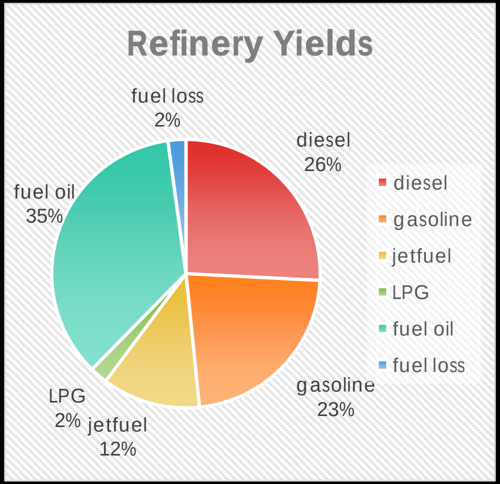
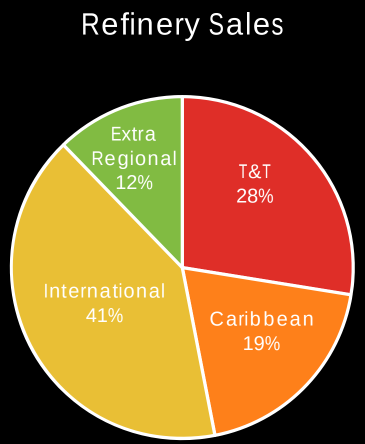
EXPORT PRICE VOLATILITY OF REFINED PETROLEUM PRODUCTS FROM A SMALL HYDROCARBON BASED ECONOMY

Roger Hosein, Don Charles, Martin Franklin

EXPORT PRICE VOLATILITY OF REFINED PETROLEUM PRODUCTS FROM A SMALL HYDROCARBON BASED ECONOMY

- Trinidad and Tobago (T&T) has 1 oil refinery situated at Point-a-Pierre. Crude oil is refined into the following products: : gasoline, diesel, fuel oil, jet fuel, and Liquid Petroleum Gas (LPG).





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- The Gross margin is the weighted average price of refinery fractions less the price of crude oil. Within the recent years, the refinery margins have began to decline. This has negatively impacted the profitability of Petrotrin's refinery.

The profitability of the refinery is of interest to T&T because: provide employment for 5,000 persons, sources services from 2,000 registered contractors, maintain roads and bridges that connects to its operations, and implements a number of positive externality projects

EXPORT PRICE VOLATILITY OF REFINED PETROLEUM PRODUCTS FROM A SMALL HYDROCARBON BASED ECONOMY

- Since refinery margins are influenced by the prices of the refinery fractions this study seeks to model the volatility of refinery fraction prices.
- Crude oil prices and refinery fraction prices are volatile. Volatility is the tendency of a series to fluctuate.
- Volatility is a also measure of risk. It is the tendency for the price of a commodity to deviate from its mean price. We are concerned about volatility because it measures the tendency of the price of refinery fractions to decline and thus refinery margins would get smaller.

EXPORT PRICE VOLATILITY OF REFINED PETROLEUM PRODUCTS FROM A SMALL HYDROCARBON BASED ECONOMY

- Objective: This study seeks to study the volatility of prices of the following commodities: gasoline, diesel, heating oil, and jet fuel. This study is distinguished from other studies by:
  - The length of the study and the utilization of the most recent data;
  - The utilization of both real and nominal data, as previous research neglected real data;
  - The consideration of a pre & post financial crisis (US Shale boom era);
  - Including oil prices in the mean equation;
  - Testing for volatility spillover for diesel, gasoline, heating oil and jet fuel;
  - Implications of volatility for a small country refinery

DATA

- Source of data:
- Both nominal and real data on the energy commodities are collected from the US Energy Information Administration (EIA). Weekly nominal data is collected from 19th April, 1996 to 1st August, 2014. Such period is used because data was available for all variables within such period. Weekly data is used over annual data since it will produce 955 observations per variable.
- Real data is collected over the period January 1979 to August 2014. The monthly data generates 428 observations per variable. Weekly data was preferred but an appropriate deflator could not be found for weekly data.

