Predictability and Determinants of Commodity Markets

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Abstract. *Using historical data from 1990 to 2015 and based on economic and financial variables such as the yield of a three month T-Bill or the VIX, this study looks for predictability in both spot and futures commodity markets by testing theoretical models such as the efficient market hypothesis, theory of backwardation, and gradual information diffusion. The results show that commodity futures returns are predictable in the short term and that there is slow reaction of commodity markets to news and therefore that these markets exhibit momentum.*

Contents

1. Introduction

Commodities are traded everyday by ordinary people, companies, and institutional investors, both in order to speculate price fluctuations or to hedge market risk. Interest in the commodity market has increased in recent times to the levels of the energy crises of the 1970s mostly due the tensions in the Middle East starting in the mid 2000s and the North American shale revolution. According to estimates, index investment in commodities was $13 billion in December 2003 and grew to $317 billion in July 2008 and open interest of commodity futures grew from $103 billion to $509 billion (Masters and White, 2009). This increased activity has increased interest, especially in the regulatory setting and recent Congressional hearings regarding excess speculation in the market, in how trading effects prices. Therefore, the relationships we are studying have important implications for both investors and policy makers.

The previous literature in this area can be divided into to sections: literature on the theory of futures returns predictability and literature regarding the empirical evidence of predictability. This second group can then be divided further into two other sections: research that examines explicit predictability and research that looks at indirect predictability. Since there are different determinants for returns across different asset classes, most literature base their arguments on the efficient market hypothesis (EMH). Therefore, some of the literature also reviews predictability of equity and fixed income as well as commodities.

The theoretical research is mostly based on the proof of Samuelson (1965), which shows that given risk neutral, rational, and market participants, futures prices are unpredictable. Samuelson shows that futures returns are unpredictable given present day market filtrations. However, this argument is based on theoretical economics and not empirical evidence. Hirshleifer (1988) estimated the expected returns of futures and finds that both systematic and commodity specific risk impact expected futures prices. These findings are corroborated by Ferson and Harvey (1991)'s study which uses a multi-beta pricing model with cross sectional risk factors that are correlated with the market, inflation, consumer expenditures, and interest rates.

Using similar methods, Bessembinder and Chan (1998) analyze the predictability of futures returns using basic regression methods with similar macroeconomic variables as explanatory variables and show that US commodity markets are predictable. De Roon et al. (2000) add on to the work of Bessembinder and Chan (1998) and conclude that cross-market hedging pressures are statistically significant predictors of commodity futures returns. They construct a model that restricts direct market participation but allow correlation between hedging pressures and non-idiosyncratic risk and futures returns (Popov, 2012).

Miffre (2002) showed that Canadian wheat futures can be forecasted relatively well using GARCH methods. She tests market efficiency using a conditional multifactor model that permits changes in diversifiable risk of futures contracts. Her results show that 86% of variation in returns can be explained by conditional risk.

Ferson et al. (2003) argue that if return predictability is systematic, it can be explained by market inefficiency or rational hedging responses to changes in intertemporal business environments, or both. They also cast a doubt on most of the previous research in the field by suggesting that most regressions conducted in financial research may be spurious.

Duong and Kale (2005) try to test the Samuelson Hypothesis explained above (Samuelson, 1965) by using intra-day futures data from the Canadian WCE, Chinese DC, European LIFFE, Japanese TOCOM, and American MGEX between 1996 to 2003. They conclude that the predictability of returns is limited only for certain types of commodities, especially agricultural futures. They also confirm the findings of Bessembinder et al. (1996) futures volatilities tend to increase as their time to maturity goes to zero when there is a negative correlation between spot price and fluctuations in carry cost.

There are only a small number of previous studies that apply the theory of currency, equity, and bond futures to commodity futures. The few studies that do exist do not look at the effect of market volume, slow reacting markets, and momentum effects. This study analyzes the determinants and predictors of commodity markets. These determinants include open interest in commodity markets, fixed income yields and spreads, and market volatilities.

