# An Empirical Exploration of the Effects of Natural Gas Prices on Solar Energy Growth

**Jeff Walton**

A senior thesis submitted in partial fulfillment of the requirements for graduation from the University of Puget Sound

**December 20th, 2013**

**Abstract**

This paper analyzes the relationship between natural gas prices and solar installation in the past ten years. The point is to explain how the fluctuations in natural gas prices have effected solar installation. Briefly, natural gas prices from three to five years ago have a positive coefficient on solar installation in the current period, meaning that as the natural gas price three to five years ago increases, solar installation today increases. In course of the analysis, we find that the Goldilocks theory holds true and a natural gas price range from $4 to $6 leads to the highest level of installed solar capacity in the United States. Since natural gas prices today are lower than the Goldilocks range, the solar industry would prosper from a cap and trade system, a carbon tax, or exporting natural gas, raising the price of natural gas to the $4 to $6 range.

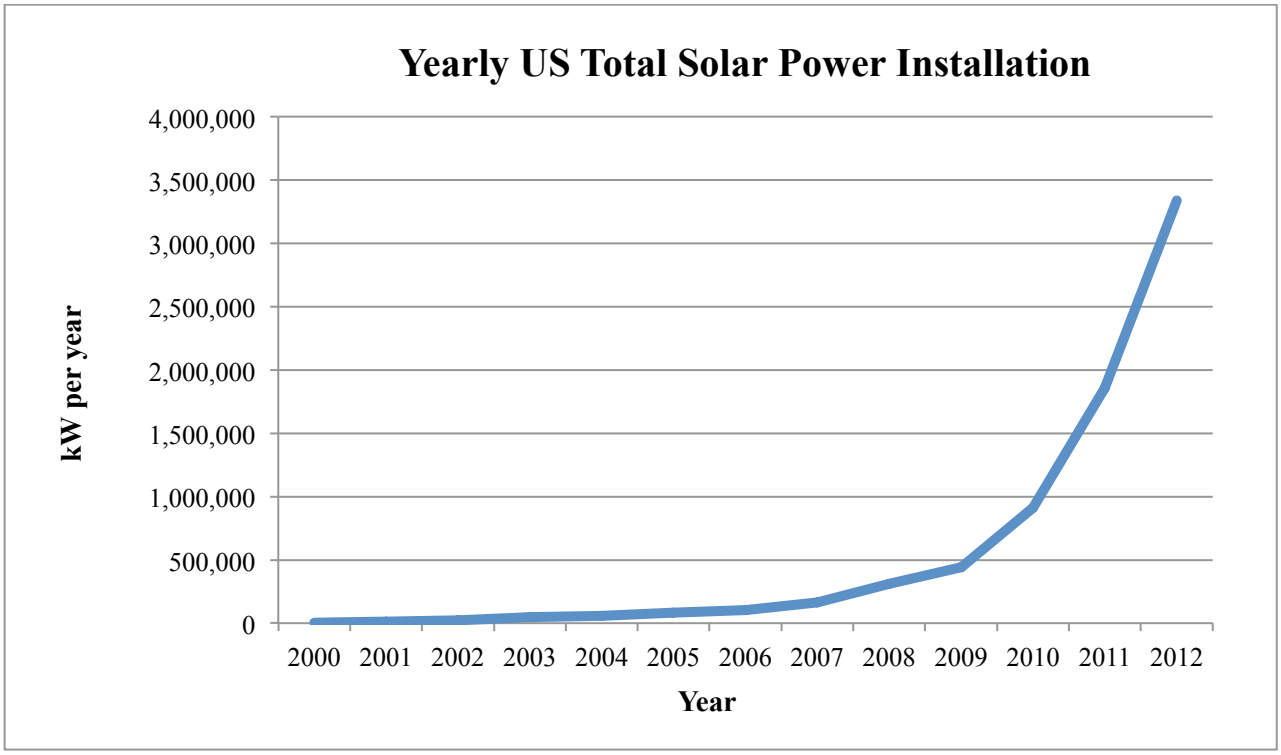
**Introduction**

Climate change has become the largest issue of the century because of increasing energy demand and awareness of greenhouse gas effects. Recently, with oil and coal costs rising and reserves decreasing, energy companies have begun to look for alternative ways to meet the increasing energy demand through energy sources such as natural gas and renewable energy. America's current energy portfolio consists of 86 percent fossil fuels, eight percent nuclear, and six percent renewable energy (U.S. Energy Information Association 2012). With the current energy portfolio composition in the United States and increasing energy demand, change needs to be made to offset the current emission rates (Obama 2013). Despite the negative consequences of climate change, fossil fuels provide the cheapest and most widely used form of energy. Although fossil fuels have an apparent social cost, renewable energy is faced with large upfront costs making it less attractive.