METHODOLOGY

- Test are performed for stationarity. The ADF, PP and KPSS test are used. Since all variables (gasoline, diesel, heating oil and jet fuel) were all I(1) they we converted into continuously compounded returns to make them stationary.
- $R_t = \log(\frac{P_t}{P_{t-1}})$
- All series were also tested for ARCH effects to determine if GARCH type models were appropriate.
- GARCH and the EGARCH models were considered to model each refinery fraction prices
- A GARCH model is a model that simulates the conditional variance of a time series. It models variance as a function of the squared residual of the mean equation, and the lagged variance

METHODOLOGY

- For both GARCH and EGARCH a mean equation is specified. The mean equation was $P_t = \beta_1 WTI + \varepsilon_t$. WTI was used as a proxy for oil price. This was to allow oil prices to affect refinery fraction prices in the mean equation.

Model	Equation
ARCH (1)	$\sigma^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_1 u_{t-1}^2$
GARCH (1, 1)	$\sigma^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2$
TARCH (1, 1)	$\sigma^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 + \gamma u_{t-1}^2 I_{t-1}$
EGARCH (1, 1)	$\log(\sigma^2) = \omega + \sum_{i=1}^{q} \alpha_i \left\lvert \frac{u_{t-i}}{\sigma_{t-i}} \right\rvert + \sum_{k=1}^{r} \lambda_k \frac{u_{t-k}}{\sigma_{t-k}} + \sum_{j=1}^{p} \beta_j \log(\sigma_{t-j}^2)$

The EGARCH model was used to test for asymmetric effects. The sign (leverage) effect is if negative shocks increase volatility more than positive shocks. The size effect is if large shocks increase volatility more than small shocks.

DIAGNOSTIC TESTS

- The MSE is given by:
- $$MSE = \frac{1}{T-(T_1-1)} \sum_{t=T}^{T} (y_{t+s} - f_{t,s})^2$$ (11)
- The MAE is given by:
- $$MSE = \frac{1}{T-(T_1-1)} \sum_{t=T}^{T} \left| y_{t+s} - f_{t,s} \right|$$ (12)
- The Theil U Statistic is given by:
- $$U = \frac{\sqrt{\sum_{t=T}^{T} \left(\frac{y_{t+s} - f_{t,s}}{y_{t+s}} \right)^2}}{\sqrt{\sum_{t=T}^{T} \left(\frac{y_{t+s} - fb_{t,s}}{y_{t+s}} \right)^2}}$$

The smaller the value of the MSE and the MAE, the better the predictive accuracy

As U tends to zero, the better the predictive accuracy, and as U tends to 1, the more unreliable the predictive accuracy

RESULTS

Table 1 A: ACF results at level

<table>
<tr><th>ACF Diesel</th><th>PACF Diesel</th><th>ACF gasoline</th><th>PACF gasoline</th><th>ACF WTI</th><th>PACF WTI</th></tr>
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<tr><th>ACF heating oil</th><th>PACF heating oil</th><th>ACF jet fuel</th><th>PACF jet fuel</th><th>ACF propane</th><th>PACF propane</th></tr>
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Table 1 B: 1st difference ACF results

<table>
<tr><th>ACF D(diesel)</th><th>PACF D(diesel)</th><th>ACF D(gasoline)</th><th>PACFD(gasoline)</th><th>ACF D(WTI)</th><th>PACF D(WTI)</th></tr>
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<tr><td>| |</td><td>| |</td><td>| |</td><td>| |</td><td>| |</td><td>| |</td></tr>
<tr><th>ACF D(heating oil)</th><th>PACF D(heating oil)</th><th>ACF D(jet fuel)</th><th>PACF D(jet fuel)</th><th>ACF D(propane)</th><th>PACF D(propane)</th></tr>
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All variables are non-stationary and I(1)

RESULTS

Table 3: Stationary results

Nominal data		Weekly from 19th April 1996 to 1st August 2014				
Variable	ADF level	ADF 1st Diff	PP Level	PP 1st diff	KPS level	KPS 1st diff
Ln gasoline	0.4876	0.0000	0.6184	0.0000	3.527408	0.031156
Ln diesel	0.7088	0.0000	0.7172	0.0000	3.467929	0.058297
Ln heat oil	0.7562	0.0000	0.7957	0.0000	3.529947	0.053852
Ln jet fuel	0.6850	0.0000	0.7288	0.0000	3.519684	0.047815
Ln lpg	0.3751	0.0000	0.3945	0.0000	3.004895	0.047909
Ln WTI	0.7026	0.0000	0.7753	0.0000	3.540030	0.053420
Real data		Monthly from January 1979 to August 2014				
Ln gasoline	0.3826	0.0000	0.5671	0.0000	0.683519	0.144884
Ln diesel	0.3010	0.0000	0.3722	0.0000	0.587386	0.118427
Ln heat oil	0.4860	0.0000	0.6271	0.0000	0.802313	0.136739
Ln WTI	0.2331	0.0000	0.4471	0.0000	0.673827	0.112796

