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by

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Abstract

The effects of global energy-price shocks on retail energy prices in Canada are examined. More specifically, the author looks at the response of the consumer price indexes for gasoline, heating oil, natural gas, and electricity in Canada to movements in world crude oil prices. Using an error-correction framework, a quarterly forecasting model is estimated for most of these price indexes. The forecasting ability of the error-correction models is found to outperform that of competing autoregressive and random-walk models.

JEL classification: C22, C51, C53, Q40
Bank classification: Econometric and Statistical Methods; Inflation and Prices; Market Structure and Pricing

Résumé

L’auteur examine les effets des variations des prix mondiaux des hydrocarbures sur les prix à la consommation de l’énergie au Canada. Il se penche plus précisément sur les réactions des composantes essence, mazout, gaz naturel et électricité de l’indice des prix à la consommation aux variations des cours mondiaux du pétrole brut. À l’aide d’un modèle à correction d’erreurs, des prévisions trimestrielles sont établies pour la plupart de ces composantes. La capacité de prévision de ce type de modèle se révèle supérieure à celle d’un modèle autorégressif et d’une marche aléatoire.

Classification JEL : C22, C51, C53, Q40
Classification de la Banque : Méthodes économétriques et statistiques; Inflation et prix; Structure de marché et fixation des prix

1. Introduction

Significant price volatility in global energy markets is of interest to policy-makers, given the impact that unanticipated movements in energy prices can have on macroeconomic performance. Despite recent attempts by oil-producing nations to introduce some stability into oil prices, there continues to be difficulty in anticipating their movements and the implications for economic activity and inflation.

In this paper, we seek to understand the effect that global energy price shocks have on the consumer price index (CPI) in Canada. In particular, we examine the relationship that exists between world crude oil prices and the components of CPI-energy, namely, gasoline, heating oil, natural gas, and electricity. Recent movements in these components, while governed by many factors, have been notable and, in many instances, are attributable to fluctuations in world oil prices. As such, it is important to establish a better quantitative understanding of how these price indexes adjust to oil price shocks.

To that end, we attempt to build a quarterly forecasting model using an error-correction paradigm. The choice of such a framework is motivated by results that show that all the CPI-energy components and the price of crude oil exhibit unit-root behaviour. Furthermore, we find evidence of cointegration among the majority of the components of CPI-energy and crude oil prices. Given these results, we believe that a dynamic error-correction framework is a useful way to forecast retail energy-price movements.

Section 2 provides an overview of the various energy markets in Canada and highlights the major factors that influence price movements in those sectors. Section 3 briefly examines the National Energy Program implemented during the early 1980s, which led to the regulation of crude oil prices in Canada. Section 4 presents an econometric analysis, and we conclude in section 5.

2. Overview of Energy Markets

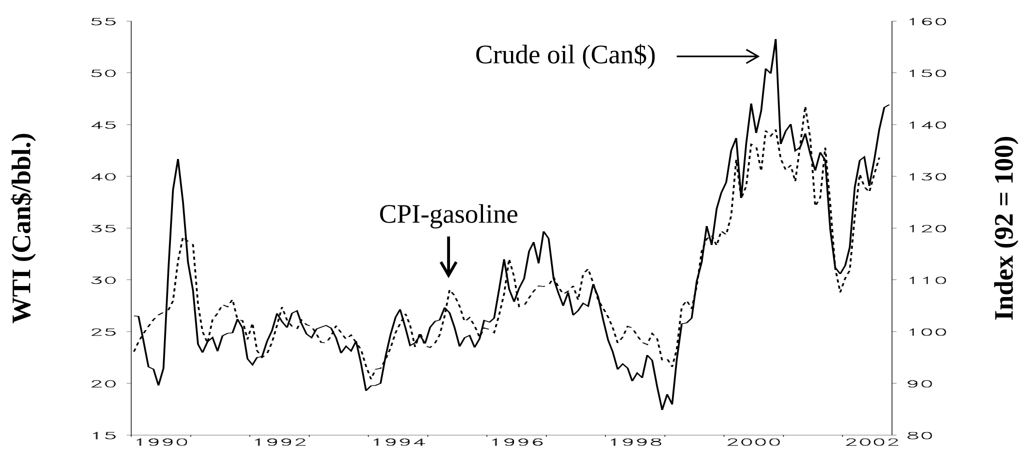
A common characteristic of Canadian energy markets is their high level of integration with those in the United States. This section presents a detailed analysis of each of these markets, starting with those that are more highly integrated with markets south of the border, namely, the gasoline, heating oil, and natural gas sectors. We conclude with a discussion of the Canadian electricity market.

2.1 The gasoline market

Gasoline has a weight of roughly 50 per cent in the overall consumer energy price index, CPI-energy. Thus, fluctuations in retail gasoline prices, also known as the pump price, heavily influence movements in the CPI-energy.

The retail price of gasoline is broken down into three components: crude costs, taxes, and a seller markup. The latter includes both a refiner margin and a retail margin. The refiner margin is the spread between the wholesale price of gasoline—the price charged by refineries to retailers—and the West Texas Intermediate (WTI) price of crude oil. The retail margin is the difference between the pump price and the wholesale price of gasoline. On average, crude oil costs account for about 30 per cent of the overall pump price, while taxes and the markup account for 50 per cent and 20 per cent of the overall price, respectively.[1] As such, changes in federal and provincial taxes and crude oil prices strongly influence retail gasoline prices, since they jointly amount to 80 per cent of the price charged to consumers. Given the relative stability of gasoline tax rates, most of the short-term volatility in gasoline prices can be attributed to fluctuations in world oil prices (Figure 1).

Figure 1: Crude Oil Prices and CPI-Gasoline



Sources: Bank of Canada, Statistics Canada

As mentioned, crude oil costs account for about one-third of the overall pump price. Thus, all else being equal, a 100 per cent change in crude oil prices should result in roughly a 30 per cent change in the pump price. Between January 1999 and November 2000, crude oil prices rose 180 per cent, while the gasoline CPI rose 50 per cent, approximately one-third of the increase in

1. Estimates are based on data from Natural Resources Canada (NRCan) for the period 1990 to 1997.

WTI prices. This represents a 100 per cent pass-through from crude oil to retail gasoline prices over that period.

Monthly correlation measures show that crude oil and gasoline prices tend to move in the same direction over time, with the correlation being strongest in the first two months of crude oil price changes (Table 1).

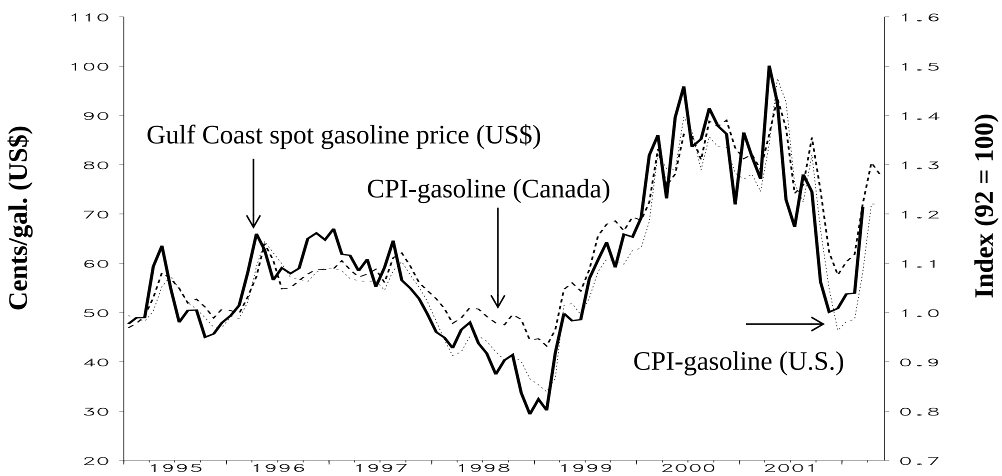
Table 1: Correlation between Crude Oil (WTI) Prices and CPI-Gasoline

	ΔCPI-gasoline[a]						
	(*t*)	**(*t* + 1)**	**(*t* + 2)**	**(*t* + 3)**	**(*t* + 4)**	**(*t* + 5)**	**(*t* + 6)**
Δ WTI(*t*,Can$)	0.44	0.50	0.16	0.10	–0.02	–0.25	–0.18

a. Correlation test results are based on monthly data for the period January 1990 to May 2002.

The Canadian market for gasoline is integrated with that of the United States, and as a result, prices in Canada are strongly affected by gasoline supply and demand factors south of the border. Given the integrated nature of the U.S. and Canadian gasoline markets, retail gasoline prices in Canada and the United States have exhibited similar price movements over time (Figure 2). This suggests that a U.S. activity measure could be useful for predicting fluctuations in Canadian gasoline prices.

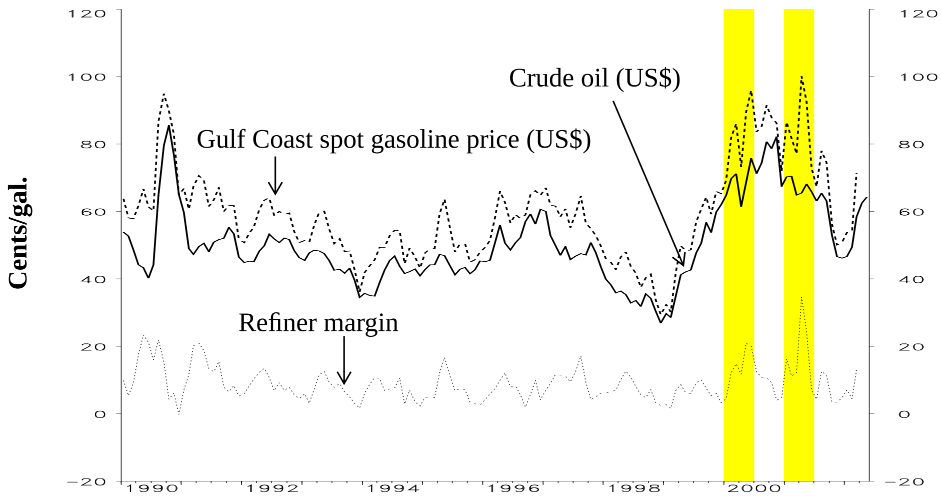
Figure 2: Wholesale and Retail Gasoline Prices—Canada and the United States



Sources: Bank of Canada, Energy Information Administration, Statistics Canada

Although the price of crude oil is a major factor affecting gasoline prices, the level of gasoline stocks also plays an important role in influencing short-run movements in pump prices. A tight inventory balance exerts upward pressure on wholesale prices beyond that attributable to crude oil prices. This widens the spread between spot gasoline and crude oil prices, also known as the refiner margin. This margin usually increases in the summer driving season and is more pronounced when stocks are low. The tight inventory conditions that prevailed in the United States in the 2000 and 2001 driving seasons led to a higher refiner margin than in previous years when petroleum inventories were greater (Figure 3).

