Exchange Rate Effects on Excess Demand in the United States for Canadian Oil

by

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Abstract

This paper examines a model of excess supply and excess demand for Canadian oil in the United States utilizing an error correction model and time series analysis. The purpose of this thesis is to examine the link, if there is any, between the imports of Canadian oil in the United States and the exchange rate of Canadian and US Dollars.

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CHAPTER 1

Introduction

Energy policy is a topic that has peaked interest. Specifically, oil production and trade in the United States has received extra attention. The importance of oil in the economy of the United States cannot be understated as current oil consumption amounts to 19 million barrels/day, which at $90 per barrel would total $630 billion per year, or roughly 4.2% of GDP. Oil is a major source of energy across all sectors of the economy from industry to individual consumers driving to and from work every morning.

The United States produces around 169 million barrels per month while it consumes around 575 million barrels per month[2]. The major US oil trading partner is, surprisingly to some, our Canadian neighbors to the north. Oil trade with Canada accounts for 21.5% of US oil imports.

With dramatic increases in oil prices in recent years (especially in early 2008 and late 2010) it is important to try to discover and pinpoint what factors are driving oil imports into the United States. This study will examine the oil trade between Canada and the United States, with particular attention given to the effect of the exchange rate as a possible factor influencing United States imports of Canadian oil.

The theory behind this interest is arbitrage and the Law of One Price. That is, the price of a good in a domestic country will equal the price of the good in the home country times the exchange rate, $P = eP^*$.

For the US to import the majority of oil from Canada, theory would suggest that there is an arbitrage opportunity in the prices of oil in Canada and the US making it more profitable to produce oil in Canada then ship and sell it to the United States. As the Canadian dollar appreciates relative to the US dollar, US oil imports should decrease. A determinant of Canadian oil imports in the US would then be the exchange rate between Canadian dollars and US dollars. This thesis finds that the effect of the exchange rate on oil imports from Canada is not very significant. This would seem to suggest that there are other overriding factors that affect oil imports into the US from Canada.

CHAPTER 2

Literature Review

Previous studies focus on the relationship between oil prices, economic variables, exports, and exchange rates. Few focus on the effect of exchange rates on excess demand, but several studies have examined relevant data. Ghouri (2001) estimates the elasticity of oil demand in the United States, Canada, and Mexico from 1980-1999 in a static model as well as a distributed lag model using yearly data from 1980 - 1999. His study concluded that oil prices were very inelastic in North America over both short and long run time spans, and that oil demand was driven to a very large degree by GDP.

Yousefi and Wirjanto (2005) examine the exchange rate effects in the price formation of oil. They utilize a static/partial equilibrium model and draw empirical conclusions on the relationship between the exchange rate of the US dollar and OPEC countries and the price of oil with yearly data spanning from 1977 - 1999. They conclude that in response to changes in exchange rates, oil exporters adjust prices in order to avoid suppressing quantity demanded. This "pricing to market" strategy implies some degree of price making power.

Krugman (1986) studies the effects of pricing-to-market and movements in exchange rates using yearly data from 1980 - 1985. He examines the effects of import prices of European luxury automobiles and the effects of their market prices in relation to a changing exchange rate. He notes that luxury automobile prices often do not change with exchange rates. He notes that not only did import prices of automobiles not decrease with a rising dollar relative to European currencies, but in some cases the prices increased. His conclusion is that pricing dynamics may fall short of perfect arbitrage all the time but ultimately competition prevails. In cars there may be product differentiation. In oil also there are well known product characteristics among traders & refiners that lead to apparent relaxation of the law of one price.

In the 1990's India implemented a flexible exchange rate. Mallick and Marques (2008) explore the effects of exchange rate pass through into export prices of various industries using yearly data from 1980 - 2001. Their study concludes that India's flexible exchange rate gave enhanced pricing power to it's export industries.

Lescaroux and Mignon (2008) investigate the relationship between oil prices, macro variables, and financial variables across several importing and exporting countries with yearly data from 1965 - 2005. They find a Granger causal relationship of oil prices on and macroeconomic and financial variables suggesting that oil prices heavily influence these other variables especially in oil exporting countries. By using Granger-causality testing for short run effects and multivariate and cointegration analysis to study long term effects, they find that oil prices, share prices, and GDP tend to evolve together over time with oil prices having long run effects on unemployment rates in non-OPEC countries.

Mehrara (2007) investigates Purchasing Power Parity (PPP) for oil exporting countries using annual data from 1965 - 2004. His study utilizes panel unit root tests and panel cointigration analysis to test for purchasing power parity in the exchange rates of oil exporting countries. His findings are that the evidence for PPP is stronger in the long run and is stronger in cases when a country is more open to trade.

Merino and Albacete (2010) study econometric modeling of short run oil prices using monthly data from February of 1999 to February of 2008. They examine the plausibility of the Euro/USD exchange rate Granger-Causing fluctuations in West Texas Intermediate oil price. Utilizing a congruent vector econometric model, they test for and conclude that the EUR/USD nominal exchange rate does not play a part in Granger-causing the price of WTI oil.

CHAPTER 3

Model/Theory

The model that this study will be exploring will be excess supply and excess demand. The structural equations for both excess supply and demand will include the price of oil, the CAD/USD exchange rate, and supply and demand shifters.

