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Arbitrage Opportunities In The New England Electricity Market

Disciplines
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ARBITRAGE OPPORTUNITIES IN THE NEW ENGLAND ELECTRICITY MARKET

By

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An Undergraduate Thesis submitted in partial fulfillment of the requirements for
the

JOSEPH WHARTON SCHOLARS

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1.1 Introduction

Global demand for electricity is highly inelastic. That is, a vast majority of the world’s populations need electricity to get through the general day-to-day life. Be it for cooking, heating, or just keeping the lights on, electricity is a commodity without which our lives would be very different. As the electricity market was deregulated, the recession-proof nature of the industry provided for attractive investment opportunities. However, coupled with that same deregulation, the price volatility and subsequent risk has dramatically increased. Prior to the privatization of electricity markets, regulators were the price makers, and relevant industry participants were unconcerned about daily price fluctuations. On the other hand, in a private market, prices are determined by “stochastic supply and demand functions. The price can change at any time”. Accompanying such an overhaul of the energy sector and subsequent volatility, risk management techniques became more prevalent, mainly through a new futures market. The Securities and Exchanges Commission defines a futures contract as “[...] an agreement to buy or sell a specific quantity of a commodity or financial instrument at a specified price on a particular date in the future”. The general electricity benchmark used by futures comes from PJM, the largest Regional Transmission Organization (RTO) in the United States. In 2013, PJM included more than 900 companies, serving over 60 million customers through approximately 100,000km of transmission lines, generating roughly 791

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1 E. Tanlapco, J. Lawarree and Chen-Ching Liu, "Hedging with futures contracts in a deregulated electricity industry,"
2 E. Tanlapco, J. Lawarree and Chen-Ching Liu, "Hedging with futures contracts in a deregulated electricity industry,"
3 SEC.gov, 2010
terawatt-hours of electricity\textsuperscript{4}. In the United States, electricity futures are traded on the Chicago Board of Trade and NYMEX. Universally, the futures are trading in units of 40 MWh per peak day, under a JM ticker, and are quoted in USD and cents per MWh\textsuperscript{5}. The bilateral participants in the electricity futures market are hedgers and speculators. Hedgers are mainly generators and retailers that use futures to hedge their short-term price exposure. Frequently, those participants make use of a “short-hedge,” in the attempt to avoid future price falls and lock in profit today\textsuperscript{6}. However, increased volatility has incentivized speculators, investors who endeavor to extract profit from forecasting errors or miscalculations of electricity companies, to enter the market. This study aims to discern whether such forecasting errors exist within the Northeast Power Coordinating Council in New England and whether established futures-arbitrage strategies could be used to extract arbitrage profit from that market segment.


\textsuperscript{5} NYMEX Website, http://futures.tradingcharts.com/marketquotes/JM.html

\textsuperscript{6} E. Tanlapco, J. Lawarree and Chen-Ching Liu, "Hedging with futures contracts in a deregulated electricity industry,"
2. Background

2.1 Finance Perspective – Conditions for Arbitrage

The simplest form of arbitrage, or a risk-less profit, is the commonly used example of the farmer. This farmer grows crops; say wheat, at his field in a rural village. Realizing that the demand and subsequent willingness to pay for his crops is higher in urban locations, the farmer transfers his harvest to a nearby town, where he can sell his yield at a higher profit. However, the formal conditions for pure arbitrage are quite complex. According to Carr and Madan, the possible price paths of an asset must be either purely continuous, pure jump, or a combination over time\(^7\). This, in turn, means, especially given that we can only observe prices in practice and then only discretely, that it is near impossible to impose a credible structure on future price paths. However, Carr, Geman, and Yor introduce a commonly accepted, simpler definition of arbitrage\(^8\). Generally referred to as static arbitrage, they reduce the amount of required information imposed by the former definition. They define such arbitrage strategies as a “Costless trading strategy which at some future time provides a positive profit with positive probability, but has no probability of a loss.” Unlike the more rigorous definition, this more liberal definition suggests that positions taken at a point in time depends solely on the time and current stock price, not historic prices or path properties. In short, static arbitrage can be summarized in three separate statements:


I. An asset cannot trade at the same price on different markets

II. Two assets with the same cash flow returns do not trade at the same price

III. An asset cannot trade with a previously-known futures price discounted at the risk-free rate (Adding storage costs for certain commodities)

For this study, it is the third statement that is most applicable, as futures derivatives are the subjects of the study. Last, for a trade to be of a pure static arbitrage nature, it is insufficient to buy a product in one market and sell it another; rather transactions must occur simultaneously. Each simultaneous trade to maintain market neutral exposure is referred to as “legs” of the trade, which minimizes execution risk by the party carrying out the arbitrage strategy.