Figure 3: Crude Oil Prices and U.S. Gulf Coast Conventional Gasoline Spot Prices



Sources: Bank of Canada, Energy Information Administration

2.2 The heating oil market

Similar to gasoline prices, the residential price of heating oil is broken down into three components: crude costs, a seller markup, and taxes. The seller markup includes a refiner margin and a retail margin. Crude oil costs account for about 50 per cent of the retail price, while the markup and taxes account for 40 per cent and 10 per cent, respectively.[2] As with gasoline, movements in crude oil prices heavily influence the price of heating oil, both in the short and long run. Monthly correlation measures show the strongest correlation between the current-period change in crude oil prices and the change in heating oil prices three months later (Table 2).

Table 2: Correlation between Crude Oil (WTI) Prices and CPI-Heating Oil

	ΔCPI-heating oil [a]						
	(*t*)	**(*t* + 1)**	**(*t* + 2)**	**(*t* + 3)**	**(*t* + 4)**	**(*t* + 5)**	**(*t* + 6)**
ΔWTI(*t*,Can$)	0.13	0.36	0.29	0.45	0.19	0.03	–0.07

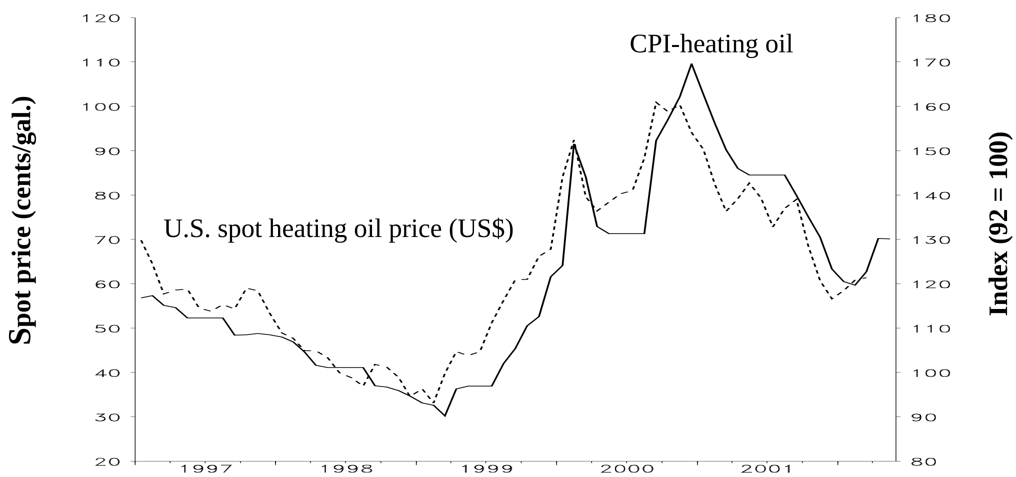
a. Correlation results are calculated using monthly data for the period January 1990 to May 2002.

2. Estimates are taken from *FuelFacts*, Canadian Petroleum Products Institute, February 2001.

These results show that crude oil prices and retail heating oil prices tend to move in the same direction. There seems to be a lag, however, between changes in their prices.

The Canadian heating oil market is also highly integrated with that of the United States. Canada is a net producer of heating oil and therefore exports significant volumes to the U.S. Northeast. Given the integrated nature of the North American oil markets, consumer prices in Canada are strongly affected by U.S. demand for heating oil, and thus, by wholesale prices in the United States (Figure 4).

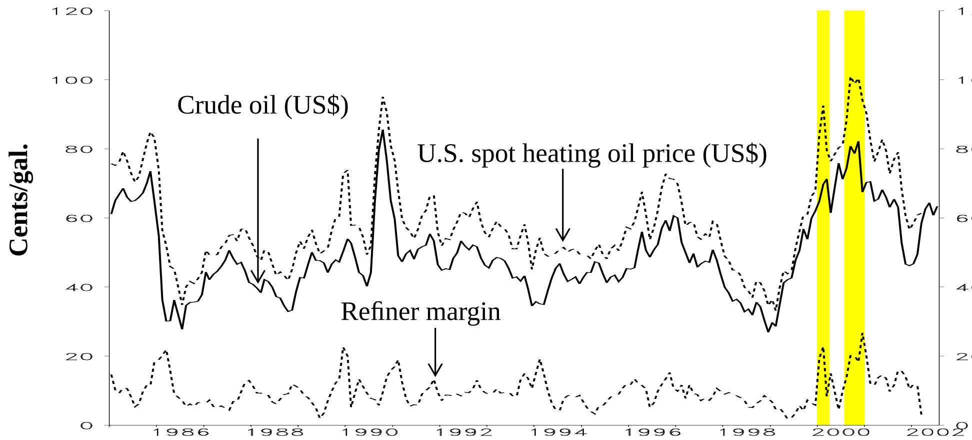
Figure 4: CPI-Heating Oil and U.S. Wholesale Heating Oil Prices



Source: Energy Information Administration, Statistics Canada

Although wholesale heating oil prices are heavily influenced by world crude oil prices, other important factors affect their behaviour in the near term. As with gasoline, the level of heating oil stocks has important implications for the short-term movements in heating oil prices. A tight inventory balance leaves the heating oil market susceptible to price volatility resulting from unusually cold winter temperatures. For example, in January 2000, a colder than normal winter snap hit the U.S. Northeast, resulting in a significant increase in heating oil demand. Given the tight oil supply conditions that prevailed at the time, the refiner margin increased significantly, pushing up wholesale prices. Colder than normal temperatures in the same U.S. region towards the end of 2000 also led to an increase in the refiner margin, leading to similar price dynamics (Figure 5).

Figure 5: Crude Oil Prices and U.S. Wholesale Heating Oil Prices



Sources: Bank of Canada, Energy Information Administration

Another factor that exacerbated price increases was fuel switching by industrial and commercial customers. As a result of spiking U.S. natural gas prices in the 2000–2001 winter season, industries, including electric utilities, switched to using residual fuel oil instead of natural gas. This incremental demand, although not large in itself, is likely to have had a significant impact on fuel oil prices under the existing tight supply conditions prevailing at the time.

2.3 The natural gas market

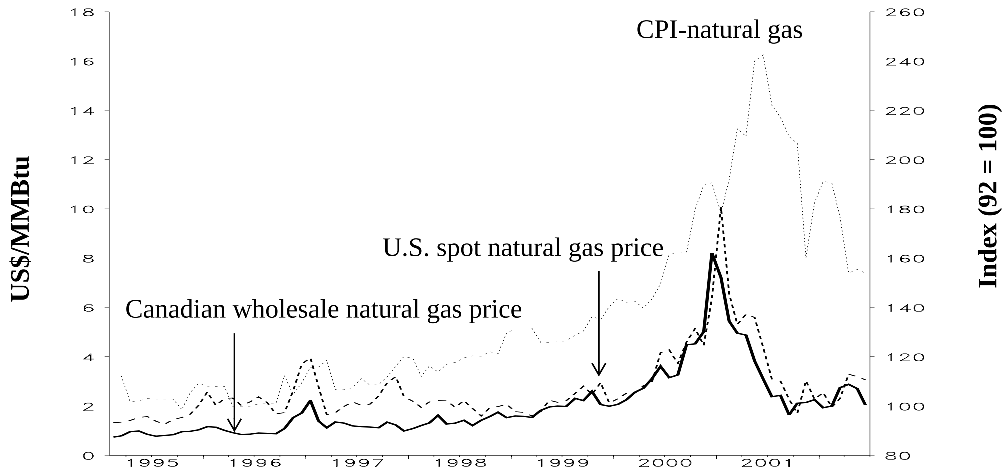
Recent price movements in natural gas have been particularly remarkable in the North American energy markets. Prompted by strong demand and low inventories in the United States, wholesale natural gas prices spiked in January 2001, rising 300 per cent year over year. The run-up in wholesale prices led to a sharp increase in retail gas prices, which prompted some provincial governments to offer consumer rebates to reduce the impact of rising gas costs. In this section, we highlight the main factors behind the recent rise in natural gas prices, in particular, the increase in residential charges.

The delivered price of natural gas to residential consumers has three components: the cost of natural gas consumption (the commodity cost), pipeline transportation costs, and a local distribution cost charged by local suppliers to end users. In 2000, the commodity cost accounted for roughly 60 per cent of total residential charges.[3] Since 1986, natural gas prices in Canada have been deregulated. Deregulation, however, only applies to the price of the natural gas commodity. Transmission and distribution costs are still subject to governmental regulation.

3. The share of the commodity cost tends to vary depending on movements in the wholesale price of the commodity.

To better understand the recent developments in retail natural gas prices, it is important to look at the wholesale market. The wholesale natural gas market in Canada is highly integrated with that in the United States. As such, Canadian retail prices are heavily influenced by movements in the U.S. wholesale natural gas price (Figure 6).

Figure 6: Wholesale and Retail Natural Gas Prices—Canada and United States



Sources: *Canadian Gas Price Reporter*, Rudyard's Canadian Explorer, Statistics Canada

The gap between Canadian wholesale prices and U.S. spot prices narrowed significantly in 1999 because of the expansion of export capacity from natural gas producing centres in Western Canada to the U.S. market. This eliminated the excess supply conditions that prevailed in that region and therefore pushed Canadian wholesale gas prices upwards. In 1999, these prices rose 42 per cent compared to an 8 per cent increase in U.S. spot prices.