Renewable energy comes from sources such as wind, sun and heat from the earth. Some of the most prominent renewable fuel sources in the world today are wind, solar, and hydropower. Of these renewable resources wind and hydropower are very restricted in terms of location and total capacity. Solar power on the other hand could exist anywhere, and its total potential capacity is much greater than both wind and hydro. These energy sources have relatively low to zero carbon emissions in their production of energy thus reducing greenhouse gas emissions. They also reduce the negative health effects of $CO_2$, as well as provide a vast inexhaustible energy supply. Renewable energy, although under constant scrutiny, has taken tremendous strides in production and development due to acknowledgment of climate change. Since 2001 total US renewable energy production has increased by 79 percent, and more specifically, solar energy installation has increased 29,342 percent. As seen in figure 1 US installed solar capacity has gone from 11,348 kW in 2001 to 3,341,127 kW in 2012. Many believe that federal and state governments, by way of

economic incentives, spurred this growth in the solar industry (U.S. Energy Information Association 2012). Because of the potential for large-scale solar energy growth, its responsiveness to incentives and its overall capabilities, we use US solar installed capacity to represent the optimistic growth of renewable energy sources.

**Figure 1. Yearly US Total Solar Power Installation (kW-DC/year)**




Since President Obama took office in 2008, he has taken a significant role in creating policy to mitigate climate change. The Obama administration increased incentives for renewable energy projects by increasing federal subsidies, creating tax breaks and grants, and giving out low interest rate loans to finance renewable energy projects. The federal government estimates it will spend about 16 billion dollars in federal support for renewable energy in 2011 (Lomborg 2012). At the same time, the federal government annually spends an estimated $35-52 billion in fossil fuel subsidies (Environmental Law Institute 2011). Although government spending for fossil fuels has decreased by about 25 percent from the second George Bush administration, fossil fuel spending still

exceeds renewable energy spending today. Despite the shift in government spending, the developments in the market for natural gas create a roadblock for renewable energy growth.