This model is based on the general structural equations in natural logs of variables:

$$XS_{cn} = f(W, P) \quad (1)$$

$$XD_{us} = f(Y, P, e) \quad (2)$$

$$XS_{cn} = XD_{us} = X \quad (3)$$

where,

XS_{cn} = Excess Supply from Canada

XD_{us} = Excess Demand from the United States

W = natural log of wages paid to workers in Canada's petroleum industry

e = natural log of the CAD/USD exchange rate

P = natural log of price in Canadian dollars

Y = natural log of personal consumption expenditures in the United States.

The model is specified as in log linear form as:

$$XS_{cn} = \alpha_0 + \alpha_1 P + \alpha_2 W \tag{4}$$

$$XD_{us} = \beta_0 + \beta_1 P + \beta_2 Y + \beta_3 e \tag{5}$$

$$XS_{cn} = XD_{us} = X \tag{6}$$

The exogenous variables are US consumption expenditures Y, Canadian wages W, and the exchange rate e. Endogenous variables are price P, and quantity X.

For this study, attention will be paid to the effect of the exchange rate on the quantity X of US imports from Canada. Solving endogenous variables in terms of exogenous variables yields the following reduced form equation,

$$X = \alpha_0 (\alpha_1 + 1) + \alpha_1\beta_0 + \alpha_1\beta_2 Y/(\alpha_1 - \beta_1) + \alpha_2 W[\alpha_1/(\alpha_2 - \beta_2) + 1] + \beta_3\alpha_1 e/(\alpha_2 - \beta_2) \tag{8}$$

or more simply,

$$X = \zeta_0 + \zeta_1 Y + \zeta_2 W + \zeta_3 e \tag{10}$$

The price of oil and oil imports are functions of US income, Canadian wages, and the exchange rate between Canadian and US dollars (Fig. 1).

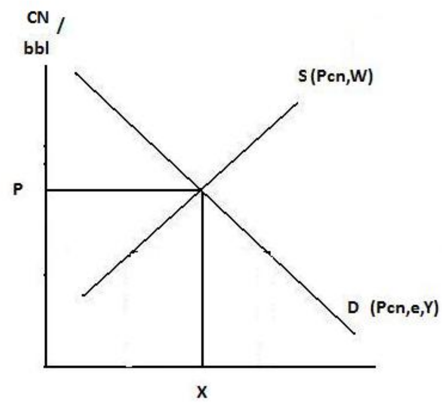

Figure 1. Excess Supply/Demand diagram. Equilibrium.

It is expected that the sign of ζ_1 will be positive. As income and expenditures in the United States increase, it would suggest that oil demand will increase as well (Fig. 2).

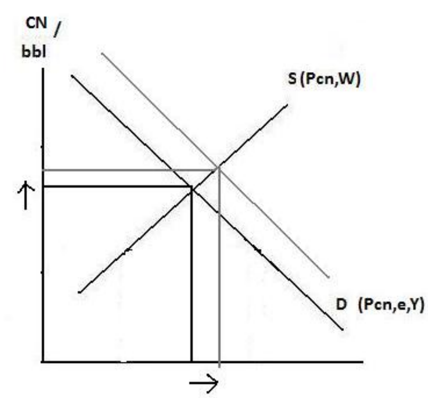

Figure 2. Excess Supply/Demand diagram. Change in Y.

It is expected that will be ζ_2 will be negative. Rising cost of inputs into Canadian oil production would reduce excess supply from Canada, raise prices for US consumers, and lower imports (Fig. 3).

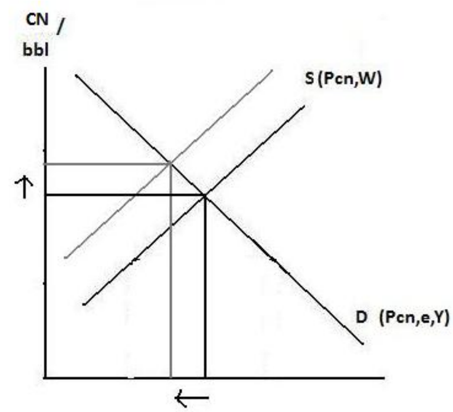

Figure 3. Excess Supply/Demand diagram. Change in W.

Finally, it is expected that ζ_3 will be negative. As the Canadian dollar appreciates relative to the US dollar, this should result in higher US dollar price of Canadian oil, which decreases demand for importing Canadian oil into the United States. An appreciating US dollar relative to the Canadian dollar should result in an arbitrage opportunity where it becomes profitable to produce oil in Canada and sell it in the United States. Canadian oil is then priced cheaper in the United States (Fig. 4).

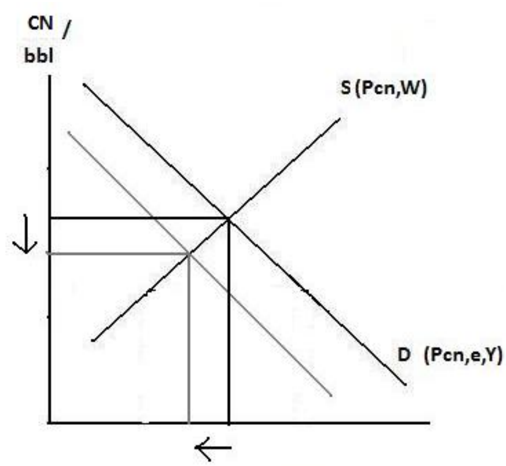

Figure 4. Excess Supply/Demand diagram. Change in e.