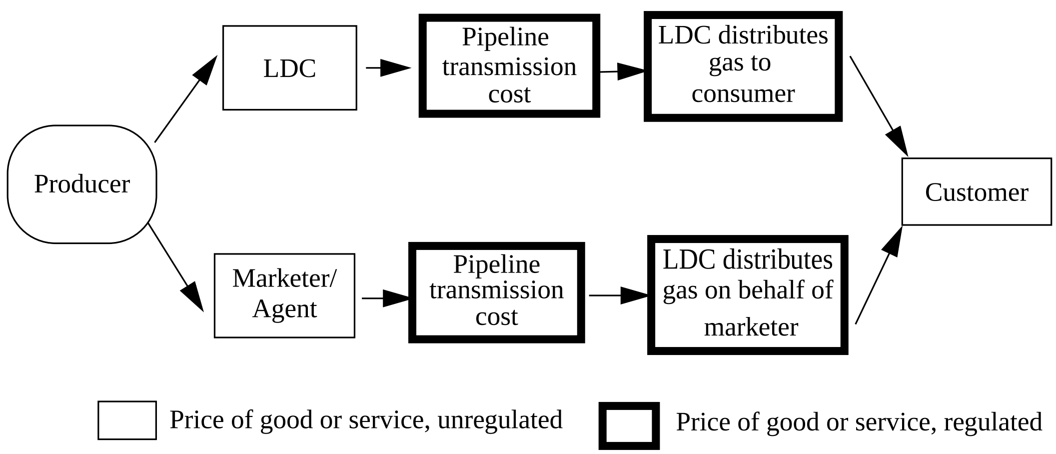
The sharp rise in North American wholesale prices towards the end of 2000 can be traced to developments in the dominant U.S. market. In the aftermath of the Asian crisis, crude oil and natural gas prices decreased steadily until 1999, leading to a significant decline in gas drilling activity in the U.S. Gulf Coast, North America's largest gas production region. This constrained production capacity in the United States and set the stage for the tight supply conditions that developed in late 2000. Colder than normal winter weather during that period boosted demand for natural gas. By January 2001, working gas inventories in the United States were 27 per cent lower than levels of the previous year, and wholesale gas prices were up 300 per cent year over year.

Since then, natural gas prices have dropped significantly as a result of a host of factors. Natural gas demand declined in early 2001 with the end of the winter season, and production increased, allowing for a healthy buildup in inventories. Furthermore, as natural gas prices increased and U.S. industrial production fell rapidly, industrial and electric utility demand for natural gas dropped significantly in the first few months of 2001, relieving some of the pressure on wholesale prices.

Rising wholesale natural gas prices had filtered through to retail consumer prices. In Canada, Ontario and Alberta dominate natural gas use, jointly accounting for 70 per cent of total residential gas demand in 1999.[4] Given that transmission and distribution costs are subject to regulation in Canada, the increase in the natural gas price index witnessed in the 2000–2001 winter season is largely attributed to increases in the market-determined commodity cost component. Local distribution companies (LDCs) do not make any loss or profit on sales of the natural gas commodity as they pass increases in wholesale gas prices to consumers. This process, however, is subject to regulation.

To better understand the pass-through process, we examine the two pricing options available to natural gas consumers. As shown in Figure 7, consumers can purchase natural gas from the LDC (top path) or from an independent marketer/agent (bottom path).

Figure 7: Gas Industry Structure*



[*] Figure adapted from *Canadian Natural Gas: Review of 1999 and Outlook to 2010*, NRCan, May 2000

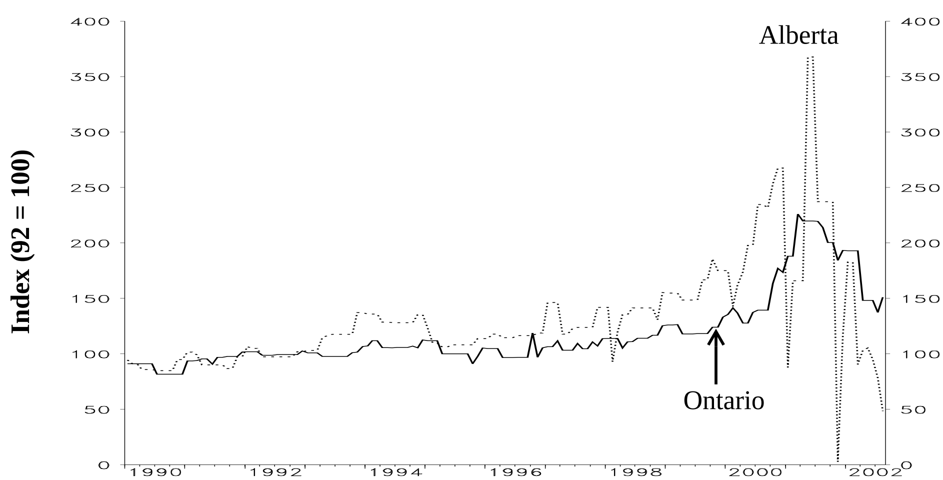
The market price at which LDCs and marketers buy their natural gas is the unregulated wholesale price. Transmission and distribution charges in both cases are subject to government regulation. The only difference between the two options is that the gas supply charge by the LDC is subject to provincial oversight, unlike the supply charge by marketers. Also, unlike marketers, LDCs are constrained by the type of purchase contracts they can sign with gas producers. In fact, LDCs buy their gas under short-term contracts, while marketers usually enter into longer-term contracts (of one, three, or five years). As a result, the underlying gas price component for a residential

4. Estimates are taken from NRCan's *Canadian Natural Gas: Review of 1999 and Outlook to 2010*, May 2000.

customer buying gas from an LDC may change each month, depending on changes in the wholesale price of the commodity. With marketers, consumers are faced with a fixed price for the duration of the contract. This comes at a cost, however. Marketers usually charge a higher rate than the LDC. It is crucial to note at this stage that the CPI monthly survey does not take into account contract agreements in the residential market for natural gas. Hence, these agreements do not affect the natural gas CPI considered in this paper.

While wholesale gas prices have a powerful influence on the natural gas consumer price index, the impact on residential charges depends on the price the utility company had paid to acquire the natural gas commodity from the gas producer. To illustrate this point, we compare the growth in natural gas prices for Ontario and Alberta (Figure 8). In 2000, wholesale natural gas prices rose 385 per cent. Between February 2000 and May 2001, residential gas prices increased 55 per cent in Ontario, compared to a 160 per cent increase in Alberta. One factor that might explain this divergence in CPI growth is that Ontario utilities were able to hedge a lot of their gas purchases by buying gas on the spot market in the summer at a lower price and selling it to consumers during the winter season at a relatively lower price than would have otherwise been charged had the utilities not hedged their purchases. The feasibility of such a strategy would depend on the ability of utilities to store natural gas. While this is the case for some Ontario utilities,[5] most of the storage in Alberta is done by the producers of natural gas rather than by the utility companies. As a result, the residential gas charges in Alberta exhibited larger increases than those in Ontario during the 2000–2001 period. Note in Figure 8 the sharp drop in natural gas prices in Alberta towards the end of 2001, owing to a provincial rebate to natural gas customers.

Figure 8: Natural Gas Price Indexes—Ontario and Alberta



Source: Statistics Canada

5. Union Gas of Ontario is believed to have most of the storage facilities in Eastern Canada.

2.4 The electricity market

Consumer electricity prices are based on the commodity cost of electricity generation, transmission cost, and local distribution costs. Electricity prices in Canada are regulated at the provincial level. The only exceptions are Alberta and Ontario, where the commodity cost is now determined by market forces, as will be explained.

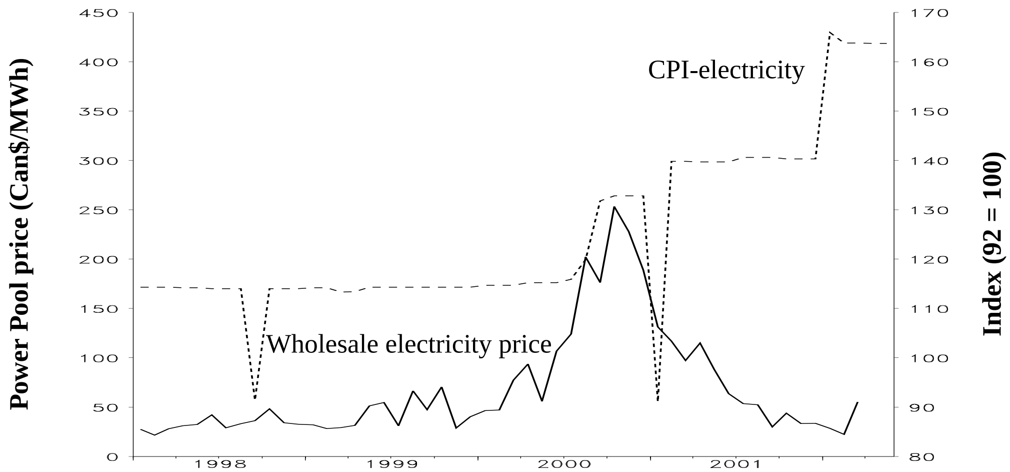
More recently, some restructuring of the electricity industry has been taking place in a number of provinces. Restructuring refers to the reorganization of electric utilities from monopolies—companies that own generation, transmission, and distribution—into separate generation, transmission, and distribution service companies, through the process of *unbundling*. It also involves the implementation of full retail and wholesale access, to be defined shortly, and the deregulation of the wholesale price of electricity. The pace of restructuring has been uneven among the provinces, with Alberta and Ontario the furthest along the way. Alberta started its market restructuring in 1996 with the creation of the Alberta Power Pool.[6] Since then, the wholesale price of electricity in the province has been deregulated, i.e., determined by market forces. Furthermore, Alberta has implemented full retail access, which gives consumers the right to choose among different power sellers. Aside from Alberta, Ontario is the only other province that has opened up its market to competition. Since May 2002, the wholesale price of electricity in Ontario has been deregulated and the province has implemented full retail access, as in Alberta.[7]

Although deregulation involves only the generation component of electricity rates, and not the transmission and distribution components, it has important implications for consumer prices. To understand this, we focus on the electricity market in Alberta, the only market in Canada that has been deregulated for a significant period of time. The deregulation of Alberta's power industry is likely to have played a significant role in the run-up in residential electricity prices seen in the province since the middle of 2000. Coinciding with the sharp increase in natural gas prices, an input used in electricity generation, wholesale electricity prices increased dramatically. By November 2000, wholesale prices were eight times the level of the previous year. Despite this sharp increase, residential electricity prices rose only 16 per cent over the same period, while remaining relatively stable in other provinces (Figure 9).