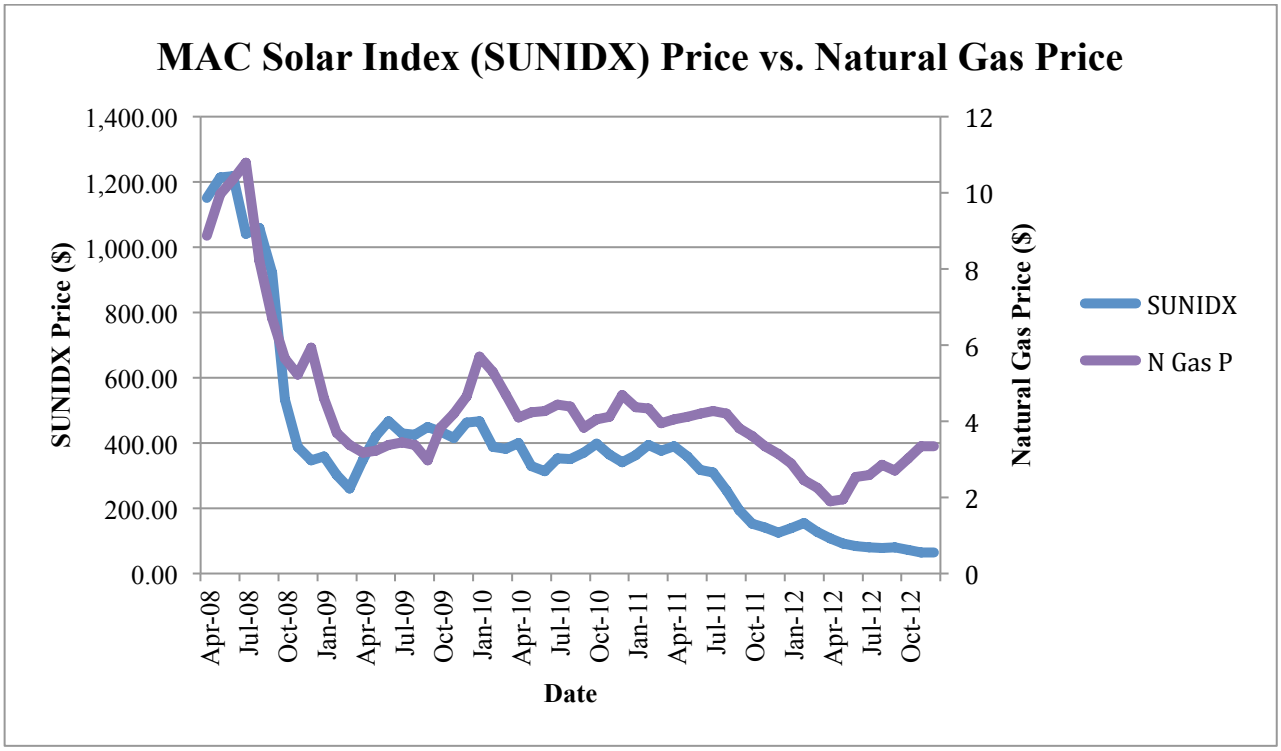
About half of the United States fossil fuel consumption has turned towards natural gas because of increases in technology and increases in recoverable reserves resulting in a drop in the price (Habjanec 2009). Natural gas reserves, due to recent development of horizontal drilling and hydraulic fracturing technology, have increased 82 percent since 2001, from 191.7 trillion cubic feet to 348.8 trillion cubic feet of recoverable reserves (U.S. Energy Information Association 2011). Horizontal drilling allows the gas rigs to drill further into a gas well underground than a slant well or vertical well. Hydraulic fracturing, also known as "fracking," used in conjunction with horizontal drilling creates fissures in the ground, generally shale rock. A "frack fluid" is then pumped into the fissures in the rock, propping open the fractures and allowing natural gas to flow into the wellbore (Stair 2013). The development of fracking and horizontal drilling, along with the increase in recoverable reserves, increased supply driving down natural gas prices, and also increasing the quantity produced.

Across the globe people are in agreement that, at current prices, renewable energy is too expensive to meet the entire energy demand (Lomborg 2012). As natural gas becomes cheaper and more abundant, the more decision makers rely on the basis that natural gas emissions levels are roughly half of conventional fossil fuels. Unfortunately, Archer (2009) argues that the reduction in emissions from switching to natural gas is still insignificant under current emission conditions and rising energy demand. Renewable production, specifically solar, must increase under current conditions in order to mitigate climate change.

Increases in technology and domestic recoverable natural gas reserves prove prosperous for energy providers in the United States; however, solar energy providers have amassed tremendous losses in the past six years since the recession in 2008. Since 2008 natural gas prices have fallen 66

percent and conversely the MAC Solar Index (SUNIDX) has fallen an estimated 90 percent both shown in figure 2 below. Because of the strong relationship between the fall in natural gas prices and fall in the MAC Solar index, there is much debate to whether or not solar can flourish as natural gas prices continue to decline.