The model that will be estimated will be the reduced form equation (10):

$$X_t = c + \zeta_1 Y_t + \zeta_2 W_t + \zeta_3 e_t + \xi_t \qquad (11)$$

The model will utilize data from the Canadian National Statistic Agency, the US Energy Information Administration, and the St. Louis Federal Reserve Bank. Monthly data spanning from 1993 to 2008 will be analyzed. The years chosen were chosen for their availability.

For income (Y), Personal Consumption Expenditures from the United States are from the Federal Reserve Bank of St. Louis due not only to their relevance in determining consumption in the United States, but also for their availability in the monthly data series.

Data for wages are from the Canadian National Statistic Agency and are hourly earnings for employees in Canada's petroleum industry. Time series data for the exchange rate is from the Federal Reserve Bank of St. Louis and represents the Canadian dollar price of the US dollar. Data for Excess Demand for Canadian Oil in the United States is total imports of Canadian oil and is from the United States Energy Information Administration. Prices for oil are spot prices for the West Texas Intermediate oil price that is set on the futures and commodities exchanges with data from the Federal Reserve Bank of St. Louis. Level variables are adjusted with data from the year 2008 = 100.

CHAPTER 4

Results

The first step will be to pretest the data for stationarity using the Augmented-Dickey Fuller test. This test will indicate whether or not the statistical properties are constant over time. Stationary processes are more useful for analyzing data and especially useful for forecasting, though this paper will focus on analyzing historical data. Running the test on the level variables and difference variables indicates that the variables are trend stationary with a lag of 9 (Table 1). This lag order is probably due to the fact that I am working with monthly data.

Variable	*ADF (9 lag)*
$\ln(W_t)$	-3.24
$\ln(e_t)$	-2.13
$\ln(Y_t)$	0.69
$\Delta\ln(W_t)$	-3.43
$\Delta\ln(e_t)$	-2.61
$\Delta\ln(Y_t)$	-1.24

Table 1. ADF Test Results
Critical Value: -3.44

Difference stationary variables suggests the difference model regression,

$$\Delta X_t = c + \zeta_1 \Delta Y_t + \zeta_2 \Delta W_t + \zeta_3 \Delta e_t + \eta_t \qquad (12)$$

or perhaps an error correction regression if the variables appear cointegrated.

It is possible to test for cointegration between variables by the Engle-Granger test conducted on the level variables.

Variable	*Coefficient*	*T-stat*	*Crit. Value*	*DW*	*ARCH(1)*
$\ln(e_{t-1})$	-0.186	-2.06	-3.9	2.96	1.90

Table 2. Engle-Granger Cointegration Test Result.
*** = 10%, ** = 5%, *** = 1%**

Although the regression does not pass the Engle-Granger test, it may be sensible to construct an error correction model to examine the effects of the level variables on the effects of the difference model. This is achieved by using the residuals of (11) as endogenously effecting ΔXD_t. An OLS regression is then conducted on the level variables (fig. 9) yields the following results. Table 3 presents the estimate of the cointegrating equation.

	c	W_t	e_t	Y_t
Coefficients	-0.025	-0.22***	0.039	0.955***
Standard Errors	0.020	0.073	0.024	0.033
DW	1.46			
R Square	0.92			
ARCH (1)	1.98			

Table 3. Natural Log Level variable estimates
* = 10%, ** = 5%, *** = 1%

The residuals ξ_{t-1} from the cointegrating regression in Table 3 are then used in the difference model (fig. 10) to produce the error correction model in the following form,

$$\Delta X_t = c + \phi_1 \Delta W_t + \phi_2 \Delta e_t + \phi_3 \Delta Y_t + \phi_4 \xi_{t-1} + \eta_t \qquad (13)$$

An OLS regression on the error correction model gives the estimates in Table 4.

	c	ΔW_t	Δe_t	ΔY_t	ξ_{t-1}
Coefficients	0.001	-0.081	0.372	0.710	-0.179*
Standard Errors	0.008	0.107	0.333	2.36	0.090
DW	2.04				
R Square	0.032				
ARCH(1)	1.62				

Table 4. ECM Estimates
*** = 10%, ** = 5%, *** = 1%**

The overall short run and long term error correction effects on the exchange rate are calculated as follows,

$$X_t = c + \zeta_1 W_t + \zeta_2 e_t + \zeta_3 Y_t + \xi_{t-1} \quad (14)$$

$$\xi_{t-1} = X_t - c - \zeta_1 W_t - \zeta_2 e_t - \zeta_3 Y_t \quad (15)$$

$$\Delta X_t = c + \phi_1 \Delta W_t + \phi_2 \Delta e_t + \phi_3 \Delta Y_t + \phi_4 (X_t - c - \zeta_1 W_t - \zeta_2 e_t - \zeta_3 Y_t) + \eta_t \quad (16)$$

The error correction effect on the exchange rate then is,

$$\phi_2 + \phi_4 \zeta_2 \quad (17)$$

In the dynamic adjustment process, ϕ_2 is the transitional adjustment of ΔX_t with respect to Δe_t and $\phi_4 \zeta_2$ is the adjustment of Δe_t toward the dynamic equilibrium. Standard errors for the error correction effect on the exchange rate variable are calculated by using an error propagation method,

$$\sigma_{\text{Total}} = [\sigma_{\phi 2}{}^2 + \{ (\phi_4 \zeta_2)[(\sigma_{\phi 4} / \phi_4)^2 + (\sigma_{\zeta 2} / \zeta_2)^2]^{.5} \}^2]^{.5} \quad (18)$$

The total effect of Δe_t on ΔXQ_{dt} has two components. First is the transitory component (ϕ_2) followed by the adjustment relative to the dynamic equilibrium ($\phi_4 \zeta_2$). This effect appears to be largely insignificant , and is in line with previous studies that suggest that a larger, driving factor behind oil trade between Canada in the US is US output growth.