2.2 Futures Pricing

As previously mentioned, a futures contract is defined as “[...] an agreement to buy or sell a specific quantity of a commodity or financial instrument at a specified price on a particular date in the future”\(^9\). How a futures contract is priced, however, is a different question. The principal of futures pricing is referred to as spot-future parity, where the spot price is the price of the asset today, and the future is the price of the futures contract. In short, the parity principal equates the price of the spot today and the price in the future adjusted for the cost of money dividends, convenience yield, and carrying costs. For commodities, carrying costs become important, which gives us the following equation for pricing:

$$F_0 = (S_0 + U)e^{rT}$$

where

\[ F_0 = \text{Today's price of futures contract} \]
\[ S_0 = \text{Today's price of spot} \]
\[ U = \text{Present value of storage costs} \]
\[ r = \text{Risk-free rate} \]
\[ T = \text{Maturity of futures contract} \]

This relationship asserts that there is an opportunity cost, interest, that can be earned should an investor choose not to invest in the spot rate and choose an alternative strategy. Thus, if forecasts indicate that a futures price does not correlate with the spot-future parity relationship, there is opportunity for investors to, through various strategies, make a risk-free arbitrage profit. In efficient markets, any erroneous pricing self-corrects expeditiously.

2.3 Futures Arbitrage Strategies

In futures arbitrage, there are two prevailing strategies investors utilize to attempt to profit from relative mispricing in the futures market.

I. Buy spot of an asset, while selling the asset short in the futures market – commonly referred to as “Cash-and-carry” trade

II. Sell short spot of an asset, while taking a long position in the futures market – commonly referred to as “Reversed cash-and-carry” trade

As previously mentioned, these strategies can provide for arbitrage opportunities when the Law of One Price (LOP) does not hold. Indeed, Protopapadakis and Stoll\(^\text{10}\) determine that there are instances of large arbitrage-profit opportunities in commodity markets. However, on average those profits are

\(^{10}\) Protopapadakis, Aris, and Hans R. Stoll. “Spot and Futures Prices and the Law of One Price
small, but within specific assets under specific times the potential for arbitrage can be substantial. Moreover, price variability is larger in the short run for spot and short-maturity futures, as longer-term futures have more ample time to reflect supply adjustment of the underlying asset. Consequently, they claim that arbitrage opportunities are more significant in the short term. However, particularly in the case of commodities and currencies, positive- or negative macroeconomic events may precipitate unrest in the futures and spot markets\(^1\). For instance, a popular cash and carry trade during the 90s was the USD/JPY trade, where investors attempted to benefit from the large interest rate differentials between the two currencies. News of bilateral trade balances had a significant effect on the futures market, evidenced by increases in the unwinding of futures and options contracts. The same is to be expected for electricity futures. Maslyuk and Smyth find that oil prices, a significant determinant of electricity futures prices, are significantly impacted by endogenous events. Indeed, supply and demand shocks add risk to a carry-trade that could completely unravel an arbitrage-strategy. In fact, hedge funds tend to homogenously reduce general risk exposure during times of macroeconomic uncertainty, which increases the systematic risk in the financial system\(^2\).

2.4 Electricity Futures

The relevant security for this study is the electricity future. Specifically, the ISO New England Mass Hub 5MW Peak Calendar-month Day-ahead LMP future. The

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\(^{1}\) Michael Hutchison, Vladyslav Sushko, Impact of macro-economic surprises on carry trade activity, Journal of Banking & Finance, Volume 37, Issue 4, April 2013, Pages 1133-1147

\(^{2}\) François-Éric Racicot, Raymond Théoret, Macroeconomic shocks, forward-looking dynamics, and the behavior of hedge funds, Journal of Banking & Finance, Volume 62, January 2016, Pages 41-61, ISSN 0378-4266
administrator of the New England electricity market is ISO New England, which is the party responsible for the Northeast Power Coordinating Council and the electricity in its five states. As previously mentioned, in the United States, electricity futures, the subject of this study included, are traded on the Chicago Board of Trade and NYMEX. Universally, the futures are trading in units of 40 MWh per peak day, under a JM ticker, and are quoted in USD and cents per MWh. Compared to other commodity and stock futures, electricity futures tend to be more complex, as they have to reflect seasonality, less liquidity, and frequent spikes and drops in the market\textsuperscript{13}. Overall, research indicates a positive risk premium for futures contracts closer to maturity, whereas longer maturity seemingly price in the fact that supply has the opportunity to adjust to adequately reflect the price.