**Figure 2. MAC Solar Index (SUNIDX) Price vs. Natural Gas Price**




Moniz et al (2011) believe that low natural gas prices will not have an effect solar energy growth because natural gas still emits carbon and has a finite supply. Since natural gas is a finite resource the price will continue to rise as the amount of reserves decreases. Also with constant pressure from NGO's, the EPA, and irrefutable changes in weather patterns, the government needs to begin pricing carbon emissions, increasing the price of fossil fuels and quickly making solar energy cost competitive (Lacey 2012). Also the emergence of new recoverable natural gas reserves provides more time to develop more efficient photovoltaic and solar panels, ceteris paribus (Stevens 2012). Lastly, natural gas, although very cheap, varies in price because of severe weather, operating

mishaps and planned maintenance. Because of this natural gas price volatility the demand for renewable energies will continue to exist, as a stable form of energy, limiting the volatility of natural gas prices, with zero carbon emissions (Mastrangelo 2007). Although many believe that natural gas prices do not have a large impact on solar energy growth, many believe that natural gas prices do affect solar energy.

Lomborg (2012) demonstrates that in the short run, without government intervention, investment from outside sources will switch focus from solar energy to the more cost effective energy source, natural gas. With the current natural gas infrastructure any plans for future development require less capital, making large scale solar energy projects much more capital intensive than natural gas. Investors believe that large-scale solar projects will not achieve a viable return on investment, and it behooves of them to invest in natural gas projects instead (Five Star Equities 2012). This increase in natural gas investment can be conveyed by the 4,570% increase in natural gas drilling permits in the state of Pennsylvania from 2007 to 2010 (Lesser 2012). As the price of natural gas declines so does the price pressure contributing to the development of renewable energy. As natural gas prices hover around $0.05 a kWh in comparison to the $0.155 a kWh for solar, a major grid scale renewable energy project seems very risky, unless the project directly complies with state renewable portfolio standards (Moniz 2013). Contrary to both of the above theories, some believe that natural gas and solar energy can perform as an effective partnership; however, natural gas price must be neither too high, nor too low, but just right.

The "Goldilocks theory" in terms of natural gas prices refers to idea that when natural gas prices are low, solar energy growth declines because solar looks expensive to consumers. Conversely when natural gas prices are high, electricity as a whole becomes less affordable, then consumers become less receptive to installing solar because they see it as an added expense. However, if natural gas prices were just right, then solar energy and natural gas could create an

effective partnership (Trabish 2012). Since the development of horizontal drilling and fracking, the United States has greatly reduced their dependence on natural gas imports and relied more heavily on domestic production. If the volume of natural gas extraction continues to increase, then the United States could become a net exporter of natural gas by 2016 (U.S. Energy Information Association 2013). If the United States were to export natural gas, prices would increase, resulting in larger scale solar energy investment.

Many disagree on the extent in which natural gas prices affect solar energy growth in the United States. This paper aims to determine the effects that natural gas prices have on US solar installation by state, and to determine the optimal natural gas price range that leads to the maximum solar installation.

**Data and Methodology**

Data primarily comes from the Energy Information Administration (EIA), the Interstate Renewable Energy Council (IREC), the Solar Energy Industries Association (SEIA), and Quote Media for dynamic market data solutions. The advantage of these databases is that they are very large, providing a large sample size and many different independent variables. Considering that the EIA is a governmental institution, the data is very reliable because they provide exact information for the government in order to make policy decisions, and to perform research on energy related concerns. IREC, an NGO, was created to influence national and state policies to help shape utility and industry standards in regards to renewable energy resources. The data received from IREC is very reliable because as a member of the SEIA they have exclusive rights to the solar market and industry data generated by the SEIA. In order to access the SEIA database, you must be a member which costs around $3000-$5000 to receive all of the solar energy market information. Lastly, the data from Quote Media is very reliable because it contains, high, low, and daily end price for all

stocks, ETF's, and Indexes listed on the NYSE and NASDAQ. Below in table 1, is a summary of statistics for the variables addressed in the following paragraphs, as well as price of coal to be used as a reference.