Variable	Total ECM Effect	Standard Error
$\ln e_t$	0.38	1.83
$\ln W_t$	-0.12	0.71
$\ln Y_t$	0.88	2.37

Table 5. Total ECM Effects and Derived Standard Errors
*** = 10%, ** = 5%, *** = 1%**

Table 6 shows the error adjustment of the variables toward their dynamic equilibrium and their associated derived standard errors.

Variable	ECM Effect	Standard Error
$\ln e_t$	0.007	3.25
$\ln W_t$	0.040	0.49
$\ln Y_t$	0.170*	0.09

Table 6. Error Adjustment and Derived Standard Errors
*** = 10%, ** = 5%, *** = 1%**

As is seen from both tables, the only statistically significant effect is that of US personal consumption expenditures.

CHAPTER 5

Conclusion

This study has examined possible effects of a change in the Canadian /US dollar exchange rate on imports of Canadian oil in the United States. It is possible to analyze the effects in an error correction model.

This analysis suggests that there is an error correction relationship between US demand for Canadian oil and the exchange rate. The effect is as expected in economic theory. A 10% dollar depreciation might imply only a 4% decrease in oil imports. Demand for Canadian oil in the US is largely unaffected by changes in the exchange rate.

The reason for the inelasticity of imports with regard to the exchange rate is likely due to other economic factors such as US output that drive oil trade between the US and Canada. The results of this study suggest that personal consumption expenditures are slightly more elastic and a stronger determinant of oil imports as oil imports would increase about 9% with a 10% rise in personal consumption. A 10% rise in wages for Canadian workers would imply about a -.4% fall in excess demand. One reason for the larger effect of PCE data may be due to there being a larger volume of economic agents spending on oil consumption as personal consumption expenditures rise. Excess demand for Canadian oil is effected to a more significant degree by changes in consumption of US consumers than it is changes in the exchange rate or changes in Canadian wages. The small amount of variation in the exchange rate may explain the lack of significance in the exchange rate effect.

Further study of interest would be to test for this effect over shorter time frames and across different industries, economic sectors, trading partners, and exchange rates as well as seeing if there is a lagged effect of the exchange rate on oil imports.

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Figures

Figure 5. Price of WTI Oil in USD and CAD

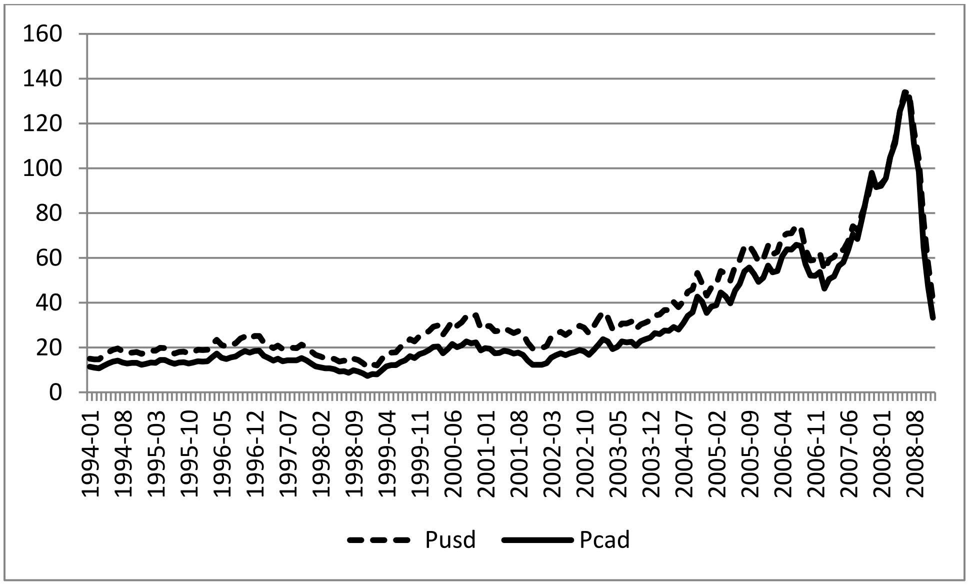


Figure 6. Exchange Rate. Canadian Dollars to One US Dollar. Monthly Data.