We hypothesize that open-interest growth along with market variables like yield spread and realized volatility contain information regarding futures returns, but not spot price growth. Additionally, there may be a delay in market reaction to changes in these variables and other market news as suggested by the theory of gradual diffusion.

This study looks at 14 commodities in three different categories and sectors: energy, metals, and agriculture (See Table 2). Looking throughout the whole time period of study (post-1990, given what data was available), spot price growth and futures returns could generally not be predicted. However, looking at smaller time periods (see Table 3) yielded more significant results. By showing that open interest growth can be used as a predictor for future commodity returns in the short term corroborate the conclusions of previous studies, notably Hong and Yogo (2012), who showed that open-interest growth contains information regarding, and can therefore be used as a predictor for, future bond returns. Our findings show that the theory of gradual informational diffusion does in fact hold, especially in regards to open interest. This shows us that when we observe under-reaction to news in the market, trading volume can be used as a predictor for futures returns.

Year	Author(s)	Market(s)	Methodology	Result
2011	Konstantinidia et al.	US	ARIMA, ARMA, VAR, PCA	Unpredictable
2008	Allan Timmermann	US	adaptive forecast combination approach	Unpredictable
2007	Goyet et al.	US	Kernel regression w/ADE estimators	Predictable
2006	Duong and Kalev	Five Exchanges	regression (intraday data)	Limited predictability
2002	Miffre	Canada	GARCH	Predictable
2001	Wang	US	regression (sentiment index)	Predictable
1992	Bessembinder and Chan	US, Canada	regression (macroeconomic factors)	Predictable for US
1991	Ferson and Harvey	US	regression (CAPM condtitions)	Predictable
1991	Fama	US	regression (business conditions)	Predictable
1988	Hirshleifer	US	regression (CAPM)	Predictable
1988	Solt and Statman	US	regression (newspaper sentiments)	Cannot reject unpredictability
1965	P. Samuelson	-	theory	Unpredictable

Table 1. Brief description of the main studies on the returns predictability. Adapted from Popov (2012).

2. Methods

2.1. Response Variables

The commodities that were analyzed in this study can be divided into three groups: energy, metal, and agriculture. These commodities are Western Texas Intermediate light sweet crude, Brent Crude, Reformulated Blendstock for Oxygenate Blending gasoline, Natural Gas, Heating Oil, Gold, Silver, Copper, Platinum, Corn, Wheat, Cocoa, Cotton, and Live Cattle (Table 2).

Sector	Commodity	Price Unit	Exchange	First Observation
Energy	WTI	USD/bbl.	NYMEX	Jan 1990
	Brent	USD/bbl.	ICE	Nov 1992
	RBOB	USD/gal.	NYMEX	Oct 2005
	Natural Gas	MMBtu	NYMEX	May 1990
	Heating Oil	USd/gal.	NYMEX	Jan 1990
Metals	Gold	USD/t oz.	COMEX	Jan 1990
	Silver	USD/t oz.	COMEX	Nov 1992
	Copper	USd/lb.	COMEX	Nov 1992
	Platinum	USD/t oz.	COMEX	Nov 1992
Agriculture	Corn	USd/bu.	CBOT	Nov 1992
	Wheat	USd/bu.	CBOT	Nov 1992
	Cocoa	USD/MT	ICE	Nov 1992
	Cotton	USd/lb.	ICE	Nov 1992
	Live Cattle	USd/lb.	CME	Jan 1990

Table 2. Summary of commodities studied.

Period	Description
1990 - 1994	Bush Presidency, Persian Gulf War
1995 - 1998	Budget Surplus, Asian Financial Crisis
1999 - 2001	Dot-Com Bubble
2001- 2008	9/11, Afghanistan, Iraq, Bush Doctrine
2009 - 2015	Financial Crisis, Shale Revolution

Table 3. Segmentation of time periods of study and description and justification of segments.