Source: Computed

All variables are I(1)

RESULTS

Table 4: Normality results

Variable	Nominal data results	Real data results	Variable	Nominal data results	Real data results
Gasoline returns	JB 485.83 prob. 0.0000 Kurtosis 6.49 Skewness -0.01	JB 1019.74 prob. 0.0000 Kurtosis 10.28 Skewness -1.02	Heating oil returns	JB 2767.24 prob. 0.0000 Kurtosis 11.33 Skewness 0.13	JB 1526.62 prob. 0.0000 Kurtosis 12.09 Skewness 0.88
Diesel returns	JB 307.68 prob. 0.0000 Kurtosis 5.76 Skewness 0.17	JB 183.05 prob. 0.0000 Kurtosis 6.11 Skewness -0.39	Propane returns	JB 4991.09 prob. 0.0000 Kurtosis 14.18 Skewness -0.34	
Jet fuel returns	JB 220.7 prob. 0.0000 Kurtosis 5.33 Skewness -0.14		WTI returns	JB 402.65 prob. 0.0000 Kurtosis 6.12 Skewness -0.31	JB 379.21 prob. 0.0000 Kurtosis 7.45 Skewness -0.61

Source: Computed

Low JB probabilities result in the rejection of the null hypothesis that the series are normally distributed. Thus all variables are not Gaussian distributed. Thus ARCH type modeling is appropriate.

RESULTS

Table 5: ARCH effects results

Variable	Test Statistic	Nominal data	Real data
Diesel returns	Prob. F(7,939)	0.0000	0.0001
	Prob. Chi-Square(7)	0.0000	0.0001
Log gasoline	Prob. F(7,939)	0.0000	0.0000
	Prob. Chi-Square(7)	0.0000	0.0000
Log jet fuel	Prob. F(7,939)	0.0000	
	Prob. Chi-Square(7)	0.0000	
Log heating oil	Prob. F(7,939)	0.0002	0.0000
	Prob. Chi-Square(7)	0.0002	0.0000
Log propane	Prob. F(7,939)	0.0000	
	Prob. Chi-Square(7)	0.0000	
Log WTI	Prob. F(7,939)	0.0000	0.0000
	Prob. Chi-Square(7)	0.0000	0.0000

Low probabilities result in the rejection of the null of no ARCH effects are present. Thus GARCH type modeling is appropriate.

RESULTS

Table 6: GARCH and EGARCH results

GARCH	Nominal diesel	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.7028	0.0200	35.1294	0.0000
Variance Eq.	C	0.0000	0.0000	2.5014	0.0124
	ARCH(-1)	0.2054	0.0407	5.0502	0.0000
	GARCH(-1)	0.7991	0.0292	27.3702	0.0000
EGARCH	Nominal diesel	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.7051	0.0186	37.8089	0.0000
Variance Eq.	C(2) constant	-0.5589	0.1113	-5.0192	0.0000
	C(3) size effect	0.3718	0.0542	6.8631	0.0000
	C(4) leverage effect	0.0834	0.0335	2.4880	0.0128
	C(5) GARCH term	0.9589	0.0137	69.9322	0.0000
GARCH	Nominal gasoline	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.8378	0.0238	35.1395	0.0000
Variance Eq.	C	0.0001	0.0000	3.2345	0.0012
	ARCH(-1)	0.2372	0.0460	5.1549	0.0000
	GARCH(-1)	0.7094	0.0464	15.2734	0.0000
EGARCH	Nominal gasoline	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.8569	0.0227	37.8288	0.0000
Variance Eq.	C(2) constant	-0.7742	0.1734	-4.4636	0.0000
	C(3) size effect	0.3393	0.0568	5.9707	0.0000
	C(4) leverage effect	0.1320	0.0363	3.6342	0.0003
	C(5) GARCH term	0.9240	0.0227	40.7086	0.0000
GARCH	Nominal heat oil	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.8113	0.0153	52.9572	0.0000
Variance Eq.	C	0.0001	0.0000	3.7531	0.0002
	ARCH(-1)	0.1977	0.0401	4.9355	0.0000
	GARCH(-1)	0.7309	0.0410	17.8254	0.0000
EGARCH	Nominal heat oil	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.8184	0.0150	54.6137	0.0000
Variance Eq.	C(2) constant	-0.7667	0.1678	-4.5697	0.0000
	C(3) size effect	0.3329	0.0512	6.5008	0.0000
	C(4) leverage effect	0.0717	0.0343	2.0929	0.0364
	C(5) GARCH term	0.9319	0.0196	47.5188	0.0000
GARCH	Nominal jet fuel	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.7837	0.0173	45.3244	0.0000
Variance Eq.	C	0.0000	0.0000	3.4583	0.0005
	ARCH(-1)	0.2249	0.0431	5.2190	0.0000
	GARCH(-1)	0.7328	0.0350	20.9512	0.0000
EGARCH	Nominal jet fuel	Coefficient	Std. Error	z-Statistic	Prob.
Mean Eq.	RW	0.7835	0.0170	46.1252	0.0000
Variance Eq.	C(2) constant	-0.8047	0.1633	-4.9290	0.0000
	C(3) size effect	0.3892	0.0554	7.0297	0.0000
	C(4) leverage effect	**0.0490**	**0.0365**	**1.3446**	**0.1788**
	C(5) GARCH term	0.9295	0.0201	46.3412	0.0000