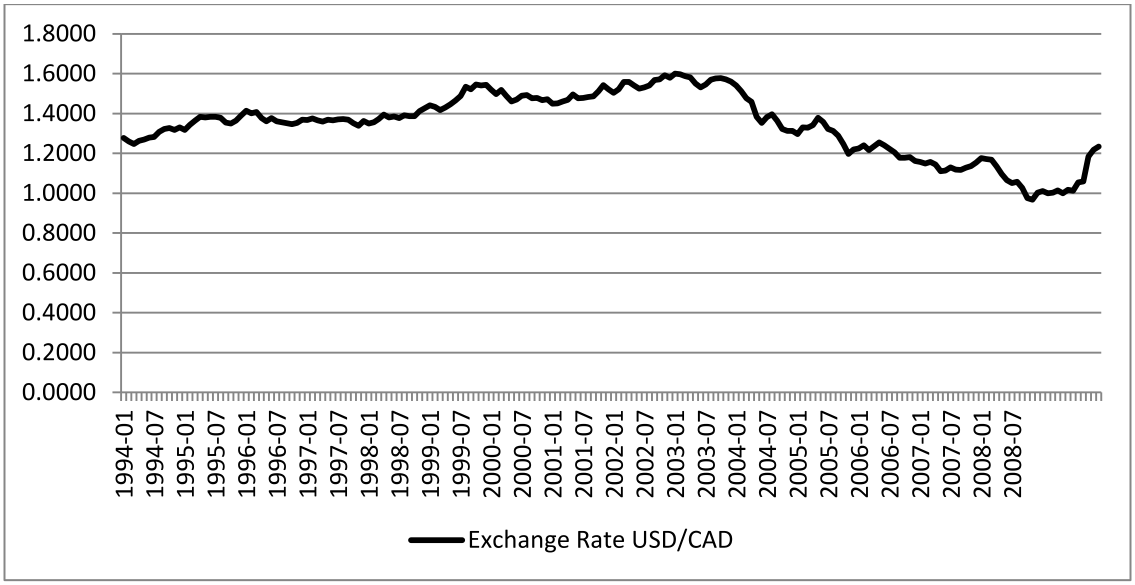


Figure 7. US Oil Imports from Canada.

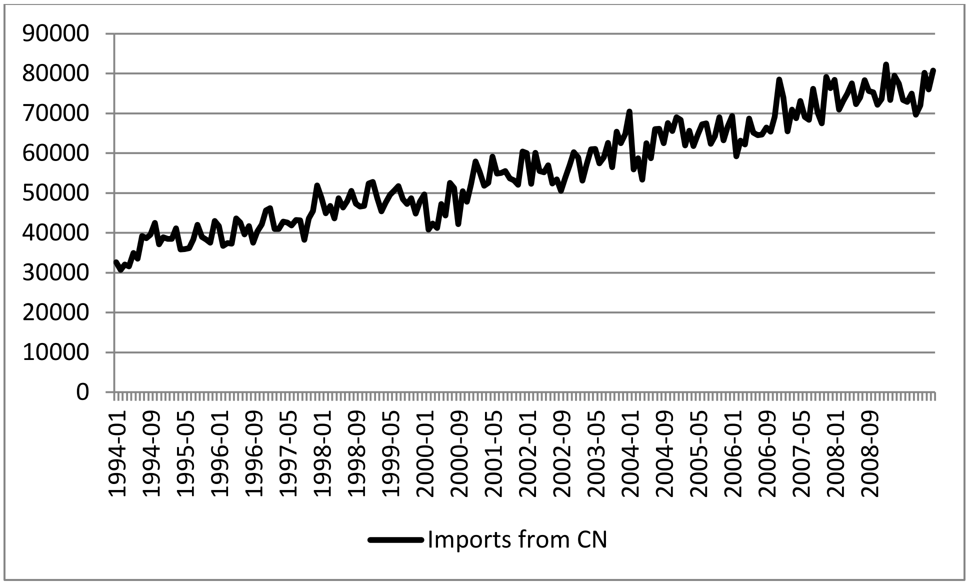


Figure 8. Adjusted Level Variables (2008=1).