In order to calculate aggregate returns, an approach similar to that of Hong and Yogo (2010) was used. Let $R_{f,t}$ be the monthly gross return on the 1-month Treasury Bill in month t; we assume this to be the risk free rate. Let $F_{i,t,T}$ be the price of a futures contract on commodity i at time t with maturity at time T. Maturities up to 24 months were studied. Therefore, the gross monthly return on commodity i is as follows:

$$R_{i,t,T} = \frac{F_{i,t,T} R_{f,t}}{F_{i,t-1,T}}$$

We then calculate the spot-price growth. Let $S_{i,t}$ be the spot price of commodity i at time t. The monthly spot-price growth is as follows:

$$G_{i,t} = \frac{S_{i,t}}{S_{i,t-1}}$$

We look at spot price growth in addition to futures price movements and futures returns because the two values of economically different. Unlike physical commodities, futures are instruments that are traded like equity and fixed income instruments. Thus, different theories suggest different conclusions regarding mean reversion between future and spot prices. We can then use our different results to differentiate among different theories (Hong and Yogo, 2010).

2.2. Explanatory Variables

The primary explanatory variable used is cumulative open interest growth, which is the growth rate of the product of the dollar open interest value of each commodity and the number of outstanding contracts for that commodity. Since this is a noisy variable, it is smoothed by taking a 12 month geometric average. Similar to the work of De Roon et al. (2004), the other explanatory variables are separated into two categories. The first group contains aggregate market predictors that are driven by theories like the Intertemporal Capital Asset Pricing Model (ICAPM), which assumes that commodity markets are fully integrated. The ICAPM suggests that commodity prices are affected by “aggregate market predictors that influence portfolio allocation decisions across different asset classes” (Hong and Yogo, 2010). This implies that commodities can be used to hedge against time-varying fluctuations in instruments of other asset classes. Therefore, as Hong and Yogo (2010) suggest, since positions can be hedged by both holding physical commodities and entering future contracts, the ICAPM says that “the same aggregate market predictors should predict returns on commodity futures and spot-price growth with similar sign and magnitude” (Hong and Yogo, 2010). The explanatory variables in this category are: the short rate, yield spread, default spread, and measures of stock market volatility. We know from the works of Fama and Schwert (1977), Campbell (1987), and Fama and French (1989) that the short rate and yield spread can predict variation in bond and stock returns and Bessembinder and Chan (1992) and Bjornson and Carter (1997) showed that these two variables also predict commodity returns. The short rate is defined as the monthly yield of a 3-month Treasury bill (3MTBill) and the yield spread as the difference between the yield of a corporate bond that is rated Aaa by Moody’s (YieldSpread). The fault spread is defined as the difference between the yield of Baa and Aaa rated corporate bonds. In order to measure aggregate stock volatility, both the realized volatility (RealizedVol) and the CBOE Volatility Index (VIX).

The second group of explanatory variables are based on the idea that commodity markets are segmented. According to the theory of normal backwardation, commodity producers enter either long or short positions in commodity futures in order to hedge against price shifts in the spot market which could lead to adverse losses (Keynes, 1923; Hicks, 1975). The theory of storage says that during times of low supply, commodity buyers increase their production inventory levels to ensure availability in the near future. This causes future prices to shift towards backwardation and spot prices increase for a short period and then mean revert back down as the supply-demand imbalances are corrected (Working, 1933; Deaton and Laroque, 1992). These two theories have different and somewhat contradictory implications regarding the movement of futures and spot prices. The theory of normal backwardation states that a low basis should correspond with high commodity future returns, while saying nothing about spot prices. On the other hand, the theory of storage suggests that a low basis implies low growth in spot prices and says nothing regarding futures prices. We will test to see which one of these theories holds.

In order to calculate the value of the basis from spot and futures prices observed in the market, we compute the basis for commodity i at time t maturing at T as follows:

$$Basis_{i,t,T} = \left(\frac{F_{i,t,T}}{S_{i,T}}\right)^{\frac{1}{T-t}} - 1$$

2.3. Procedure

Regressions with different lags on the explanatory variables: zero, six, and twelve months were conducted. This is in order to test the proposed recent theory of gradual information diffusion in asset markets. For example, Menzly and Ozbas (2006), Hong et al. (2007) and Cohen and Frazzini (2008) find, in similar studies, that firm or industry specific positive returns in a given time interval leads to positive returns for customers and/or suppliers of that firm or industry in the next period (Hong and Stein, 2007).