6. The Power Pool is a system of exchange that determines the market price of electricity based on supply and demand factors.
7. For further discussion on the restructuring of the Canadian electricity industry, please refer to "Canadian Electricity Trends and Issues," National Energy Board, May 2001.

The escalation of wholesale prices in 2000 would have resulted in a larger increase in consumer prices. However, a full-year cash rebate implemented in January 2001 and government regulation that capped power rates limited price hikes. Prices increased again in early 2002, owing to the end of the cash rebate program (Figure 9).

Figure 9: CPI-Electricity and Wholesale Electricity Prices—Alberta



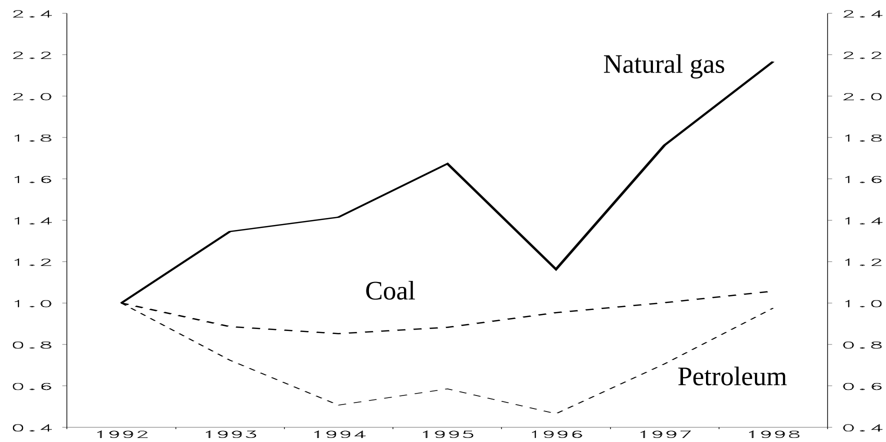
Source: Statistics Canada, Power Pool of Alberta

Another factor that limited a larger increase in consumer prices is the fact that some power suppliers buy electricity from generators through contracts. This guarantees the purchaser a specified power supply at a predetermined price over an extended period of time and shields suppliers from unexpected increases in wholesale power prices. Consequently, fluctuations in consumer rates would be mitigated by such arrangements.

The increase in wholesale prices in Alberta in 2000 can be attributed to many factors. These include a tight supply/demand balance, higher natural gas costs, and higher import prices for electricity. Natural gas prices, which had been rising towards the end of 2000, put upward pressure on wholesale power prices, reflecting the increasing use of natural gas by electric utilities.

Natural gas use for power generation has increased in Canada over the past several years. Between 1992 and 1998, natural gas use in power generation had doubled, unlike that of coal and petroleum, which remained unchanged (Figure 10). Alberta and Ontario are leaders in gas-fired generation. In 2000, Alberta produced 30 per cent of its power from natural gas. In Ontario, where 8 per cent of electricity in 2001 was generated from natural gas, the use of natural gas has been increasing at an annual average rate of 10 per cent. In Nova Scotia, the availability of Sable Island gas provided new generation options for local power plants. Despite the increasing use of natural gas by electric utilities, its share of total generation stood at 4 per cent in 1999, compared to hydro-electric (61 per cent), coal-fired (18 per cent), nuclear (13 per cent), and oil and renewables generation (4 per cent).[8]

Figure 10: Natural Gas, Coal, and Petroleum Usage in Power Generation—Canada (1992 = 1.0)



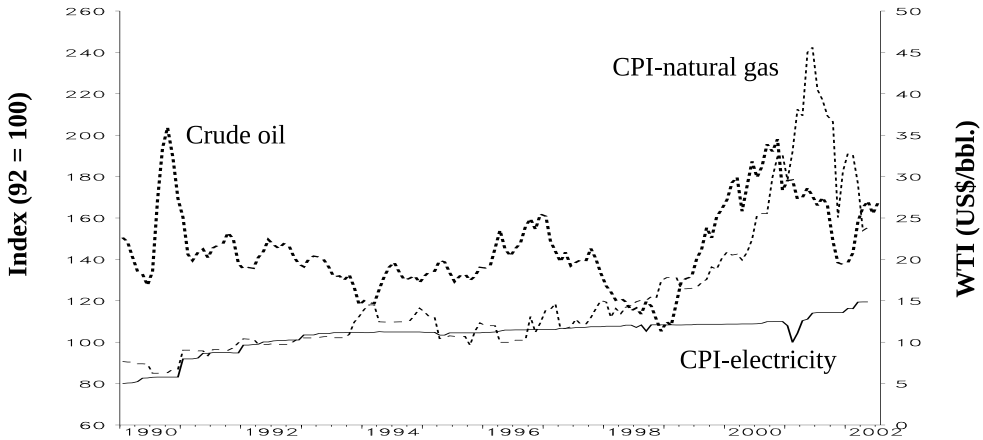
Source: *Electric Power Generation, Transmission and Distribution*—Statistics Canada

Broadly speaking, residential electricity prices in Canada have been stable over the past decade. This is in contrast with rising residential natural gas prices towards the end of the decade, and with highly volatile crude oil prices throughout much of the 1990s (Figure 11). This long-term stability in electricity rates is attributed to the stabilizing effect of government regulation and, in some provinces, to the implementation of price freezes. Furthermore, the dominance of low-cost hydro-electric power generation has contributed to an environment of low and stable electricity prices.

Note, however, that deregulating the electricity market in Ontario is likely to result in greater price volatility in that market, and hence, in the total CPI-electricity. In fact, since the deregulation of the electricity market in Ontario, electricity prices have increased substantially in July and August 2002. Furthermore, movements in crude oil prices could have more effects on electricity prices in the short term through their impact on natural gas and fuel oil costs.

8. Estimates are published in “Canadian Electricity Trends and Issues,” National Energy Board, May 2001 and in “The Exchange,” Power Pool of Alberta, September 2000.

Figure 11: Crude Oil Prices and the Electricity and Natural Gas Price Indexes



Sources: Bank of Canada, Statistics Canada

3. Overview of Energy-Price Regulation under the National Energy Program (NEP)

In response to the run-up in world oil prices in 1973, the federal government froze the domestic price of crude oil at a level below that of world prices. In 1974, the federal and provincial governments agreed to gradually increase the domestic price of oil to match rising world prices. Government regulation of the Canadian price of crude oil was implemented by levying a charge on oil exports and using the proceeds to subsidize oil imports in oil-dependent provinces in Eastern Canada. This revenue tax remained in place until June 1985, when domestic oil prices were deregulated. This information regarding the NEP is crucial to understanding the econometric analysis that follows.

4. Empirical Results

In this section, we present the results of an in-depth econometric analysis aimed at constructing a quarterly forecasting model for each of the components of CPI-energy. Section 4.1 describes the data used in the analysis. In sections 4.2 and 4.3, we present the results of unit-root and cointegration tests, and in section 4.4, we outline model estimation results. This is followed by tests for structural stability and forecast performance evaluation in sections 4.5 and 4.6.

4.1 Data

To analyze the relationship between crude oil prices and the CPI-energy components, we use quarterly data for the period 1972Q1 to 2002Q1. For crude oil prices, we use the West Texas

Intermediate (WTI) price in Canadian dollars per barrel. Data for the various CPI components are those published by Statistics Canada, and are seasonally unadjusted. In the case of gasoline, we use the *ex-tax* retail price calculated as the *gross* price less indirect taxes.[9] The measure of the U.S. output gap is produced by the International Department at the Bank of Canada.[10]

4.2 Unit-root tests

Table 3 shows the results of unit-root tests conducted on the price of crude oil and each of the components of CPI-energy. We test the null of non-stationarity at the 5 per cent level. Both the Augmented Dicky-Fuller (t_{ADF}) and the Phillips-Perron ($Z(t_\rho)$) tests do not reject the null of a unit root. For all the tested series, the absolute values of the estimated statistics are less than the critical value, indicating that the series are non-stationary. Similar results are obtained when we apply unit-root tests to the *real* price of crude oil and the *real* CPI-energy components.[11]

Table 3: Unit-Root Test Results (nominal levels)

Item	ADF lags[a]	PP lags	t_{ADF}[b]	$Z(t_\rho)$[b]	*Ljung-Box* Q[c]	*t*-statistic (last lag)
Crude oil (Can$)	3	3	–2.7	–2.5	21.7	2.1
Gasoline (excl. taxes)	3	3	–2.0	–1.8	35.3	1.8
Heating oil	3	3	–2.1	–2.0	21.5	2.6
Natural gas	4	3	–2.4	–1.8	18.2	2.3
Electricity	4	3	–1.2	0.3	14.4	8.3

a. Number of lags chosen based on last lag that is significantly different from zero.
b. t_{critical} = –3.45 at the 5 per cent level for an ADF test including a time trend.
c. Q_{critical} = 43.77 at the 5 per cent level.

To determine the order of integration for each series, we conduct unit-root tests on *first differences* of each series. All the *differenced* series, both nominal and real, were found to be stationary, meaning that the *level* series are integrated of order one, I(1). The only exception occurs in the case of the nominal electricity index where we get conflicting results from the ADF and the

9. The *gross* price is obtained by multiplying the CPI-gasoline series by the average price of a litre of gasoline in 1992. Indirect taxes include federal (excise and GST) and provincial taxes. Data for gasoline taxes were obtained from NRCan and Statistics Canada.
10. The series is estimated using a structural VAR.
11. The *real* series were obtained by deflating the nominal series by the CPI excluding food and energy components.