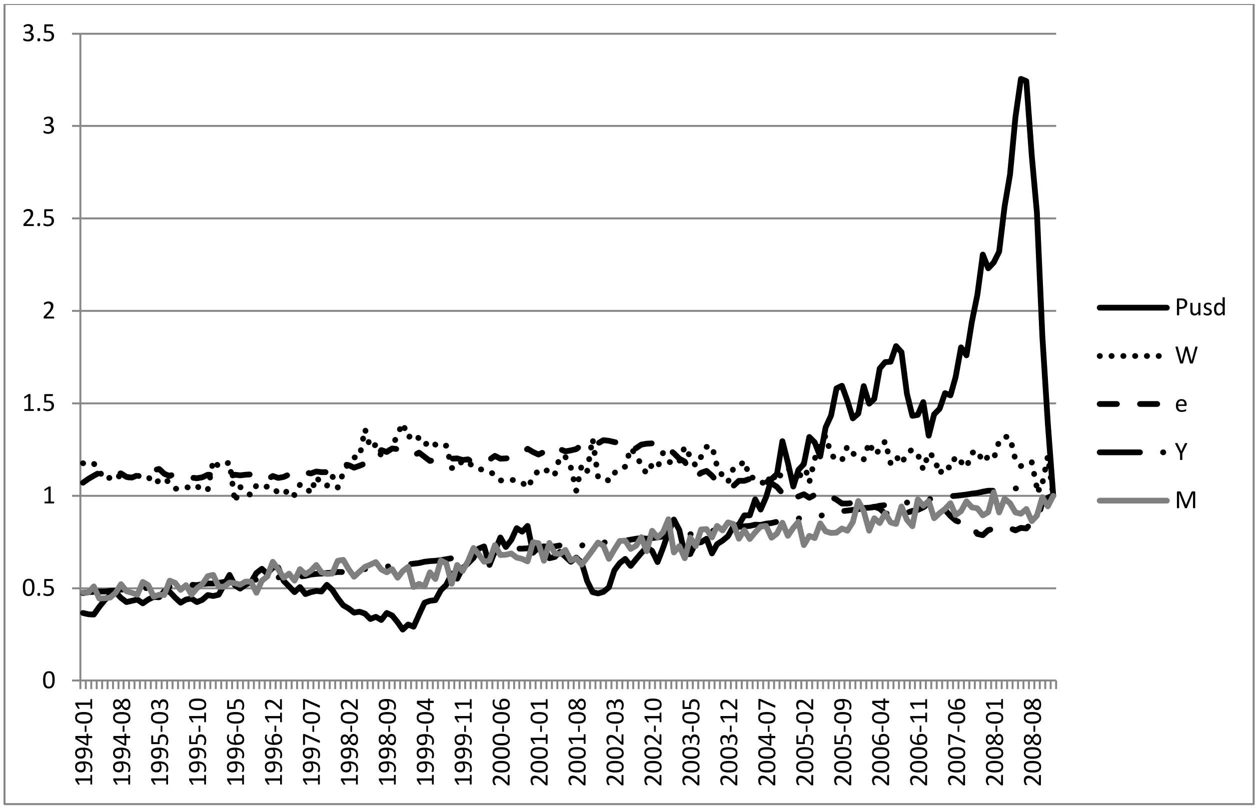
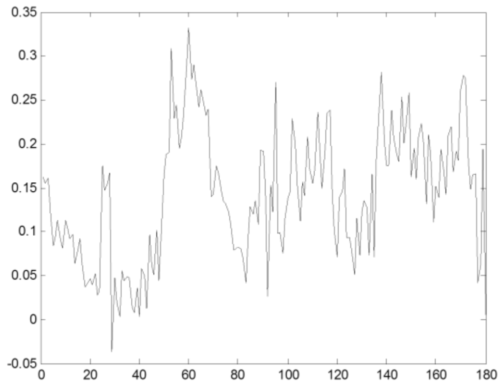
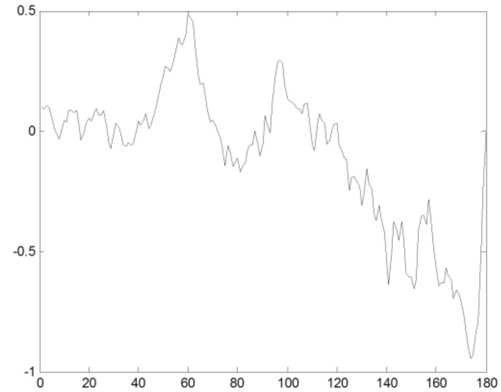


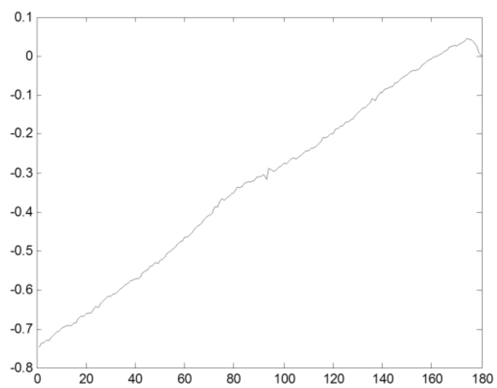
Figure 9. Natural Log Level Variables.