In order to see the differences between short and long term predictability, in addition to running regressions across the entire time period of study, regressions were also conducted across five different segments of time outlined in Table 3. This study also tested the theory of normal backwardation and the theory of storage by regressing the basis defined above on the spot price growth and the futures returns.

Regressions were also conducted with lags on the explanatory variables in order to test for gradual information diffusion (eg. $R_{i,t,T} = \beta_0 + \beta_1 VIX_{t-\gamma} + \beta_2 YieldSpread_{t-\gamma} + \epsilon_t$) for $\gamma = 6, 12$ instead of the case where $\gamma = 0$. This procedure was the extended to values of γ from 0 to 24 in order to find the optimal lag time for best predictive model. The coefficient of determination (R^2), Akaike Information Criterion (AIC), and the Bayesian Information Criterion (BIC) of the model were used as measurements to find the model that fit best.

3. Results

3.1. Summary Statistics

The summary statistics for the explanatory variables used in the study are given in Table 4.

3.2. Single Variable Regressions

The results for RBOB gasoline spot price growth show significant regressors for all of the explanatory variables. Regressing the three month T-Bill yields on RBOB prices produces a coefficient of -0.048236 and t-stat of -2.0524. Using the market realized volatility as the regressor gives a coefficient of -0.048236 and t-stat of -2.0524. A simple regression with VIX as the explanatory variable has coefficient 0.35502 and t-stat of 4.7272. These results are summarized in Table 5.

	Mean	Std. Dev	Variance	Skewness	Kurtosis	Autocorrelation	
3MTBill	3.03	2.34	5.48	0.06	1.73	0.91	0.74
YieldSpread	116.85	81.06	6571.46	0.04	1.75	0.88	0.73
RealizedVol	15.80	11.31	127.84	3.43	17.54	0.96	0.92
VIX	19.89	7.59	57.56	1.69	7.37	0.52	0.41

Table 4. Summary statistics of explanatory variables studied. The two autocorrelation values given are six and twelve month lags respectively.

	Coeff.	Std. Error	t	p
3MTBill	-0.048236	0.023502	-2.0524	0.042123
RealizedVol	-0.048236	0.023502	-2.0524	0.042123
VIX	0.35502	0.075102	4.7272	3.4916e-06

Table 5. Results of single variable regressions on RBOB gasoline spot price growth. Regressors lised in first column.

Regressing the open interest of the commodity on both the spot price growth and the futures returns both gave insignificant results for all 14 regressions. Not only were the results significant, but also the general least squares estimator for the slope of the regression line was essentially zero (less than 0.01) for all models. The short term period regressions showed significant results across all commodity classes. The most significant results were from the last two periods of study: 2001-2008 and 2009-2015 (Table 8).

The univariate regressions testing for gradual information diffusion with six and twelve month lags: $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$ where x_j is each of the explanatory variables that are listed in the previous section. The results of these regressions with five month Natural Gas futures returns as the response variable for $\gamma = 6$ and $\gamma = 12$ are given in Table 6.

	$\gamma = 6$					$\gamma = 12$				
	β	p	R^2	**AIC**	**BIC**	β	p	R^2	**AIC**	**BIC**
3MTBill	0.00335	0.206	0.00543	-520.4	-513.0	0.00187	0.492	0.00164	-509.3	-502.0
YieldSpread	0	0.343	0.0033	-479.1	-471.9	0	0.323	0.0036	-480.3	-473.1
RealizedVol	-0.00047	0.420	0.00222	-519.4	-512.1	0	0.988	0	-508.8	-501.5
VIX	0	0.986	0	-518.8	-511.4	0	0.905	0	-508.8	-501.5

Table 6. Results of single variable regression with five month Natural Gas futures returns as the explanatory variable.