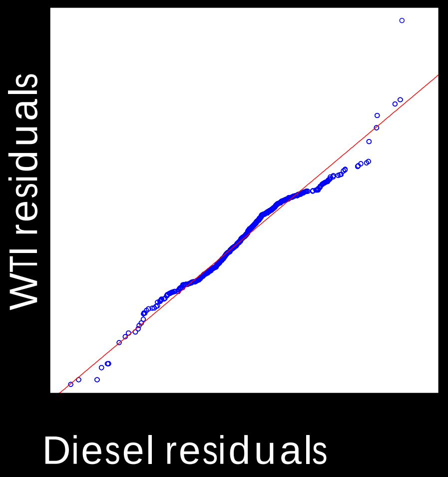
In all models, WTI is significant in the mean equation, suggesting oil prices affect refinery fraction prices.

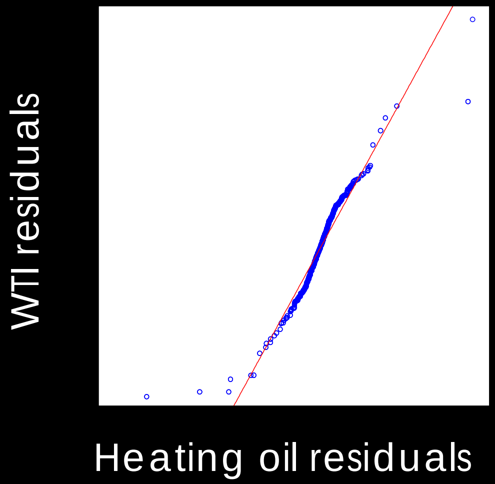
The leverage effect for gasoline, diesel and heating oil were positive and significant. Thus negative shocks increase their volatility more than positive shocks. The leverage effect for jet fuel was insignificant, suggesting symmetric in sign of shock effects.

For all models the GARCH term is large and over 0.71 suggesting the persistence of shocks.

DIAGNOSTIC TESTS

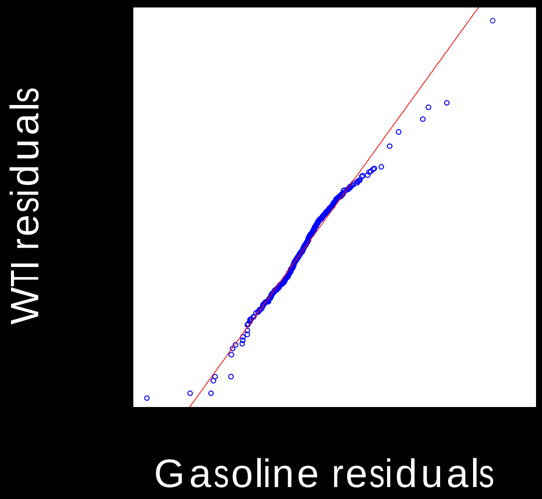
Nominal data QQ plot of diesel residuals





The QQ plot shows how the distribution of 1 series matches the distribution of another series.