Phillips-Perron (PP) tests. We adopt the results from the PP test since the finite-sample power of the test has been documented to be superior to that of the ADF test (Table 4).

Table 4: Unit-Root Test Results (nominal first differences)

Item	ADF lags[a]	PP lags	t_{ADF}[b]	$Z(t_\rho)$[b]	*Ljung-Box* Q[c]	*t*-statistic (last lag)	order of integration
Crude oil (Can$)	2	3	–5.0	–8.6	21.0	–1.9	I(1)
Gasoline (excl. taxes)	2	3	–4.8	–9.1	34.4	–1.9	I(1)
Heating oil	2	3	–3.9	–7.8	20.7	–2.8	I(1)
Natural gas	3	3	–3.3	–7.6	17.6	–2.1	I(1)
Electricity	3	3	–2.3	–11.1	12.7	–9.9	I(1)

a. Number of lags chosen based on last lag that is significantly different from zero.
b. $t_{\text{critical}} = -2.89$ at the 5 per cent level for an ADF test excluding a time trend.
c. $Q_{\text{critical}} = 41.33$ at the 5 per cent level.

4.3 Cointegration tests

Given that crude oil prices and each of the CPI-energy components were found to be integrated of the same order, we test for the presence of a long-run relationship between these series. Using the Engle-Granger methodology, we estimate the cointegration regression:

$$y_t^i = \alpha + \beta crude_t + \xi DU_t + \varepsilon_t,$$

where

y^i: CPI-energy component (*i* = gasoline ex-tax, heating oil, natural gas, or electricity)
crude: crude oil price (Can$)
DU: dummy variable such that: $DU = 1$; $t \geq 1973{:}4$ and $t \leq 1985{:}2$; 0 otherwise.

We test separately for cointegration using nominal and real data to determine whether the long-run relationship between the various series is attributable to a common inflation trend in the tested series. The inclusion of the dummy variable, *DU,* in the long-run relationship corresponds to the period during which crude oil prices had been regulated in Canada. As mentioned, the run-up in world crude oil prices in the early 1970s prompted oil price regulation and led to the implementation of the National Energy Program. Our cointegration test results are sensitive to the inclusion of *DU* in the cointegration regression. We find no evidence of cointegration when we remove *DU* from the long-run relationship. The sign of the coefficient is negative, which is consistent with expectations that domestic policies kept crude oil prices lower than world prices.

To detect whether the variables are cointegrated, we test the estimated residuals ε_t for the presence of a unit root. If ε_t exhibits non-stationary behaviour, then the tested series will not be cointegrated and the relationship between them will be spurious. As to critical values, we use those tabulated by Davidson and MacKinnon (1993). A different set of critical values is also tabulated in Gregory and Hansen (1996), who, unlike Davidson and MacKinnon, test for cointegration in the presence of a regime shift in the long-run relationship. However, Gregory and Hansen assume that the timing of the break point is unknown. In our analysis, the date and duration of the regime shift are known. The added uncertainty in the Gregory and Hansen analysis partly explains why their critical values are notably higher in absolute value than those published by Davidson and MacKinnon. Since our objective is to construct forecasting models, we will emphasize more the forecasting performance of the equations, the value of the parameter estimates, and whether or not the models are well specified.

Results reveal the presence of cointegration between crude oil and each of the CPI-energy components, with the exception of electricity. The conclusions are identical for both the real and nominal data regressions. This suggests that, while there might be a common inflation component in the data, the co-movement between the CPI components and crude oil prices is not attributable to overall inflation. Since we are interested in forecasting the nominal CPI-energy components, we estimate the regressions in nominal terms. Table 5 shows the estimated and critical values for the ADF and PP statistics for the nominal series. With the exception of electricity, at least one of the estimated test statistics is greater than the critical value, indicating that there is a long-run relationship between the price of crude oil and each of the gasoline, heating oil, and natural gas series.

Table 5: Cointegration Test Results (nominal series)

Item	**ADF lags**[a]	**PP lags**	t_{ADF}[b]	$Z(t_\rho)$[b]	***Ljung-Box*** Q[c]	***t*-statistic (last lag)**	**cointegration**
Gasoline (excl. taxes)	2	2	–3.3	–4.8	15.7	–2.0	√
Heating oil	2	2	–3.8	–4.7	12.1	–2.2	√
Natural gas	1	1	–4.6	–4.2	15.9	–2.3	√
Electricity	2	2	–3.3	–3.7	9.6	–1.8	–

a. Number of lags chosen based on last lag that is significantly different from zero.
b. Critical value = –3.74 at the 5 per cent level (Davidson and MacKinnon 1993).
c. Q_{critical} = 42.56 at the 5 per cent level.

In the case of electricity, there does not seem to be much evidence of cointegration with crude oil prices, given that both the ADF and PP statistics are below the critical value. This can be attributed to several factors. First, coal-fired, nuclear, and hydro-powered generation account for roughly 90 per cent of total Canadian power generation. Second, electricity prices are regulated in most provinces, a factor that limits retail price variability in response to oil shocks. Even in Alberta and Ontario, where markets have been deregulated, temporary price caps have been introduced to limit consumer price hikes resulting from the move to a deregulated electricity market.[12]

A strict view of these cointegration results would be to interpret them as implying that the series *crude* captures all the permanent innovations in the variables under consideration. We prefer, however, to follow a more pragmatic approach of interpreting the cointegration results as suggesting that the variables are linked in the long run without denying the possibility that other factors may also influence movements in energy price indexes.

In the case of the cointegration regression, a graphical examination of the actual and fitted values from the nominal regressions reveals that the long-run equilibrium value of y_t exhibits more variability than the actual series. This behaviour may be justified by the fact that crude oil prices have been relatively more volatile historically and by "adjustment-cost" models where agents incur a cost in moving towards the long-run equilibrium value. The theory governing adjustment-cost models is applicable to our analysis. In the case of energy prices, adjustment costs could be associated with purchase contracts, which limit the ability of energy retailers to fully and quickly adjust their prices to fluctuations in input costs. Inventory management techniques, government regulation, and the competitive environment in which retailers operate could also explain the lagged adjustment of retail prices to changes in upstream costs.

4.4 Model estimation and residual diagnostics

Given the cointegration test results we found earlier, we proceed to estimate dynamic error-correction models (ECMs) for gasoline, heating oil, and natural gas. Modelling retail electricity prices will not be pursued in this paper, because the Canadian electricity market is currently being restructured in some provinces. Therefore, historical relationships may not be useful for forecasting.

12. In Ontario, where the electricity market opened up in May 2002, price caps on consumer rates have been introduced for a period of three years. In Alberta, electricity rates were also capped during 2001 following spiking natural gas prices last year.

4.4.1 Gasoline

For gasoline, we start with the following general form of the dynamic ECM:

$$\Delta gas_t = \alpha(gas_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1}^{4} X_{t-i}\delta + \mu seasons + \nu_t,$$

where

crude: WTI price (Can$)
gas: ex-tax gasoline price
DU = dummy variable
seasons: seasonal dummy = 1 at the second and third quarter of each year[13]
$X_t = \Delta gas_t$, $\Delta crude_t$, and *U.S. output gap*$_t$.

The vector of variables X_t and the seasonal dummy are introduced into the regression to account for short-term price dynamics. The coefficients c, α, β, ζ, δ, and μ are parameters to be estimated. We estimate the regression by non-linear least squares over the period 1972Q1 to 2002Q1. All series except the output-gap measure are in logs. Preliminary results reveal that *all* lags of the dependent variable, the fourth lag of the crude oil variable, and all lags of the U.S. output gap are insignificant. As such, the refined regression becomes:

$$\Delta gas_t = \alpha(gas_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1}^{3} \delta_i \Delta crude_{t-i} + \mu seasons + \nu_t .$$

Table 6 shows the various parameter estimates, their respective standard errors, and *t*-statistics. Overall, the parameter estimates have the correct sign and are significant at the 5 per cent level, with the exception of the third lag of crude oil prices, which is significant at the 15 per cent level. The negative sign on the speed of adjustment parameter, α, indicates that gasoline prices adjust each period to their long-run equilibrium value. The long-run adjustment parameter, β, indicates roughly a 75 per cent pass-through rate from crude oil price growth to *ex-tax* gasoline price growth. This means that, in the long-run, a 100 per cent increase in the price of crude oil results in a 75 per cent increase in the *ex-tax* gasoline price. This is expected, given that crude oil constitutes roughly 60 per cent of the net gasoline price. Regarding the short-run dynamics, a shock analysis exercise revealed that a 10 per cent increase to the quarterly price of crude oil results in an increase in the net gasoline price of about 4 per cent the following quarter. As expected, lagged

13. This period coincides with the spring-summer driving season.

changes in crude oil prices are, on average, positively correlated with changes in gasoline prices and so is the seasonal dummy.[14]

Table 6: Gasoline Model

Parameters	Estimate	Standard error	*t*-statistic
α	–0.117	0.037	–3.12
c	0.844	0.244	3.46
β	0.767	0.082	9.36
ζ	–0.232	0.076	–3.04
δ_1	0.300	0.051	5.90
δ_2	–0.123	0.044	–2.77
δ_3	0.070	0.048	1.46
μ	0.029	0.010	3.00
R^2		39.7%	

Residual diagnostic tests reveal the presence of ARCH(1) and ARCH(2) type heteroscedasticity at the 5 per cent level in the full sample (Table 7). This heteroscedastic behaviour is attributable to the volatility in crude oil prices in 2001Q4, following the terrorist events in the United States. This behaviour also resulted from speculation in oil markets about production plans by OPEC and non-OPEC countries. When we exclude that period from the data and re-estimate the model until 2001Q2, the errors are found to be well-behaved.[15] Note that this contamination in the data has important implications for structural stability test results shown later. Given the heteroscedastic behaviour of the residuals of the full sample regression, the reported standard errors are henceforth the Newey-West heteroscedasticity and autocorrelation consistent (HAC) estimates.