Sensitivity analysis shows that there is a tent like structure in the plot of γ vs. R^2 and inverse tent structures for the plots of γ vs. AIC and γ vs. BIC. These results show presence of gradual information diffusion. However, the speed of diffusion of information into the market differs by the commodity and the commodity class. In energy commodities, the optimal lag time in basis vs. futures returns is approximately six months: four months for WTI Crude, three months for BRENT Crude, seven months for Heating Oil, and eight months for Natural Gas (Figures 1, 2, and 3). However, metal markets were found not to be predictable based on basis values and there was no gradual information diffusion. Maximum fit for metal markets was found to be at zero lag ($\gamma = 0$) (Figure 6).

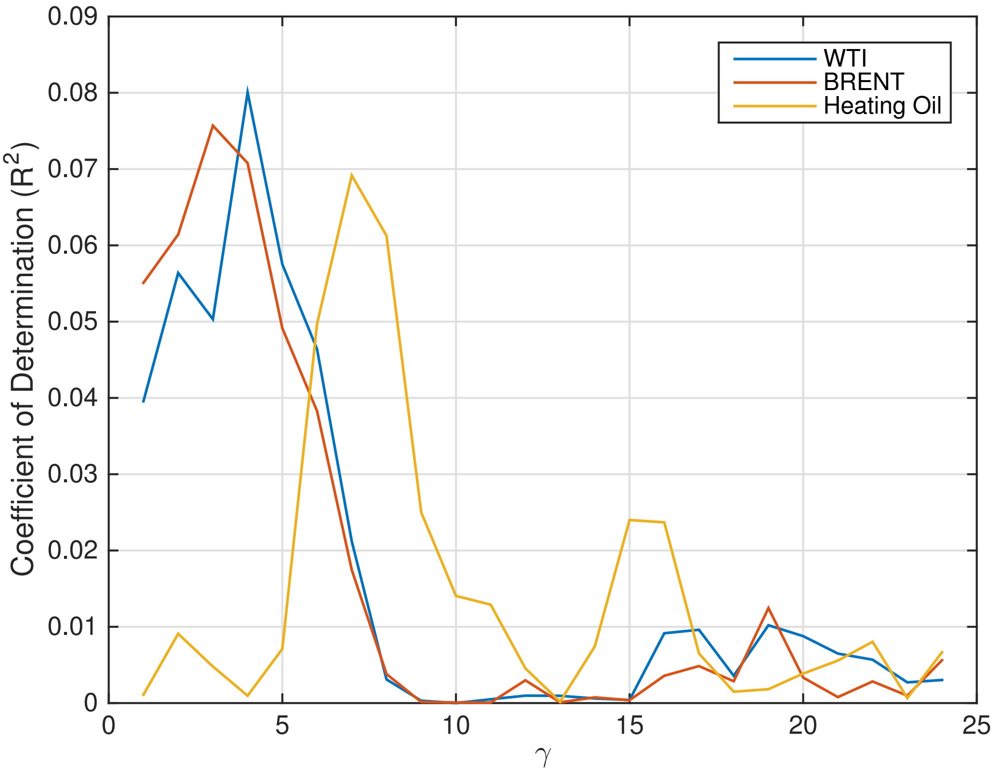

Figure 1. R^2 **values of single variable regressions of the basis lagged with different** γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$

3.3. Multi-variable Regressions

When conducting multivariate regressions on the entire period of study, again only regressions with RBOB gasoline futures returns yielded significant results. The results of these gressions are given in Table 7. Regressions where the data was split up between different time periods is givne in Table 8 in the Appendix.

