11.88} + \underset{(20.77)}{0.01} \cdot TREND - \underset{(-8.86)}{0.016} \cdot OIL_t + RESID2_t$

Note:

Numbers in the square parentheses are t statistics.

Continued...

Table 3. Engle-Granger Cointegration Tests

Stage 2:

	Full Sample		Subsample	
	Without trend	With trend	Without trend	With trend
Residuals 1	-1.46[0]	-1.84[0]	-2.75[12]	-2.69[12]
Critical Value (5%)	-3.35	-3.80	-3.36	-3.82
Residuals 2	-1.19[8]	-2.69[8]	-0.86[4]	-3.13[4]
Critical Value (5%)	-3.38	-3.84	-3.42	-3.91

Note:
Numbers in the square parentheses determined by the BIC criterion are lag orders used in the ADF tests. The critical values are calculated through EGCRTVAL.SRC in RATS 5.02.

Table 4: Hidden Cointegration Tests

Dependent Variables (Y)	Independent Variables (X)	Full Sample (1961:02-2000:12)		Subsample (1982:02-2000:12)	
		Without trend	With trend	Without trend	With trend
UR^+	OIL_M^+	-1.92[1]	-1.83 [3]	-1.27[1]	-1.91[5]
UR^+	OIL_M^-	-1.09[1]	-2.59[3]	-1.54[1]	-2.17[5]
UR^-	OIL_M^+	-2.35[1]	-0.71[0]	-2.18[1]	-3.11 [0]
UR^-	OIL_M^-	-3.66[0]*	-0.63 [0]	-4.11[1]*	-2.02[0]
Critical Value (5%)		-3.35	-3.80	-3.36	-3.82

Note:
" * " indicates that the hidden cointegration relationship exists.
Numbers in the square parentheses determined by the BIC criterion are lag orders used in the ADF tests.
The critical values are calculated through EGCRTVAL.SRC in RATS 5.02.

Table 5: Hidden Cointegration Tests

Dependent Variables (Y)	Independent Variables (X)	Full Sample (1961:02-2000:04)		Subsample (1982:2-2000:04)	
		Without trend	With trend	Without trend	With trend
GDP^{+}	OIL_Q^{+}	-2.82[0]	-2.51[4]	-2.79[1]	-3.24[4]
GDP^{+}	OIL_Q^{-}	-2.74[3]	-2.52[4]	-1.71[2]	-2.25[13]
GDP^{-}	OIL_Q^{+}	-3.15[2]	-2.39[4]	-3.48[4]*	-3.47[4]
GDP^{-}	OIL_Q^{-}	-2.66[1]	-1.48[6]	-3.04[0]	-2.31[4]
Critical Value (5%)		-3.38	-3.84	-3.42	-3.91

Note:

“ * “ indicates that the hidden cointegration relationship exists.

Numbers in the square parentheses determined by the BIC criterion are lag orders used in the ADF tests.

The critical values are calculated through EGCRTVAL.SRC in RATS 5.02.