14. We have also tested for the presence of asymmetry in the response of gross gasoline prices (including taxes) to crude oil price movements. Preliminary estimations using quarterly data reveal the absence of asymmetry in the response of retail gasoline prices to oil price shocks.
15. The parameter estimates and the corresponding *p*-values from the shorter sample regression are not significantly different from those of the full sample regression.

Table 7: Tests for Serial Correlation and Heteroscedasticity—Gasoline Model

Test	1972Q1 to 2002Q1 *p*-value	Test	1972Q1 to 2001Q2 *p*-value
LM(1)	0.214	LM(1)	0.133
LM(2)	0.161	LM(2)	0.254
LM(3)	0.220	LM(3)	0.233
LM(4)	0.068	LM(4)	0.415
Runs	0.994	Runs	0.395
ARCH(1)	0.009	ARCH(1)	0.890
ARCH(2)	0.032	ARCH(2)	0.931
ARCH(3)	0.076	ARCH(3)	0.986
ARCH(4)	0.111	ARCH(4)	0.933
Breusch-Pagan	0.283	Breusch-Pagan	0.413

4.4.2 Heating oil

As with gasoline, we apply a general-to-specific estimation to the following ECM:

$$\Delta hoil_t = \alpha(hoil_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1}^{4} X_{t-i}\delta + \mu seasons + \nu_t ,$$

where

crude: WTI price (Can$)
hoil: heating oil price index
DU = dummy variable
seasons: seasonal dummy = 1 at the first and fourth quarter of each year[16]
$X_t = \Delta hoil_t$, $\Delta crude_t$, and *U.S. output gap*$_t$

and α, *c*, β, ζ, δ, and μ are parameters to be estimated. We apply non-linear least squares over the period 1972Q1 to 2002Q1. All series except the output gap measure are in logs. Initial results show that, on average, the lagged dependent variable and output gap measures are largely insignificant.[17] As such, we adopt the following regression form:

16. This variable is introduced to account for periods of high demand for home heating fuels.
17. Among the lags of the dependent variable, only the third lag was found to be significant. In the U.S. output gap measure, only the third and fourth lags were found to be significant, but only at the 15 per cent level. Worth noting, as well, was the decline in the significance level of these lags with the refining of the regression.

$$\Delta hoil_t = \alpha(hoil_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1,3} \delta_i \Delta crude_{t-i} + \mu seasons + \varepsilon_t .$$

Overall, estimates are significant at the 5 per cent level, except ζ, which is significant at the 15 per cent level (Table 8). The coefficient on the error-correction term, α, is negative and significant, indicating convergence of retail prices to a long-run equilibrium price. The pass-through rate from crude oil price growth to retail heating oil price growth is estimated at 86 per cent. This estimate is higher than expected, given that crude costs account for roughly 50 per cent of the heating oil retail price. In the short run, a 10 per cent shock to the quarterly price of crude oil results in a shock to the heating oil price of about 3 per cent the following quarter. Lagged changes in crude oil prices and the seasonal dummy are positively correlated with changes in heating oil prices, in line with expectations.

Table 8: Heating Oil Model

Parameters	**Estimate**	**Standard error**	***t*-statistic**
α	–0.056	0.024	–2.27
c	1.671	0.343	4.88
β	0.860	0.167	6.91
ζ	–0.239	0.125	–1.43
δ_1	0.266	0.045	5.86
δ_3	0.079	0.043	1.86
μ	0.020	0.007	2.64
R^2		54.3%	

Diagnostic tests on the estimated residuals, ε_t, reveal strong evidence of heteroscedasticity. This behaviour, however, is attributed to sharp fluctuations in heating oil prices brought about by unusual weather conditions during the 1999 and 2000 winter seasons in the U.S. Northeast, a region that depends on oil for home heating purposes. In fact, when we exclude these unusual weather episodes from the data and re-estimate the model over the period 1972Q1 to 1999Q4, the errors are well-behaved and show no evidence of heteroscedasticity or serial correlation (Table 9).[18]

18. For the majority of the variables, there is no significant difference between the parameter estimates from the shorter sample regression and those outlined in Table 8. The third lag for crude oil, however, becomes insignificant in the shorter sample regression.

Table 9: Tests for Serial Correlation and Heteroscedasticity—Heating Oil Model

Test	**1972Q1 to 2002Q1** ***p*-value**	**1972Q1 to 1999Q4** ***p*-value**
LM(1)	0.293	0.648
LM(2)	0.246	0.855
LM(3)	0.058	0.896
LM(4)	0.041	0.737
Runs	0.999	0.489
ARCH(1)	0.005	0.535
ARCH(2)	0.010	0.463
ARCH(3)	0.001	0.569
ARCH(4)	0.002	0.553
Breusch-Pagan	0.001	0.369

4.4.3 Natural gas

The following general ECM is estimated for natural gas prices:

$$\Delta ngas_t = \alpha(ngas_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1}^{4} X_{t-i}\delta + \mu seasons + \nu_t ,$$

where

crude: WTI price (Can$)
ngas: natural gas price index
DU = dummy variable
seasons: seasonal dummy = 1 at the first and fourth quarter of each year[19]
$X_t = \Delta ngas_t$, $\Delta crude_t$, and *U.S. output* gap_t,

and α, *c*, β, ζ, δ, and μ are parameters to be estimated. We apply non-linear least squares over the period 1972Q1 to 2002Q1. All series except the output gap measure are in logs. Preliminary estimation results show that the coefficient estimate on the last lag of the output gap is insignificant. The second and fourth lags of the dependent variable were also found to be insignificant, leading to the following regression form:

19. This coincides with episodes of high demand for natural gas.

$$\Delta ngas_t = \alpha(ngas_{t-1} - c - \beta crude_{t-1} - \zeta DU_{t-1}) + \sum_{i=1,3} \delta_i \Delta ngas_{t-i} + \sum_{i=1}^{3} \lambda_i usgap_{t-i} + \mu seasons + \upsilon_t ,$$

where all coefficient estimates are significant at the 5 per cent level (Table 10). As in the previous two cases, the speed of adjustment parameter α is negative and significant.

Table 10: Natural Gas Model

Parameters	**Estimate**	**Standard error**	***t*-statistic**
α	–0.078	0.030	–2.59
c	1.762	0.313	5.63
β	0.856	0.103	8.28
ζ	–0.324	0.110	–2.94
δ_1	0.182	0.070	2.61
δ_3	0.272	0.085	3.21
λ_1	0.011	0.005	2.07
λ_2	–0.019	0.006	–3.48
λ_3	0.011	0.005	2.33
μ	0.028	0.007	4.18
R^2		28.6%	

It is also important to recognize the net positive contribution of the U.S. output gap to changes in domestic natural gas prices. This is unlike the cases of gasoline and heating oil, where the U.S. output gap was insignificant in explaining domestic price fluctuations. The wholesale price of gas is sensitive to industrial and utility demands and therefore to industrial production and electricity generation, both of which are correlated with the output gap. Short-term fluctuations in crude oil prices were found to be insignificant in explaining fluctuations in natural gas prices. One reason is that in the short run, there is a very limited substitution between natural gas and oil products. However, there seems to be a long-run effect of crude oil prices on natural gas prices through the pass-through parameter, β. Note that this parameter estimate is virtually the same for natural gas and heating oil. This is to be expected, because in the long run, when substitution is not impeded by equipment in place, natural gas and heating oil are in direct competition for home heating and consequently, their prices should evolve similarly relative to crude oil prices.

In the case of the residuals, diagnostic tests reveal strong evidence of heteroscedasticity when the regression is estimated over the full sample period. Factors contributing to this behaviour are unusual winter weather, and more importantly, fluctuations in retail prices due to rebate programs implemented by the province of Alberta in 2001.[20] When re-estimating the model over the period 1972Q1 to 1999Q4, the residuals were found to display only weak evidence of fourth-order serial correlation (Table 11).[21]

Table 11: Tests for Serial Correlation and Heteroscedasticity—Natural Gas Model

Test	**1972Q1 to 2002Q1** ***p*-value**	**1972Q1 to 1999Q4** ***p*-value**
LM(1)	0.662	0.472
LM(2)	0.691	0.638
LM(3)	0.751	0.771
LM(4)	0.646	0.039
Runs	0.510	0.196
ARCH(1)	0.001	0.627
ARCH(2)	0.000	0.765
ARCH(3)	0.000	0.891
ARCH(4)	0.000	0.413
Breusch-Pagan	0.001	0.288