4. Discussion

Present research (Girma and Mougoue, 2002) lagged volume and open interest can explain futures spread volatility when analyzed separately, but using multivariate autoregressive conditional variance GARCH methods has greater predictability power. This study corroborates these findings using robust multivariate regression techniques. The theory of normal backwardation states that a low basis should correspond with high commodity future returns (Rockwell et al., 1967). This study shows that across the 25 year period of study and zero to 24 month maturity this theory holds. We see significant negative coefficients in the robust single variable regressions that were conducted. This is most evident in energy commodity markets. The high cost of storage and carry is a major factor in the backwardation property of crude oil. In layman's terms, markets in bacwardation say that a commodity is needed today, and should not be stored and delivered immediately. The

Regressor	**(1)**	**(2)**	**(3)**	**(4)**
3MTBill	0.0859**	0.7874**		0.0716*
	(0.0277)	(0.0256)		(0.02909)
RealizedVol	-0.00760		-0.0278*	0.0044
	(0.00445)		(0.0115)	(0.0089)
VIX		0.0233**	0.0081	-0.0184
		(0.0078)	(0.0090)	(0.0119)
SER	0.572	1.03	0.58	0.569
$\bar{R}^2$	0.0943	0.756	0.0689	0.104
F-stat	7.87**	473**	5.88**	6.1**
n	133	305	133	133

Table 7. Regressions with RBOB gasoline spot price growth as the response variable. Heteroskedasticity-robust standard errors are given in parenthesis under coefficients. The individual coefficient and/or joint coefficients (F-stat) is statistically significant at the *5% level or **1% significance level using a two-sided test.

opposite is true of precious metals (especially Gold and Silver) which are mostly kept in storage and not consumed or consumed much less than crude oil and gasoline.

The only commodity that exhibited predictability of spot price growth was RBOB gasoline. This may be due to the fact that gasoline is the only commodity studied that is mostly purchased by consumers and in the spot market rather than metals and agricultural commodities which are bought by companies as raw input for their products. Additionally, gasoline futures are not traded as frequently for hedging purposes as compared to, for example, crude oil. Therefore, the market is affected by less outside factors and can therefore be predicted with a higher coefficient of determination than other commodities studied (75.6% compared to approximately 10%).

According to Hong and Yogo (2010), information diffuses into the market at a slow rate due to segmentation and limits to arbitrage. Increases in the basis and trade volume (open interest) take time reflect in changes of futures returns. However, slow diffusion may be due to behavioral factors. Gradual integration of information is a signal of the momentum effect. Energy markets are exposed to political risks as well as standard market risks. Additionally, energy commodities are heavily scrutinized in the media and public sentiment could lead to policy changes both in the public and private sector that could lead to price changes, however these changes take time.

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5. Appendix

	90 - 94	95 - 98	99 - 01	01 - 08	09 - 15
3MTBill	-0.0073	-0.0016	0.0066	-0.0086	0.0130
	(0.0113)	(0.0418)	(0.0155)	(0.0086)	(0.0079)
VIX	0.0067	-0.0005	-0.0101	-0.0012	-0.0027**
	(0.0042)	(0.0021)	(0.0059)	(0.0019)	(0.0010)
SER	0.103	0.0781	0.112	0.0846	0.0914
$\bar{R}^2$	0.018	-0.0426	0.0557	-0.0148	0.0795
F-stat	1.53	0.039	2.03	0.54	5.19**
n	59	48	36	64	98

Table 8. Regressions with WTI Crude spot price growth as the response variable broken up with respect to time periods. Heteroskedasticity-robust standard errors are given in parenthesis under coefficients. The individual coefficient and/or joint coefficients (F-stat) is statistically significant at the *5% level or **1% significance level using a two-sided test.