Figure 1 Oil Prices versus Unemployment Rates

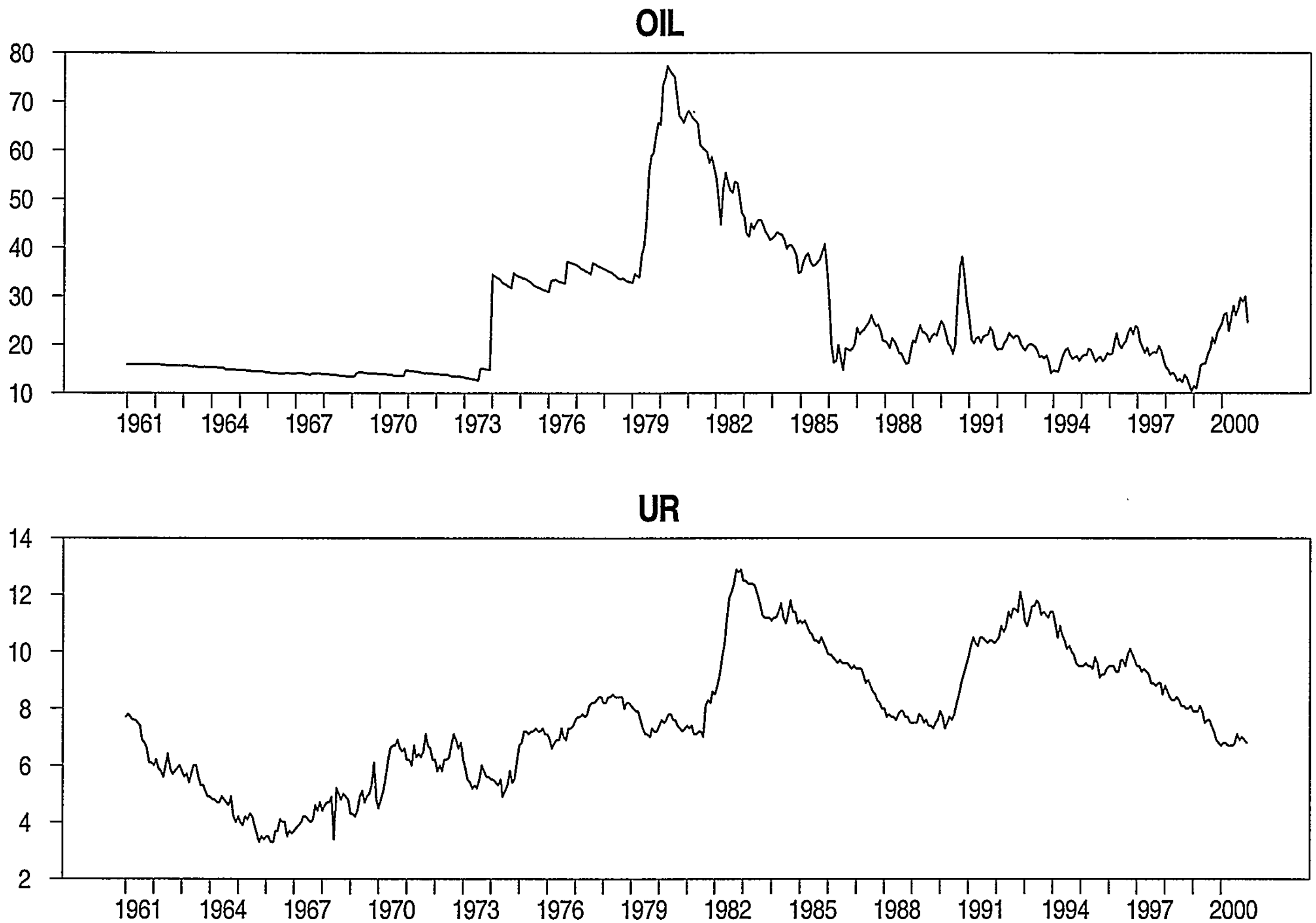
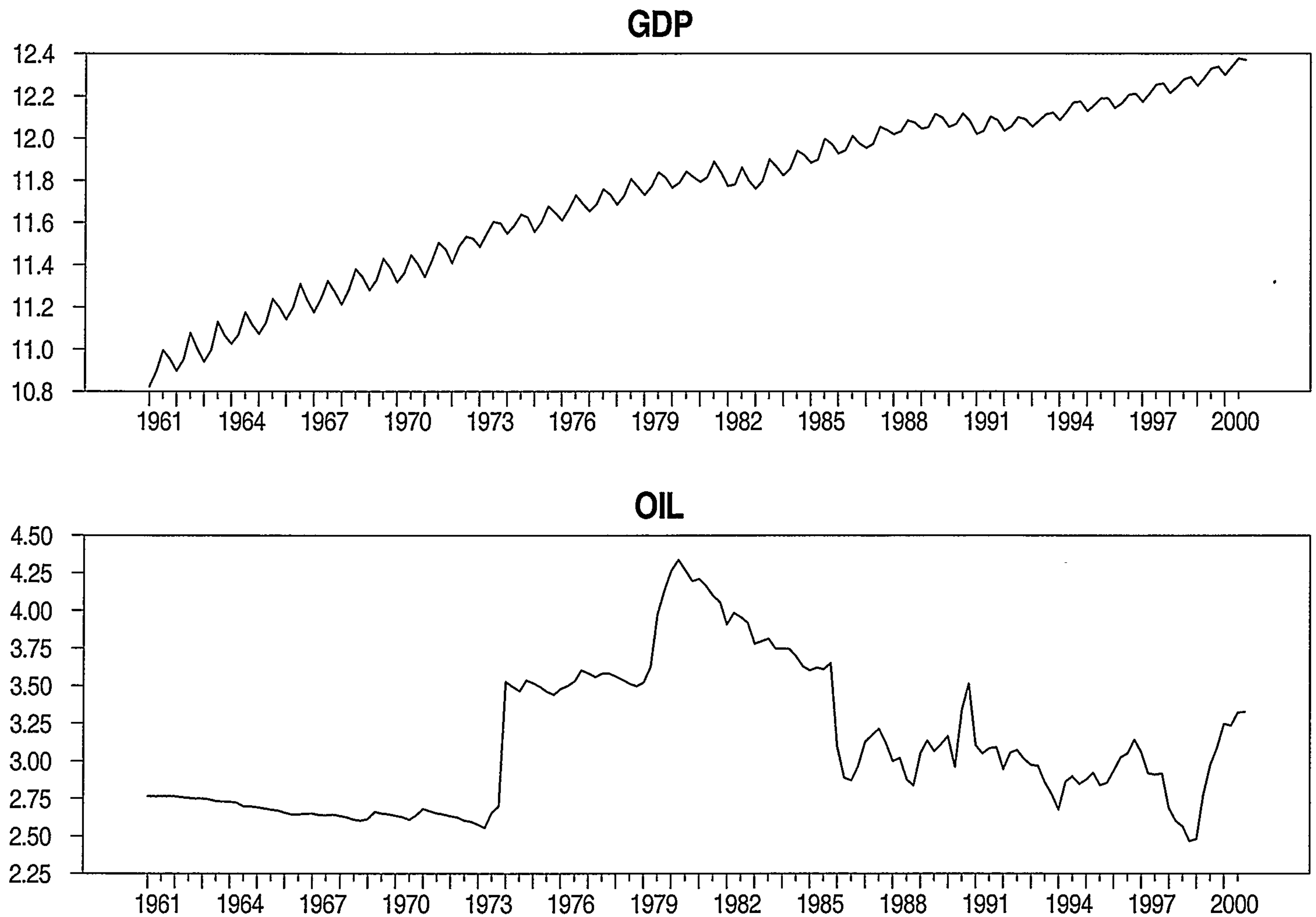