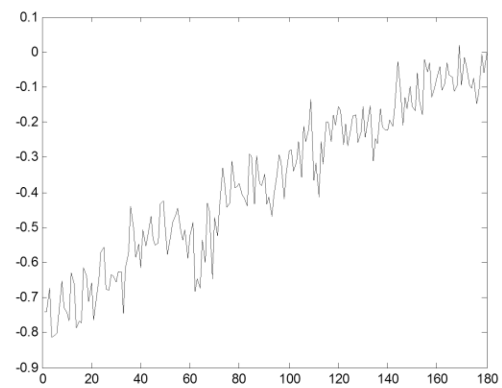
lnW



lne

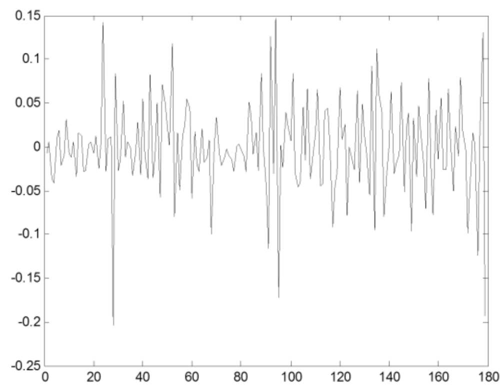


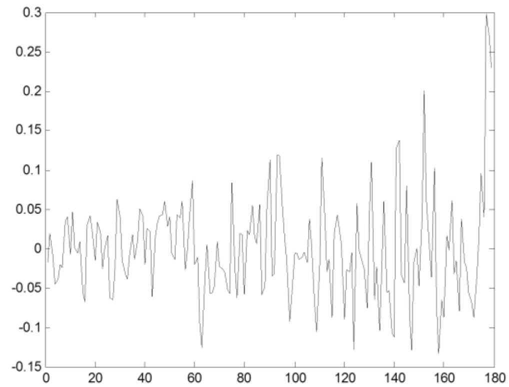
lnY



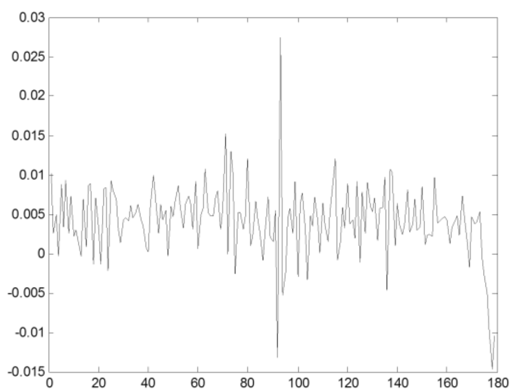
lnXD

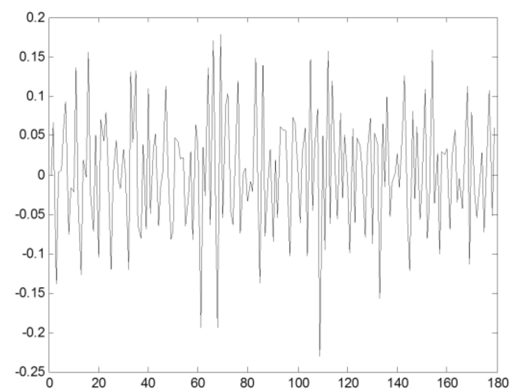
Figure 10. Natural Log Difference Variables.





ΔlnW **Δlne**





ΔlnY **ΔlnXD**

Figure 11. ECM Residual Plot.

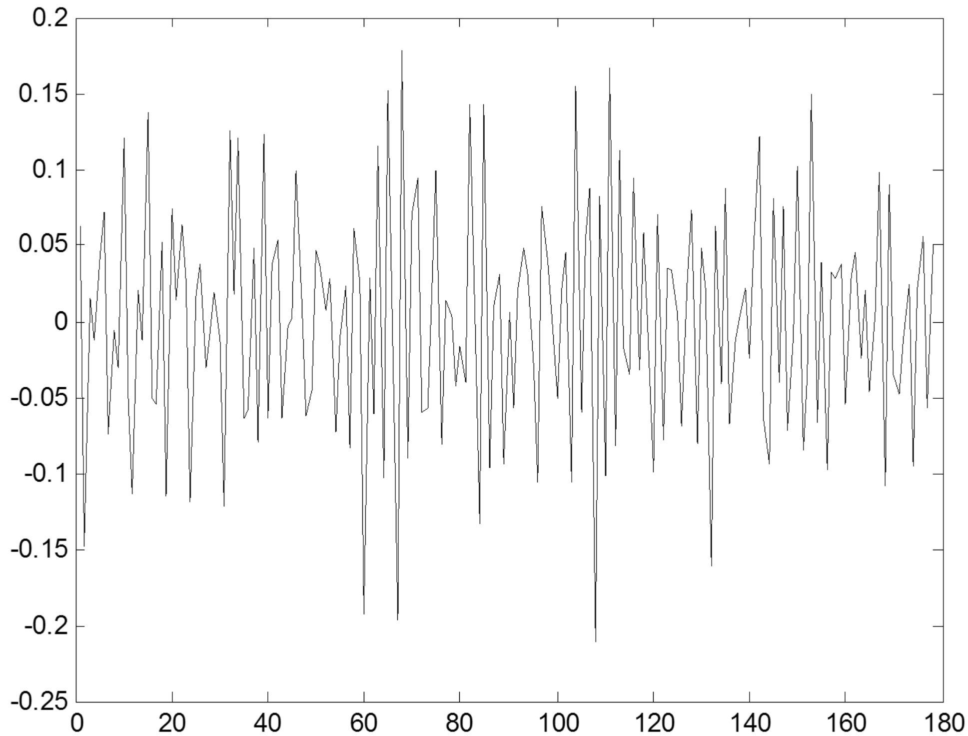
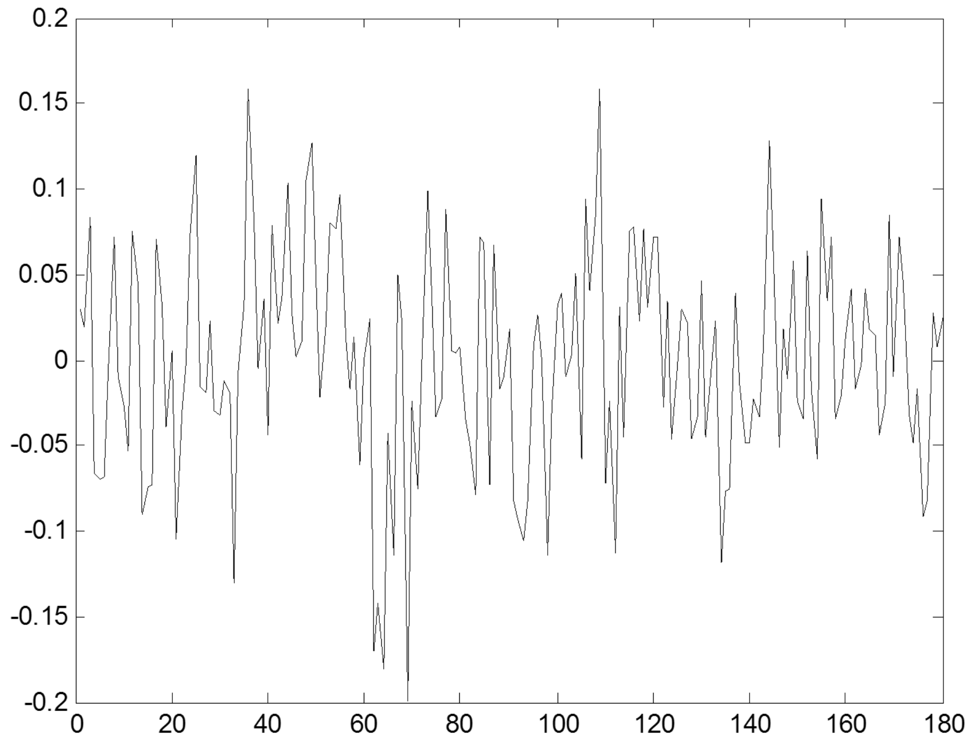


Figure 12. Natural Log Level Variable Residual Plot (2008=1).