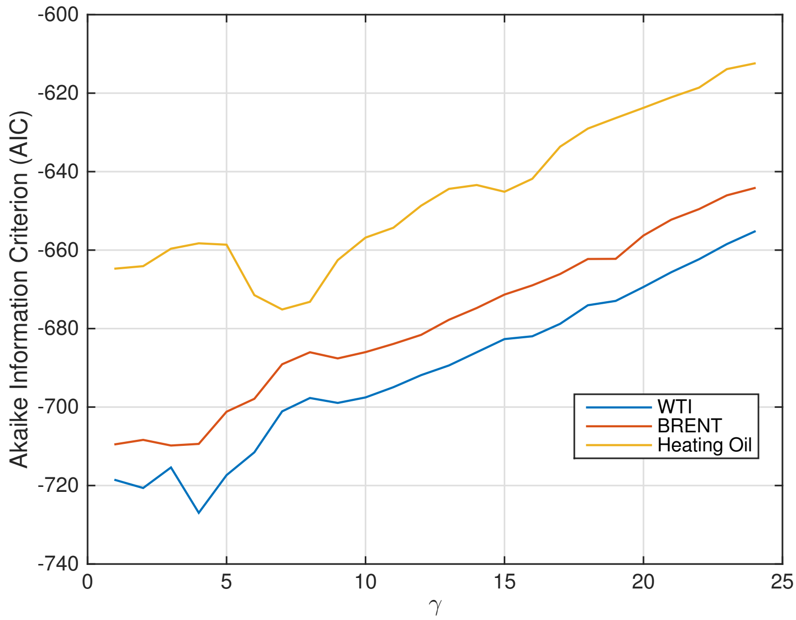

Figure 2. AIC **values of single variable regressions of the basis lagged with different** γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$

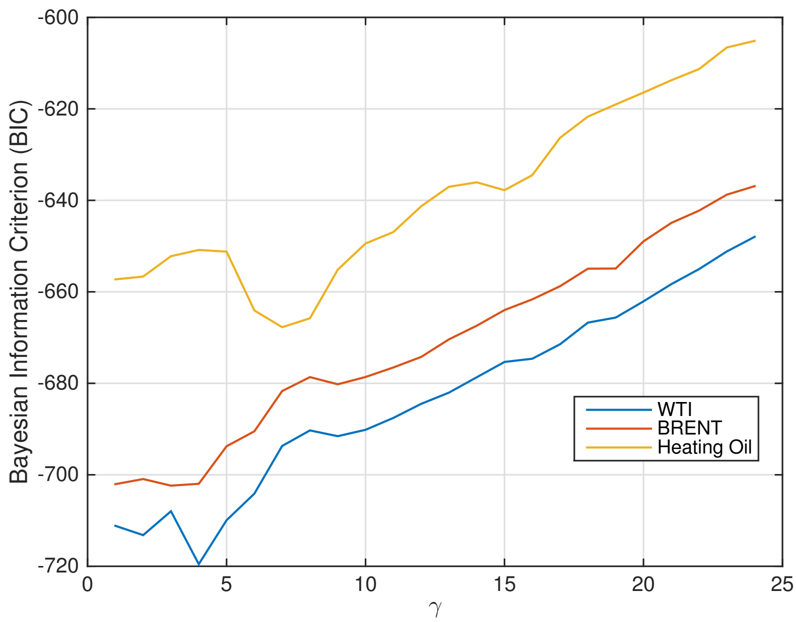

Figure 3. BIC **values of single variable regressions of the basis lagged with different** γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$

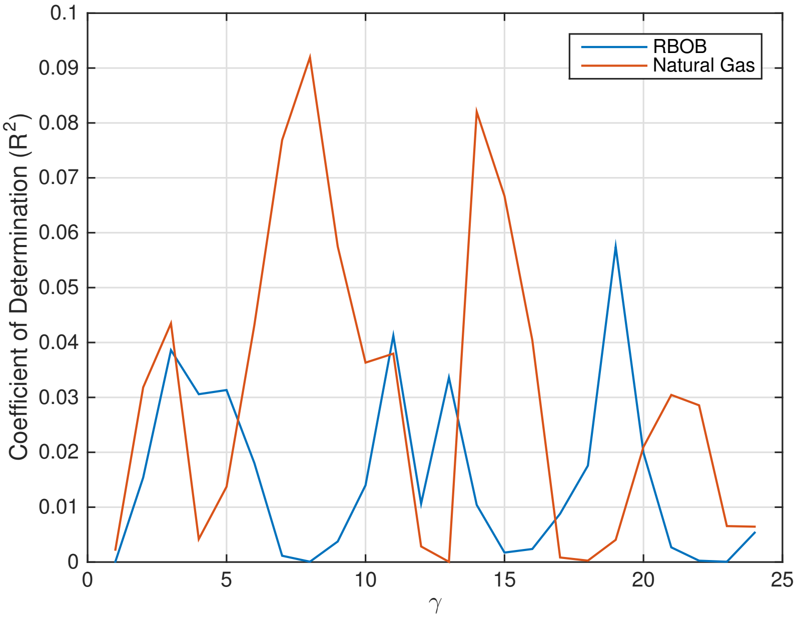

Figure 4. R^2 **values of single variable regressions of the basis lagged with different** γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$