**Table 1. Summary of Statistics**

| Variables | Average | Max | Min |
|---|---|---|---|
| US Yearly Installed Solar Capacity (2000-2012) kWh | 10,481 | 983,152 | 0 |
| Natural Gas Price Average (1995-2012) $/Tcf | $4.103 | $7.97 | $1.55 |
| Coal Price (1995-2011) $/short ton | $22.40 | $36.91 | $16.63 |

The dependent variable used in this paper is the log of annual installed solar capacity by state, from 2000 to 2012. By using the annual installed solar capacity by state, we will address the direct growth of installed solar capacity as opposed to how natural gas prices affect the price of a stock index or ETF. This data is constructed using panel data by state, and will contain dummy variables to capture unexplained differences in the states. The log of installed solar capacity is used to transform the data so that the residuals are symmetrically distributed around zero. Since some states have a value of zero in their installed solar capacity, we added one to every data point, and then took the log to avoid taking the log of zero.

The first independent variable used in this paper is the average yearly natural gas price at wellhead. The reason natural gas price at wellhead is used as opposed to natural gas price at city gate or price delivered to consumers is because the further down the supply chain, the larger variance in the price. Natural gas price at wellhead reduces variance in the data, and reduces the chance for omitted variable bias. Lastly, since a majority of solar installation projects are larger scale as opposed to residential, they will be responding to the natural gas price at wellhead more than the natural gas price delivered to consumers.

The next independent variable used in this paper is the natural gas price in each time period squared. The natural gas price squared represents how installed solar capacity would react with the natural gas price being on the high side of the spectrum. This variable will complete the quadratic equation for each time period, thus determining if the goldilocks theory is significant.

Dummy variables for each state are also used to capture the unexplained differences in the states. Also, Washington State is left out of the dummy variables to be used as a comparison state. Washington State lies around average in terms of solar energy installation, giving us a general midpoint to examine the data.

We thus estimate the equation:

$$\log Y_{it} = \beta_0 + \beta_1 P_{t0} + \beta_2 {P_{t0}}^2 + \beta_3 P_{t-1} + \beta_4 {P_{t-1}}^2 + \beta_5 P_{t-2} + \beta_6 {P_{t-2}}^2 + \beta_7 P_{t-3} + \beta_8 {P_{t-3}}^2 + \beta_9 P_{t-4} + \beta_4 {P_{t-4}}^2 + \beta_5 P_{t-5} + \beta_6 {P_{t-5}}^2 + \beta_i \sum_{i=1}^{52} D_i + u$$

**Results and Implications**

By running an ordinary least squared regression in Stata using the regression equation above we received the results seen below in **table 2**.

**Table 2: Regression Results for log of US Installed Solar Capacity** (p-value)

| | Model A | Model B |
|---|---|---|
| Constant | -2.317 | .649*** |
| | (.101) | (.002) |
| $P_{t0}$ | -.9569 | -.1023** |
| | (.101) | (.019) |
| $P_{t0}^2$ | .0462 | |
| | (.325) | |
| $P_{t-1}$ | -.6974 | -.0722* |
| | (.125) | (.088) |
| $P_{t-1}^2$ | .0148 | |
| | (.669) | |
| $P_{t-2}$ | -.8325* | -.0222 |
| | (.058) | (.614) |
| $P_{t-2}^2$ | .0789* | |
| | (.058) | |
| $P_{t-3}$ | 1.545*** | .0286 |
| | (.002) | (.520) |
| $P_{t-3}^2$ | -.1360*** | |
| | (.003) | |
| $P_{t-4}$ | .8503 | .2166*** |
| | (.201) | (.000) |
| $P_{t-4}^2$ | -.0893 | |
| | (.221) | |
| $P_{t-5}$ | 3.587*** | .6499*** |
| | (.001) | (.000) |
| $P_{t-5}^2$ | -.3689*** | |
| | (.003) | |
| R-squared | .3371 | .3222 |
| F-stat | 29.20 | 55.05 |
| No. Obs. | 702 | 702 |

P-values are reported in parentheses
*, **, *** Indicates significance at the 90%, 95%, 99% level, respectively