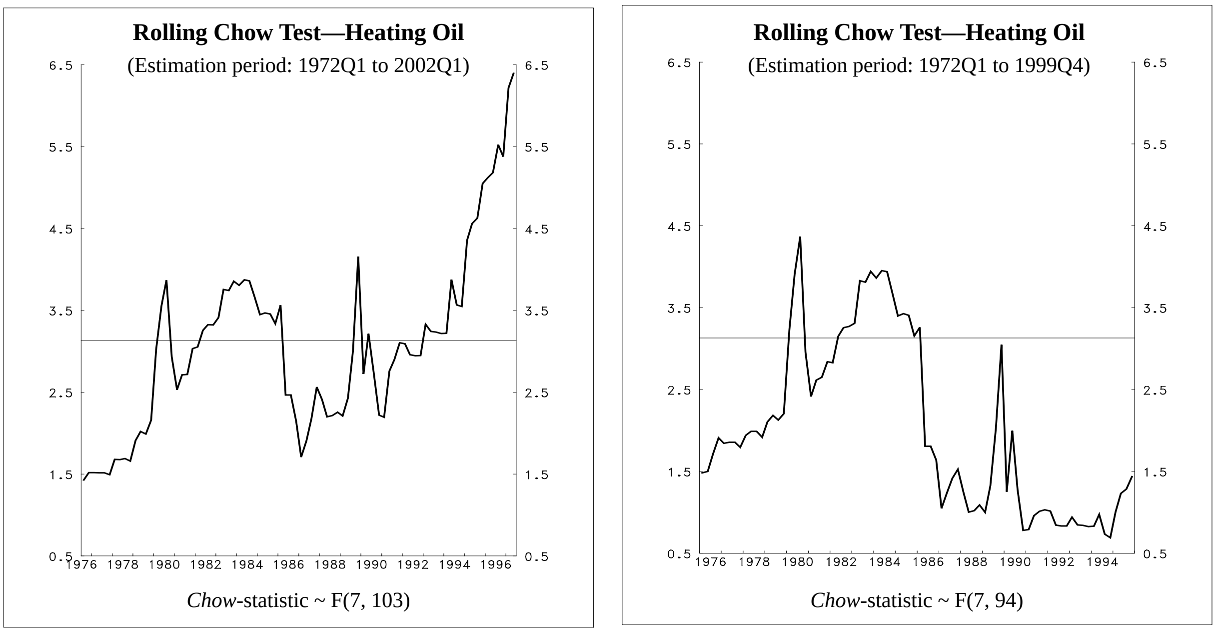
4.5 Structural stability tests

In this section, we test for parameter stability for each of the forecast equations. We test the null of stability at the 5 per cent level using critical values tabulated by Andrews (1993). We remove 15 per cent of the observations from sample ends and test for break points over the remaining sample period. Note that Chow test results are valid under the assumption of homoscedastic errors. As we have mentioned, the contamination in the data towards sample end results in heteroscedastic error terms in all three equations, and thus, has important implications for stability test results. This becomes clear when we compare test results for the full sample with those for a shorter sample, excluding the contaminated data, as shown below.

20. Estimating the model with dummy variables corresponding to the rebate episodes in Alberta yields similar parameter estimates to those shown in Table 10.
21. For the shorter sample regression, the β estimate is smaller in magnitude than that from the full regression (0.711 versus 0.856). Furthermore, the coefficients ζ and δ_1 become insignificant in the shorter sample regression.

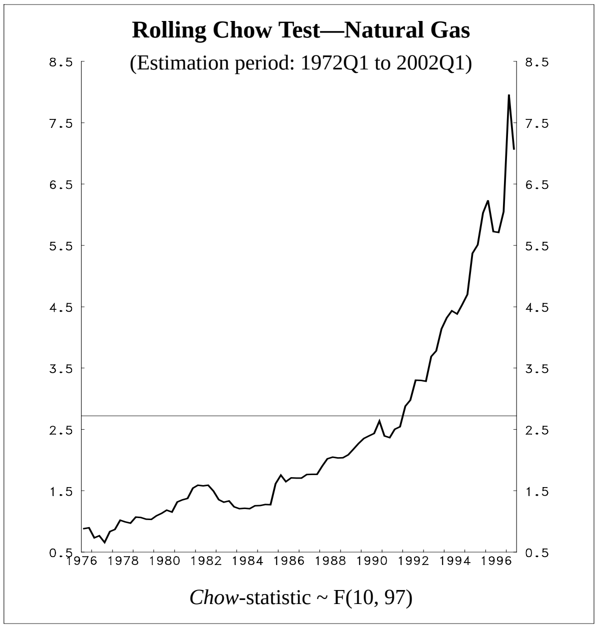
Starting with the heating oil regression, the *Chow*-statistic exhibits an upward shift starting in 1979 and ending in 1986, the period associated with consistently high world crude oil prices. Note the systematic increase in the test statistic starting in 1990 (Figure 12, left graph). We suspect this is related to the heteroscedastic behaviour of the residuals at sample end. In fact, when we estimate the model over the period 1972Q1 to 1999Q4, the *Chow*-statistic indicates stability rather than instability in coefficient estimates over that period (Figure 12, right graph).

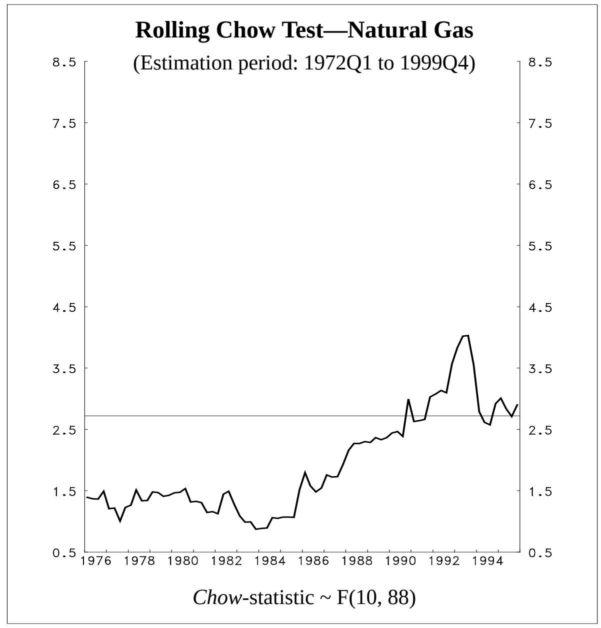
Figure 12: The Rolling Chow Test—Heating Oil



In the natural gas regression, as well, the Chow test results from the full sample (Figure 13, left graph) are markedly different from those of the shorter sample that excludes the contaminated data (Figure 13, right graph). Yet there seems to be some evidence of instability in 1993 for the shorter sample regression.

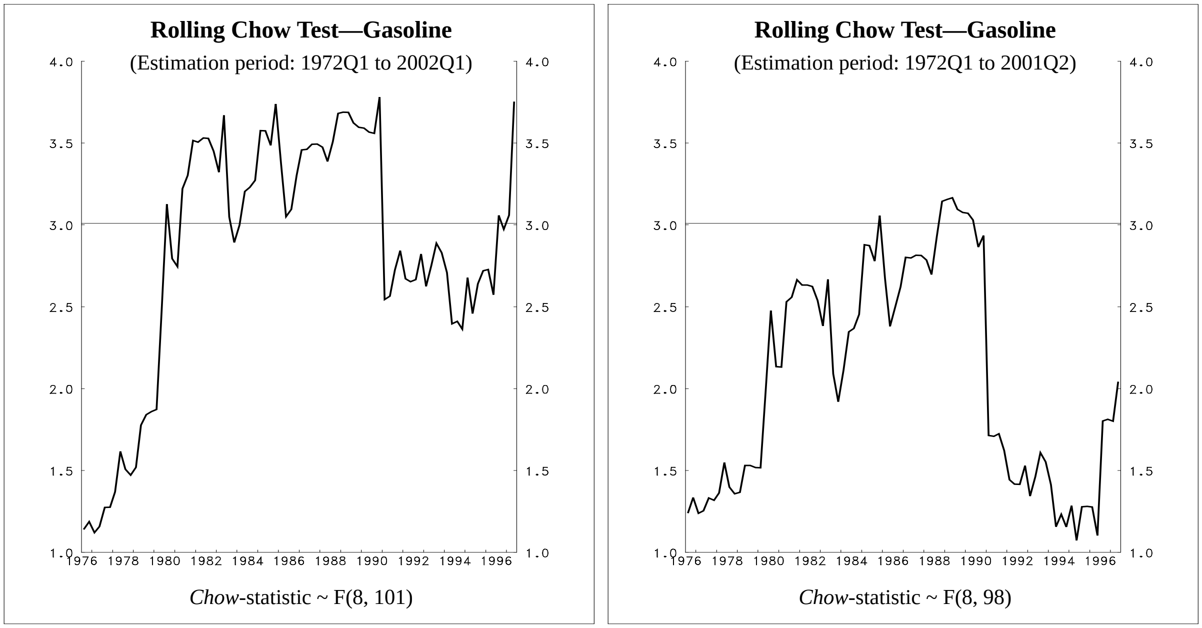
Figure 13: The Rolling Chow Test—Natural Gas





The gasoline equation exhibits structural instability throughout the 1980s (Figure 14, left graph). Notable as well is the behaviour of the test statistic towards sample end, which we suspect is related to the heteroscedastic behaviour of the error terms. When we estimate the regression over a shorter sample period, the Chow test indicates the absence of a structural break after 1990. Also note the drop in the level of the test statistic during the 1980s in the shorter sample estimation period (Figure 14, right graph). Remember that in all three equations, we test for stability of *all* parameter estimates, not separately for each coefficient.

Figure 14: The Rolling Chow Test—Gasoline



4.6 Out-of-sample forecasts

Although each model exhibits evidence of instability, we test the forecasting ability of the models over recent history. We compare the predictive power of the dynamic ECMs with that of an autoregressive (AR) model and a random-walk (RW) model. If the models are able to outperform an AR or RW model, then the ECMs, even though they may be unstable, provide some marginal information about energy-price movements. There are several criteria for evaluating the predictive ability of forecasting models. These include the root-mean-square error (RMSE) criterion, forecast encompassing tests, and the ability of the model to capture turning points.

While the RMSE measure is a good indicator of forecast accuracy, it cannot be used to conduct formal hypothesis testing. An alternative criterion that allows hypothesis testing is the forecast encompassing test. It examines whether the forecasts from a competing model contain information that could explain the forecast errors of the preferred model. As such, the forecast of model A is said to encompass that of a competing model B if the forecast errors of model A, (fe_A), cannot be explained by the forecasts of model B, (f_B). Testing for forecast encompassing thus involves running the following regression and checking for the significance of the β coefficient:

$$fe_{A,t} = \alpha + \beta f_{B,t} + \varepsilon_t .$$

If β is not significantly different from zero, then model A is said to forecast encompass model B. In our analysis, the preferred model is the ECM, while the competing models are the AR and RW models. We conduct tests for the hypothesis (H_A) that the ECM forecast encompasses those from the competing models and for another hypothesis (H_B), which claims that the competing model forecasts encompass those from the ECM.