3. Methodology

The methodology for this study is derived from that of Bianco, Manca, and Nardini in their study of the future demand within the Italian electricity market\(^\text{14}\). In this study, the authors use linear regression models to forecast electricity consumption. Indeed, they claim that solid forecasting techniques are essential for the planning and execution of infrastructure developments around the electricity sector, which subsequently affects adjacent futures markets.

This study will apply parts of the regression framework utilized by aforementioned authors, and add more independent variables to improve the validity of application to the New England energy market.

3.1 Elasticities Estimation

A multi-variable regression in linear logarithmic form, which links the consumption of electricity to electricity price, GDP per capita, and the price of natural gas (Most New England electricity comes from natural gas\(^\text{15}\)), will be used to determine the relevant price and income elasticities. The model takes the following form:

\[
\log(Y_t) = \alpha_0 + \alpha_1 \log(X_{3,t}) + \alpha_2 \log(P_{1,t}) + \alpha_3 \log(P_{1,t-3}) + \alpha_4 \log(P_{2,t}) + \alpha_5 \log(P_{2,t-3}) + \alpha_6 \log(Y_{t-3})
\]

where \(Y_t\) is the electricity consumption, \(X_{3,t}\) is the GDP per capita, \(P_{1,t}\) is the electricity price, \(P_{2,t}\) is the price of natural gas. Regression coefficients with a \(t - i\) form indicate lag terms. For instance, \(t - 1\) means lag 1.


\(^{15}\) ISO New England Website
In the regression model, $\alpha_1$, $\alpha_2$, and $\alpha_3$ are particularly important, because they represent the income and price elasticities, respectively.

3.2 Application of elasticity to New England demand forecasts

Price elasticity of demand can be defined as:

$$\gamma = \frac{\Delta Q}{\Delta P}$$

Reorganizing the formula gives us the following equation:

$$\Delta P = \frac{\Delta Q}{\gamma}$$

Thus, in short, by statistically estimating the elasticity and applying it to the meticulously researched ISO New England forecast data, one can solve for future prices. By plotting those prices against the yield curve implied by futures of different maturity, it is possible to gauge whether arbitrage opportunities are present. For instance, if the forecasts indicate that futures prices are lower than implied by the forecast, it would be sensible to undertake a Cash-and-carry trade and profit from the subsequent mispricing.

3.3 Assumptions

I. Data science perspective

The statistics used in this study inherently uses past data in order to apply it to future scenarios. Historic volatility is not the same as future volatility, especially not when working with energy markets. As a result of seasonality, volatility, and illiquidity, running a model on the future implies using data from a historic “training period,” which is not necessarily correlated with the future timeframe. One way to mitigate this problem is by attempting to not look at past trends when analyzing the
results from the model. Although imperfect, these statistical problems are inherent 
with every energy study, and should thus not discriminate the validity of this study.

II. No transaction costs

Generally, each position undertaken by an investor carries some fractional 
transaction cost. However, this study assumes that investor can buy and sell futures 
at the bid-ask levels. Although this not necessarily reflective of reality, finance 
thories generally assume zero transaction costs to make an argument for efficient 
markets and financial theories.

III. Second-degree least squares analysis

With the multivariable regression approach used in this model comes a series of 
assumptions. Namely, it assumes that there is a linear relationship between 
response and independent variables, multivariate normality, no or little 
 multicollinerarity, no autocorrelation, and homoscedasticity. However, since this 
study uses an estimation of a regression coefficient to independently forecast 
another independent variable, it is impossible to verify whether there is correlation 
in the error terms implied by the equation. Rather than using such a simplified 
approach, one could use the instrumental variable method. An instrumental variable 
“is a variable that is uncorrelated with the error term but correlated with the 
explanatory variables in the equation”\textsuperscript{16}. By ensuring that the error terms are 
uncorrelated with the independent variables, the statistical model becomes more 
reliable. However, such methods go beyond the scope of this assignment, which is 
why it is not used.

\textsuperscript{16} G.S. Maddala \textit{Introduction to Econometrics, p.305}
4. Data Collection and Processing

4.1 Data Sets

I. GDP Data

The Bureau of Economic Affairs provides quarterly GDP data for every state and region in the United States. Their data for the GDP development for the New England area will be used in this study.

II. Electricity Price Data

Electricity prices used for the regression analysis are the day-ahead Location Marginal Prices (LMPs) for the NEPOOL area. These are public at ISO New England’s website.

III. Natural Gas Price Data

Given that natural gas is the underlying commodity that is commonly used for New England’s electricity generation, Bloomberg data on Henry Hub monthly gas prices will be used in this analysis.