QQ plot of gasoline residuals



For all series, the refinery fraction residuals matched WTI residuals, however, positive and negative shocks caused the occasional deviation of a few data points

RESULTS

Table 7: Volatility spillover effects.

Equation	Probability	Equation	Probability
Diesel-gasoline	0.0279	Gasoline-Diesel	0.0249
Diesel-heating oil	0.0000	Gasoline-heating oil	0.0048
Diesel-jet fuel	0.0000	Gasoline-jet fuel	0.0000
Diesel-WTI	0.0025	Gasoline-WTI	0.0767
Heating oil–diesel	0.0000	Jet fuel-Diesel	0.0000
Heating oil-gasoline	0.0113	Jet fuel-gasoline	0.0000
Heating oil-jet fuel	0.0000	Jet fuel-heating oil	0.0000
Heating oil-WTI	0.0001	Jet fuel-WTI	0.0023

For each series, the variance term was significant in the volatility spill over equation. This suggested volatility spillover effects.
E.g. It means that the volatility of diesel prices affects the volatility of gasoline prices.

DIAGNOSTIC RESULTS

Nominal data	diesel	gasoline	Heating oil	Jet fuel
GARCH (1,1)	MSE: 0.0393 MAE: 0.0272 Thiel: 0.5156	MSE: 0.0418 MAE: 0.0282 Thiel: 0.4679	MSE: 0.0316 MAE: 0.0192 Thiel: 0.4024	MSE: 0.0315 MAE: 0.0204 Thiel: 0.4109
TARCH (1,1)	MSE: 0.0393 MAE: 0.0272 Thiel: 0.5152	MSE: 0.0418 MAE: 0.0282 Thiel: 0.4656	MSE: 0.0316 MAE: 0.0192 Thiel: 0.4021	MSE: 0.0315 MAE: 0.0204 Thiel: 0.4104
EGARCH(1,1)	MSE: 0.0393 MAE: 0.0272 Thiel: 0.5151	MSE: 0.0418 MAE: 0.0282 Thiel: 0.4642	MSE: 0.0316 MAE: 0.0192 Thiel: 0.4014	MSE: 0.0315 MAE: 0.0204 Thiel: 0.4109
Real data				
GARCH (1,1)	MSE: 0.0403 MAE: 0.0289 Thiel: 0.2638	MSE: 0.0369 MAE: 0.0265 Thiel: 0.4957	MSE: 0.0390 MAE: 0.0248 Thiel: 0.6615	
TARCH (1,1)	MSE: 0.0403 MAE: 0.0289 Thiel: 0.2639	MSE: 0.0369 MAE: 0.0265 Thiel: 0.4951	MSE: 0.0390 MAE: 0.0248 Thiel: 0.6615	
EGARCH(1,1)	MSE: 0.0403 MAE: 0.0289 Thiel: 0.2638	MSE: 0.0369 MAE: 0.0265 Thiel: 0.4902	MSE: 0.0388 MAE: 0.0246 Thiel: 0.6381	

Low values of the MSE and the MAE suggested relatively good predictive accuracy

POLICY RECOMMENDATIONS

- In summary, gasoline, diesel, heating oil and jet fuel were all I(1). Their normality test results indicated that each series was not normally distributed. ARCH effects test results all indicated a presence of ARCH effects, thus GARCH type models were appropriate for modeling.
- There was volatility spillover between all series. This suggests that each refinery fraction's volatility is affected by the volatility of the other refinery fractions. Given that refinery margins may be slim in the future, refiners need to take a number of steps to ensure their survival.

POLICY RECOMMENDATIONS

- A key factor to ensure the survival of refineries outside of the US is the controlling of costs. Such refineries need to cut their operational costs and find more to do with less. Refinery firms may redesign their core processes and automation, try to minimize shut in productions, better organization of shifts for workers, and concentrating on work that drives performance.
- The local refinery should try to increase oil production and use more locally produced crude as this will decrease refinery costs.
- The refinery firm can consider hedging with forwards contracts for both crude oil and refinery fractions. This is where they enter a contract today to pay an agreed price of oil, or get an agreed price of refinery products, but the delivery of the commodity will be at a future date.

CONCLUSION

- Thank you