Model A describes the original regression equation as explicitly stated above to test the goldilocks theory that as natural gas prices are low, solar capacity will increase with an increase in natural gas price, and as natural gas price gets too high ($P^2$) installed solar capacity will eventually

decrease. From these results we find that natural gas prices both in t-3 and t-5 are significant at the 99 percent confidence level. By looking at the coefficient of $P_{t-3}$ we discern that as natural gas price average three years ago increases by one dollar, installed solar capacity will increase by 154.5 percent. Conversely looking at the coefficient of $P_{t-3}^2$ we discern that as the natural gas price average three years ago, squared, increases by one dollar, installed solar capacity will decrease by 13.6 percent. Although the natural gas price t-3 is significant at the 99 percent level natural gas t-5 has a much larger impact at the 99 percent level because of the size of the coefficient. By looking at $P_{t-5}$ we see that as natural gas price average five years ago increase by one dollar, installed solar capacity will increase by 358.7 percent. Conversely looking at the coefficient of $P_{t-5}^2$ we discern that as the natural gas price average five years ago, squared, increases by one dollar, installed solar capacity will decrease by 36.9 percent. The natural gas prices in t-2 were also statistically significant; however, they were only significant at the 90 percent level. The interpretation on the $P_{t-2}$ coefficient is that as natural gas price average two years ago increases by one dollar, installed solar capacity decreases by 83%. Conversely looking at the coefficient of $P_{t-2}^2$ we find that as the natural gas price average two years ago, squared, increases by one dollar, installed solar capacity will increase by 7.89 percent. Even though the coefficients of the t-2 variables are the opposite of the t-3 and t-5 variables, they are not as significant, nor as large as the t-3 and t-5 coefficients.

Model A has an r-squared value of .3371 meaning that 33.71% of the dependent variable (installed solar capacity), can be explained by the independent variables used in the regression. The F-statistic of 29.20 has a p-value of 0.00 with 12 independent variables and 702 observations. This means that there is a zero percent chance that the data occurred by chance, and that the model as a whole has a statistically significant predictive capability.

Model B describes the regression equation ran without the squared terms of the original equation to determine the direct effects of natural gas prices on solar installation. In this equation, $P_{t-}$

$_4$, $P_{t-5}$ and the constant were significant at the 99 percent level. $P_{t0}$ was significant at the 95 percent level, and $P_{t-1}$ was significant at the 90 percent level. Both of the coefficients on $P_{t-4}$ and $P_{t-5}$ were positive. The coefficient of .2611 on $P_{t-4}$ means that as natural gas price average four years ago increases by one dollar, installed solar capacity increases by 26.11 percent. The coefficient of .6499 on $P_{t-5}$ means that as natural gas price average five years ago increases by one dollar, installed solar capacity increases by 64.99 percent. Both of the coefficients on $P_{to}$ and $P_{t-1}$ are both negative meaning that as natural gas prices increase by one dollar, installed solar capacity decreases. Although both $P_{to}$ and $P_{t-1}$ are significant, they are much less significant and the coefficient is much smaller than the lagged natural gas price variables. Lastly, although the constant is statistically significant at the 99 percent level, it doesn't provide much insight because the intercept of zero lies outside our range of data. In the real world natural gas price will never reach zero.

Model B has an r-squared value of .3222 meaning that 32.22% of the dependent variable (installed solar capacity) can be explained by the independent variables used in the regression. The F-statistic of 55.05 has a p-value of 0.00 with 6 independent variables and 702 observations. This means that there is a zero percent chance that the data occurred by chance, and that the model as a whole has a statistically significant predictive capability.