IV. Futures Price Data

The market quotes are taken from the CME group, a leading derivatives market place that handles nearly three billion contracts annually. The CME group is the company in charge of, among other exchanges, NYMEX; the prime market place for electricity futures. The quotes are for the ISO New England Mass Hub 5MW Peak Calendar-month Day-ahead LMP future, specifically for 5MW per peak hour, with a minimum price fluctuation of $0.05 per MWh. The available maturities stretch from next month to five calendar years.

V. Demand Forecasts
ISO New England provides detailed demand forecasts for upcoming five years in annualized data. This data was pro-rated to monthly demand based on historic averages.

4.2 Elasticities Calculations

Although multiple regressions make strong assumptions regarding the relationship between the independent and response variables, it does not individually model the variables. In other words, the model does not tell us about decision-making processes, rather whether changes in independent variables explain variation in the response. However, similar to simple regression, multiple regressions do make assumptions regarding the errors; namely that they are independent observations sampled from a normal distribution with mean 0 and equal variance. Along with multiple regressions come several tests to check for statistical significance, many of which will be used in this study. First, the F-test calculates the F-statistic to check the combined effect of all independent variables on the response. In a sense, it tests the $R^2$ and adjusts it for the amount of variables used. The test takes into account that more variables always increase the variance explained by the independent variables in the regression, and adjusts accordingly. Moreover, another issue is collinearity; when independent variables are correlated with each other. Although collinearity complicates the interpretation of the regression model, it does not violate underlying assumption of the multiple regression model. One way of identifying collinearity is the Variation Inflation Factor (VIF). High collinearity produces very wide confidence interval that the estimates are not useful. As a result, regression variables with high VIF’s should be
removed so that variables with unique variation are more prevalent. As a result, this study will run several consecutive regressions to determine what variables in the aforementioned methodology explains the most variation in electricity consumption.

I. Trial One

In *Exhibit 1* one can see the parameters of the first regression run with the full set of variables outlined in 3.1. Evidently, high p-values of the variables indicate insufficient statistical significance for reliable regression results.

*Exhibit 1 – Parameter Estimates from First Trial*

| Term                           | Estimate  | Std Error | t Ratio | Prob>|t| |
|--------------------------------|-----------|-----------|---------|------|---|
| Intercept                      | 16.719025 | 4.321283  | 3.87    | 0.0031* |
| Log ISO Electricity Prices     | 0.0785167 | 0.019987  | 3.93    | 0.0028* |
| Log(NE GDP Data)               | -0.13472  | 0.212199  | -0.63   | 0.5398 |
| Log(NG1 Prices)                | -0.021169 | 0.052673  | -0.40   | 0.6962 |
| Log(ISO Electricity Lag 3)     | 0.0358031 | 0.029531  | 1.21    | 0.2532 |
| Log(NG1 Prices Lag3)           | 0.0042973 | 0.04013   | 0.11    | 0.9168 |
| Log(Historic Consumption Lag3) | -0.650308 | 0.290084  | -2.24   | 0.0489* |

Although *Exhibit 2* and *Exhibit 3* show desirable R Squared values and lack of structure in the residual plot, lack of statistical significance in the independent variables creates the need for another trial with the removal of explanatory variables.
II. Trial Two

By removing the price of natural gas and its lag, the two variables with the lowest t-statistics, we get the following parameter estimates outlined in Exhibit 4.

Although the statistical significance of the variables has increased, we still see statistical insignificance in the Lag3 of the ISO Electricity data.

**Exhibit 4 – Parameter Estimates from Second Trial**
Exhibit 5 – Summary of Fit Second Trial

<table>
<thead>
<tr>
<th>Summary of Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSquare</td>
</tr>
<tr>
<td>RSquare Adj</td>
</tr>
<tr>
<td>Root Mean Square Error</td>
</tr>
<tr>
<td>Mean of Response</td>
</tr>
<tr>
<td>Observations (or Sum Wgts)</td>
</tr>
</tbody>
</table>

Exhibit 6 – Residual Plot Second Trial

III. Trial Three

As evidenced by the t-statistics and subsequent p-values in Exhibit 7, the third trial produces statistically significant estimates of regression coefficients. Judging from Exhibit 8 and Exhibit 9, there seems to be no structure in the residual plot.