Tables 12, 13, and 14 show the results of forecast performance tests for each of the three ECM equations and the competing model specifications. We evaluate the forecasts of the gasoline equation over the period 1995Q1 to 2001Q2 and those of the heating oil and natural gas equations over the period 1995Q1 to 1999Q4. The choice of end points for the forecast performance tests coincides with the end points of the shorter sample regressions that yield relatively more stable parameter estimates. We report the ratio of the RMSE of the ECM to that of the various competing models and the *t*-statistic for the coefficient β from the forecast encompassing regressions. A ratio below one means that the ECM outperforms the alternative specification in terms of forecast accuracy. A *t*-statistic less than the 5 per cent critical value at 1.96 means that we do not reject the tested hypothesis. The chosen forecasting horizon is the one-quarter and two-quarter-ahead forecasts.

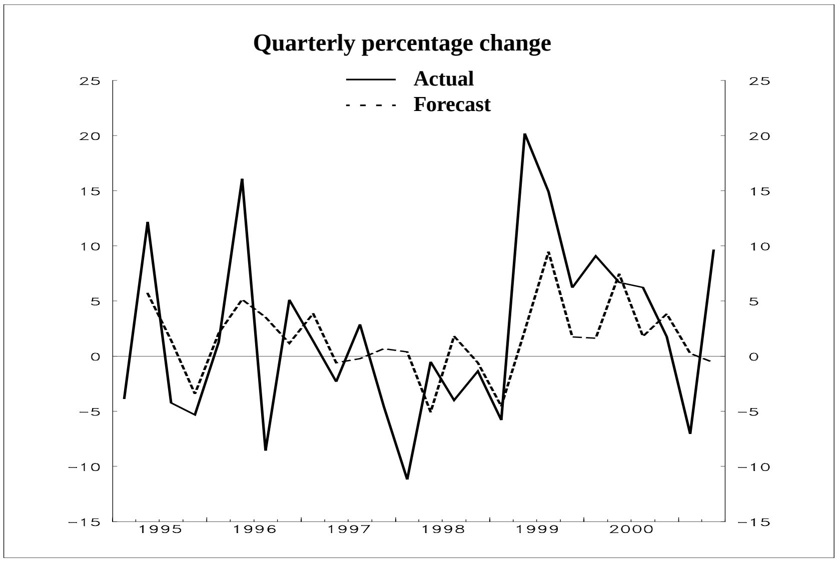
Table 12: Out-of-Sample Forecast Performance—Gasoline ex-tax

	RMSE (ECM)/RMSE (competing model)		**H_A: ECM encompasses competing model**		**H_B: competing model encompasses ECM**	
Model specification	**# steps ahead**		**# steps ahead**		**# steps ahead**	
	1	**2**	**1**	**2**	**1**	**2**
ECM	1.000	1.000				
AR(1)	0.844	0.869	0.48	–0.36	–2.34	–2.64
AR(2)	0.837	0.858	0.71	0.03	–2.17	–2.54
AR(3)	0.851	0.874	0.37	–0.26	–1.90	–2.31
RW	0.639	0.639	0.98	0.73	0.10	0.67

As shown in Table 12, the gasoline ECM specification outperforms the competing models in terms of forecast accuracy. In the case of the AR models, the estimates of the *t*-statistic for the hypothesis H_A are well below the critical value, and those of the hypothesis H_B, with the exception of the one-step-ahead AR(3) *t*-statistic, are above the critical value, which suggests that the ECM forecasts encompass those of the AR models. As shown in Figure 15, the forecast from the ECM is also able to capture most of the turning points in the growth of actual *ex-tax* gasoline prices.[22]

22. The forecast series in the graphs is the one-quarter-ahead forecast.

Figure 15: Forecast versus Actual Inflation—Gasoline ex-tax

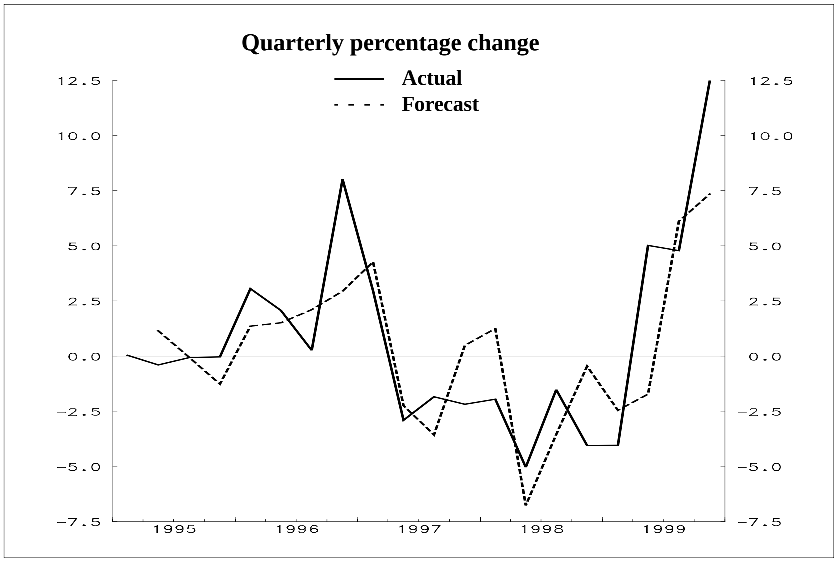


Similarly, the ECM specification for heating oil prices also seems to outperform the alternative model specifications (Table 13). Relative to the AR competing models, the heating oil ECM seems to do a better job explaining retail heating oil prices than does the gasoline ECM in explaining gasoline prices. This is evident when comparing the RMSE ratios in Tables 12 and 13. As in the case of the gasoline model, the ECM forecasts of the heating oil equation encompass those of the competing AR models. The ECM also captures many of the turning points in the growth of heating oil prices (Figure 16).

Table 13: Out-of-Sample Forecast Performance—Heating Oil

	RMSE (ECM)/RMSE (competing model)		H_A: ECM encompasses competing model		H_B: competing model encompasses ECM	
Model specification	**# steps ahead**		**# steps ahead**		**# steps ahead**	
	1	**2**	**1**	**2**	**1**	**2**
ECM	1.000	1.000				
AR(1)	0.712	0.635	–0.17	–0.88	–3.22	–4.42
AR(2)	0.711	0.632	–0.16	–0.86	–3.22	–4.42
AR(3)	0.699	0.618	–0.07	–0.56	–3.45	–4.59
RW	0.712	0.702	0.41	0.31	–0.98	–1.01

Figure 16: Forecast versus Actual Inflation—Heating Oil

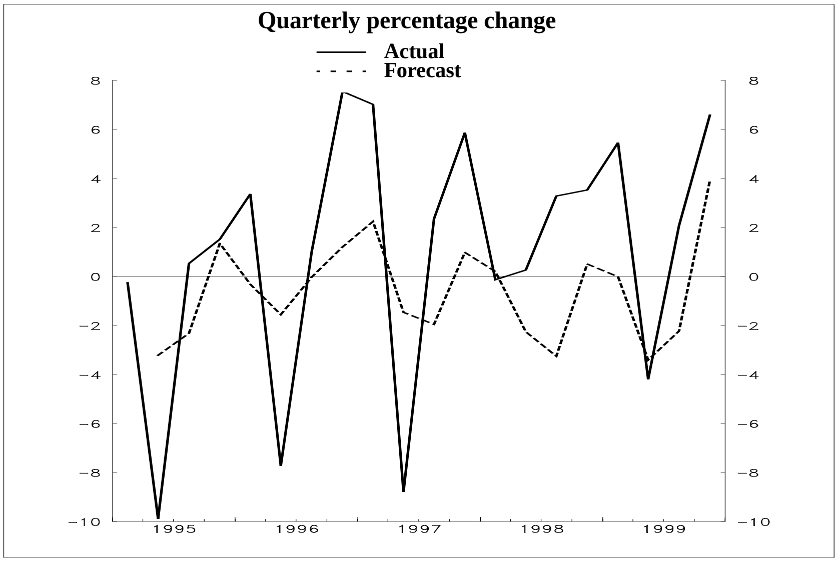


Similarly, the natural gas equation outperforms the alternative models in forecast accuracy (Table 14). Concerning the forecast encompassing test, the ECM seems to outperform the AR models in the one-period-ahead forecasts. That is not the case, however, for the two-period-ahead forecasts where both H_A and H_B hypotheses are rejected by the data. The forecast of the ECM is also capable of predicting most of the turning points in the growth of natural gas prices (Figure 17).

Table 14: Out-of-Sample Forecast Performance—Natural Gas

Model specification	RMSE (ECM)/RMSE (competing model) # steps ahead 1	2	H_A: ECM encompasses competing model # steps ahead 1	2	H_B: competing model encompasses ECM # steps ahead 1	2
ECM	1.000	1.000				
AR(1)	0.820	0.903	–0.36	–1.93	–2.50	–3.13
AR(2)	0.823	0.916	–0.34	–2.02	–2.38	–3.03
AR(3)	0.845	0.980	–0.80	–2.77	–2.51	–3.04
RW	0.605	0.593	0.75	0.42	–0.91	–1.09

Figure 17: Forecast versus Actual Inflation—Natural Gas



5. Conclusions

We have presented a detailed analysis of the price dynamics in the Canadian retail energy markets. Prices at the retail level are determined by input costs, industry dynamics, and in some cases, by government regulation. The adjustment process of downstream prices to input shocks is governed by a host of factors. In many instances, government regulation leads to a sluggish adjustment process, as is evident in the retail natural gas and electricity markets. While we do not carry out an in-depth micro-analysis, it would appear that in some sectors with strong competition, the response of retail prices to oil price shocks seems to be more spread over time, as in the case of heating oil.

Another significant finding is the integration between Canadian and U.S. energy markets. In most cases, energy prices in Canada were found to move similarly to those in the larger U.S. market.

Empirically, we find evidence of pair-wise cointegration between crude oil prices and gasoline, heating oil, and natural gas prices. Because of the heavily regulated nature of the electricity sector, no evidence of cointegration was found with oil prices. Given the increasing use of natural gas in power generation across North America, however, the continent's electricity and natural gas markets are likely to become more integrated, a significant development when we consider the restructuring drive that is taking place in the Canadian electricity sector. The forecasting ability of our models outperforms that of competing model specification, although we must note that the equations exhibit structural breaks, which, to some degree, goes against their merits.

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