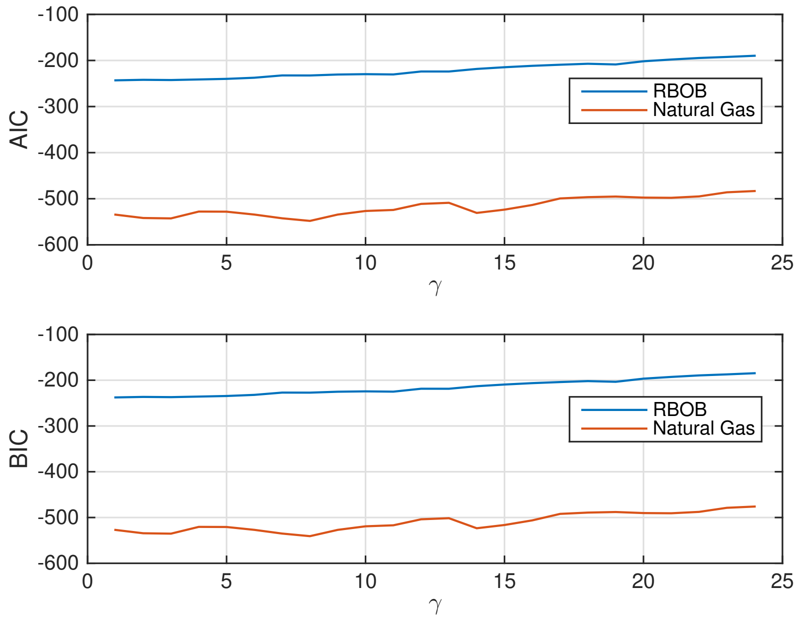

Figure 5. AIC and BIC values of single variable regressions of the basis lagged with different γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$

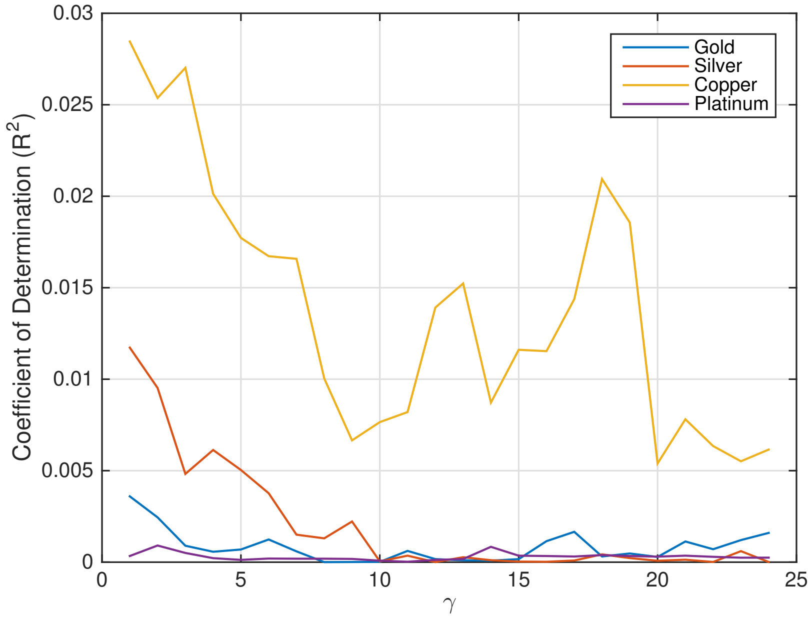

Figure 6. R^2 **values of single variable regressions of the basis lagged with different** γ **values:** $R_{i,t,T} = \beta_0 + \beta_1 x_{j,t-\gamma} + \epsilon_j$