Figure 2 Oil Prices versus GDP



54

Figure 3 Components of Unemployment Rate and Oil Price

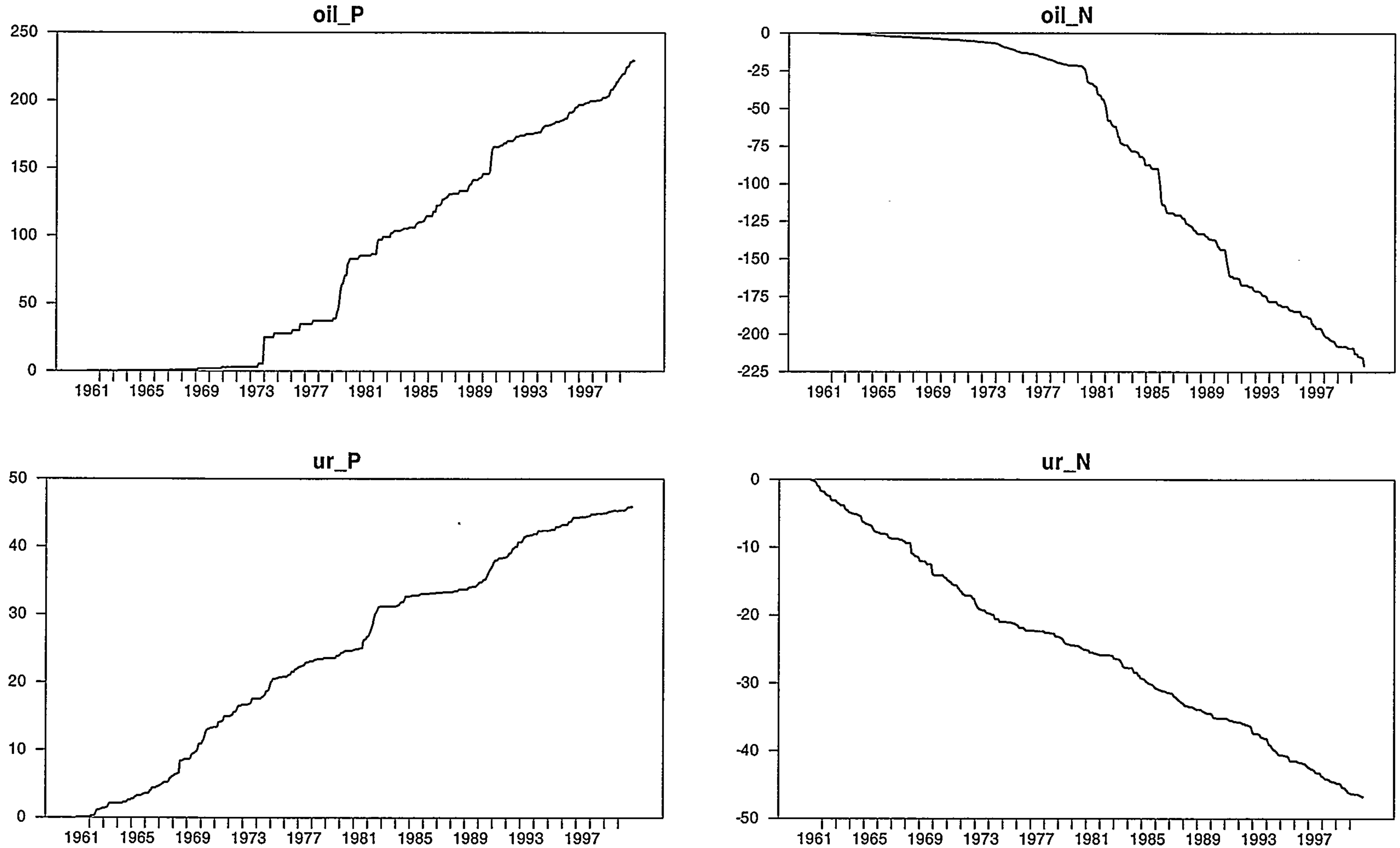


Figure 4 Components of GDP and Oil Price