Appendix A.

Data Sets (2008=1).

LnXD	LnW	Lne	LnY	dLnXD	dLnW	dLne	dLnY	E[t-1]
-0.74058	0.161787	0.105099	-0.74744					
-0.74066	0.154954	0.08781	-0.73725	-7.8E-05	-0.00683	0.018875	0.010197	
-0.6745	0.160876	0.106789	-0.7347	0.066153	0.005922	0.016256	0.002549	0.030385
-0.81267	0.124807	0.097404	-0.72977	-0.13817	-0.03607	0.01354	0.00493	0.019722
-0.80882	0.083928	0.052561	-0.73013	0.003846	-0.04088	-0.00159	-0.00036	0.084014
-0.80261	0.094296	0.01337	-0.72137	0.006212	0.010368	0.002026	0.008757	-0.0665
-0.74446	0.112914	-0.00714	-0.71802	0.058155	0.018618	-0.00072	0.003351	-0.06963
-0.65185	0.091316	-0.03121	-0.70876	0.092606	-0.0216	-0.00311	0.009257	-0.06796
-0.72754	0.08211	0.003916	-0.70618	-0.07569	-0.00921	-0.01779	0.002582	-0.00808
-0.74378	0.112822	0.044107	-0.69887	-0.01624	0.030712	-0.00274	0.007313	0.071829
-0.76608	0.10428	0.037486	-0.69664	-0.0223	-0.00854	0.010608	0.002227	-0.00974
-0.62928	0.091757	0.084223	-0.69362	0.136794	-0.01252	0.017865	0.003023	-0.02772
-0.66064	0.097363	0.084307	-0.69192	-0.03136	0.005606	0.017057	0.001703	-0.05378
-0.78777	0.063602	0.07821	-0.6922	-0.12713	-0.03376	-0.00903	-0.00029	0.075529
-0.76816	0.079697	0.08618	-0.68534	0.019608	0.016095	0.005128	0.006866	0.043786
-0.77209	0.092665	0.030303	-0.68454	-0.00393	0.012968	-0.02263	0.000794	-0.09032
-0.6161	0.064251	-0.03716	-0.67597	0.155995	-0.02841	-0.01118	0.00857	-0.07401

-0.63886	0.037443	-0.00734	-0.66706
-0.71091	0.040429	0.034714	-0.66846
-0.66023	0.046264	0.056474	-0.66139
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-0.57108	0.032207	0.068514	-0.64315
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0.050678	0.005834	-0.00442	0.007063	0.032088
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0.043046	-0.02467	0.005631	0.008263	-0.10412
0.080246	0.004751	0.01168	0.008292	-0.03039
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0.043783	0.011693	-0.0047	0.006881	-0.01566
-0.0055	-0.20332	0.007403	0.003108	-0.01911
-0.01722	0.083607	-0.00256	0.001332	0.023247
0.031587	-0.0275	0.002851	0.004269	-0.02931
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0.130745	-0.01196	-0.01368	0.006064	-0.0195
0.041552	0.005248	-0.00945	0.004543	-0.13087
0.132762	-0.00166	0.01785	0.005132	-0.00704
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0.008063	0.071563	0.009624	-0.00028	0.011242
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0.047319	0.002565	0.009275	0.006579	0.048957
0.041417	0.117607	0.010713	0.008649	-0.02165
0.020991	-0.07959	0.013949	0.005804	0.020175
0.021294	0.016291	0.014497	0.00321	0.079967
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0.063496	0.043935	0.001881	0.00919	0.012917
0.037478	-0.05852	-0.01561	0.000588	-0.06143
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0.057334	-0.02556	0.007305	0.004094	-0.01754
-0.0355	0.065992	-0.02994	0.004746	-0.00339
-0.00423	0.010638	-0.05126	0.002309	0.041973
-0.04289	-0.05091	-0.00844	0.007348	0.017858
0.019524	0.02361	0.035448	0.004539	0.014383
0.111974	-0.01132	0.007754	0.001129	-0.04373
-0.11445	0.078756	-0.01125	-0.00173	-0.02479
0.079858	0.018288	0.004297	0.00465	0.084269
-0.0254	-0.00262	0.010711	0.003747	-0.01012
-0.05427	-0.09871	-0.01431	0.00398	0.071507
-0.00673	-0.02815	0.017164	0.00537	0.044652
0.027698	0.01603	-0.00355	-0.00051	-0.03192
-0.07314	0.00158	0.039202	-0.00268	-0.04866
0.03299	-0.12379	0.004451	-0.00507	-0.01749
0.107269	0.020695	0.11292	-0.00999	-0.09142
-0.05262	0.131063	0.026981	-0.01464	-0.08263
0.059836	-0.19381	0.013547	-0.01043	0.027168
				0.007131
				0.025003