Exhibit 7 – Parameter Estimates from Third Trial

| Parameter Estimates | Estimate | Std Error | t Ratio | Prob>|t| |
|---------------------|----------|-----------|---------|------|
| Intercept           | 16.348174| 1.972211  | 8.29    | <.0001* |
| Log ISO Electricity Prices | 0.0789846 | 0.011959  | 6.60    | <.0001* |
| Log(NE GDP Data)    | -0.264823 | 0.091301  | -2.90   | 0.0081* |
| Log(Histrocic Consumption Lag3) | -0.404704 | 0.113965  | -3.55   | 0.0017* |
Thus, judging from the regression coefficient, the price elasticity of demand with regards to ISO Electricity Prices is determined to be:

\[ \gamma = 0.079; \ SE(\gamma) = 0.012 \]

**4.3 Application of Elasticities to New England Demand Forecasts**

Applying the previously calculated elasticity to demand forecasts for the New England region yields the following price forecast
4.4 Comparison of Futures Prices with Forecasted Prices

Adding the NYMEX quote for New England energy futures yields the following result:
5. Discussion

5.1 Potential Trading Strategies

Discrepancies between the price forecast and the futures curve imply that there is indeed potential for risk-less arbitrage profit. First, when predicted spot rates are higher than the futures price, an investor should hold a long position in the futures market. For instance, in July 2017, the forecasted spot price is ~$80, while the future for the corresponding time is priced at $50. With a long position in the futures market, an investor could then settle the contract in July 2017 for $50, and instantaneously sell the corresponding asset in the spot market for $80, yielding a $30 profit. On the contrary, when predicted spot rates are lower than the futures curve, an investor should hold a short position in the futures market. By selling short the future, the investor locks in a certain price where the party buying the future is forced to pay the price that was agreed upon. Consequently, upon settlement, if the spot price is lower than the futures price, the party with a short position in the underlying asset can buy spot at a lower price than what the counterpart has agreed to pay, locking in a profit. For instance, in December 2017, the forecasted spot price is ~$50. Current futures for the corresponding time are trading at $70. As a result, by buying spot at $50, while selling it to the holder of the future at $70, an investor can lock in a $20 profit.

5.2 Spot Price Volatility

As evidenced by the forecast graph, the predicted spot price is extremely volatile, sometimes even in sub-zero territory. Evidently, a negative spot price is infeasible, and the extreme volatility is attributed to the following factors:
I. Insufficient Data Points

As demonstrated in Exhibit 8, the final sum of observation amounts to 17, which arguably is not enough for a truly feasible study. In fact, lower amounts of observations could yield statistically insignificant results for independent variables, when in reality more observations would not. Consequently, future research has several options for improving the validity of the study. For instance, rather than using historic monthly data, one could become as granular as using hourly data. By matching historic hourly wholesale prices with historic hourly demand, coupled with stock market indices as proxies for GDP, one could potentially extract significantly more observations and subsequently build a more accurate regression. As a result, it would be expected that the elasticity is negative, rather than positive.

II. Incorrect Natural Gas Data

Given that the majority of electricity consumed in New England stems from natural gas prices, it was expected that there would be a higher correlation between natural gas prices and energy consumption. However, this study indicated that the inherent correlation was statistically insignificant. In reality, natural gas prices vary widely nationwide, even from state to state. Actually, New England’s remote location makes pipeline transport of gas to the area difficult. As a result, New England sees significant volatility in its gas prices, more so than the rest of the nation, which is not reflected in the regression. Future research on the topic could thus attempt to find prices on local New England exchanges to potentially yield a higher correlation between gas prices and demand.

III. Methodology
The methodology used in this study was two-fold. First, running a regression to establish New England electricity’s price elasticity of demand. Second, applying that elasticity to ISO New England demand forecasts to predict future spot prices. However, as previously mentioned, for more accuracy a second-degree least-squares analysis could be used to ensure that error terms are uncorrelated. Indeed, more sophisticated econometric forecasting methods like ARIMA could be used to get more accurate price estimates. However, that is outside the scope and capability of this study.
6. Conclusion

This study has shown that, given the methodology, there is potential for arbitrage profit in the New England energy futures market. Comparing forecasts to futures prices imply miss pricing in the sector, which investors could trade upon through aforementioned trading strategies to yield an arbitrage profit.

However, highly volatile energy markets due to seasonality, less liquidity, and frequent spikes and drops in the market question the feasibility of any forecasting attempts. As of now, given inherent assumptions, as well as insufficiently rigid data and methodology, investors should not rely on the derived model to invest either own or limited partners’ capital. Should, however, future research fill the gaps in the methodology, one could more reliably act upon the data for investment decisions.
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François-Éric Racicot, Raymond Théoret, Macroeconomic shocks, forward-looking dynamics, and the behavior of hedge funds, Journal of Banking & Finance, Volume 62, January 2016, Pages 41-61, ISSN 0378-4266