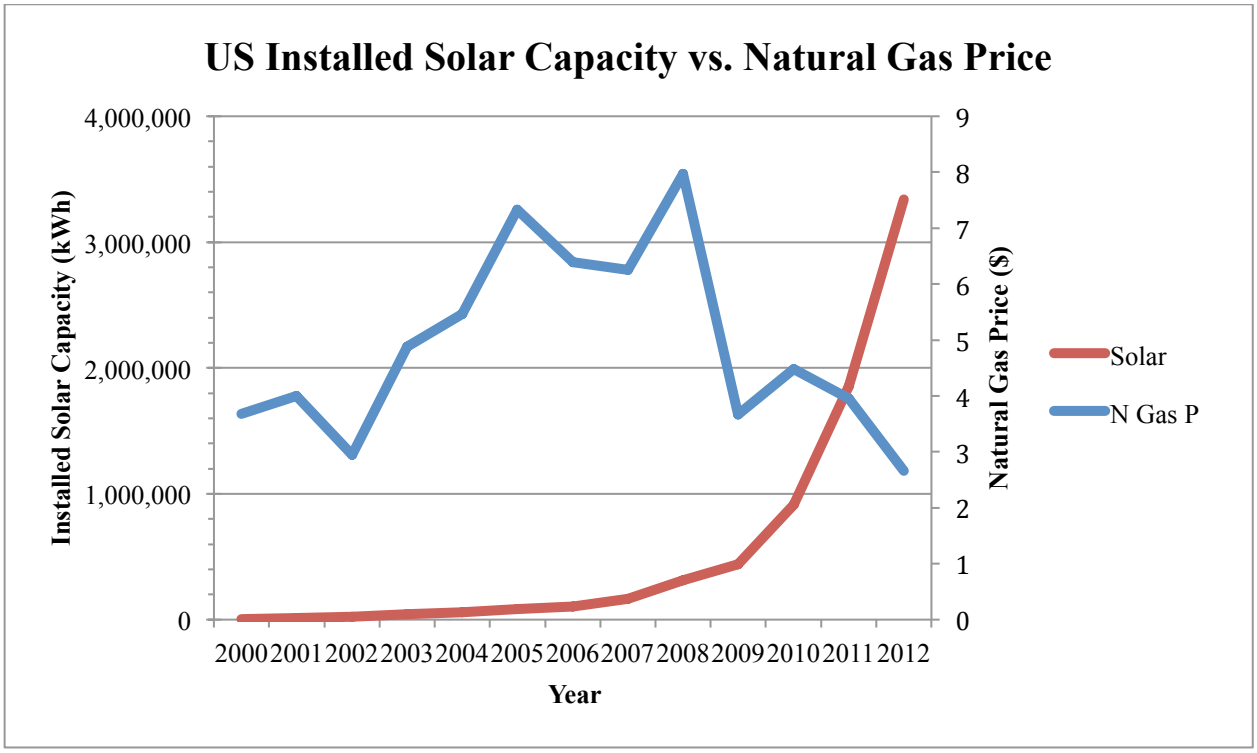
As a whole both models have a statistically significant predictive capability. Both models demonstrate that when natural gas prices, lagged three to five years, increase so does installed solar capacity, until a certain point in which natural gas prices would be so high that installation would divert to other sources of energy, i.e. coal. By taking the derivative of our quadratic regressions ceteris paribus, we effectively find the optimal natural gas price to promote the highest level of installed solar capacity.

The quadratic form shows a maximum point of $5.68 and $4.86 by taking the derivative in the t-3 regression and the t-5 regression respectively. Since both of these values fall within our range

of data, we can say that solar installation is at it's maximum when natural gas price is around $4 to $6. This proves the goldilocks theory holds true with this regression model. The reasoning behind the goldilocks theory is that when natural gas is cheap, solar is perceived as expensive by consumers; however, if natural gas is expensive, electricity as a whole becomes more expensive. Consumers are then less receptive to solar because they see it as an added expense, while switching to coal and other energy sources. If natural gas prices were in a range from $4 to $6 with little variance, installed solar capacity would be at it's maximum ceteris paribus.

One reason that the longer lags might be significant is that large-scale solar projects are very capital intensive and require tremendous planning, financing, and approval. Solar installation decision makers may take notice of high natural gas prices and respond by planning, financing, and developing large-scale solar projects three to five years later. This explains the extremely high percentage increases of solar installation from 2007 to 2012 considering that natural gas prices hit all time highs from 2003 to 2008. This high natural gas price lag and installed solar capacity can be seen in Figure 3 below.

**Figure 3. Installed Solar Capacity vs. Natural Gas Price Average (2000-2012)**




In 2012 the natural gas price average hit a low of $2.66 with a monthly low of $1.89 per thousand cubic feet, its lowest value since 1999, when solar energy was practically non-existent. This means that because of the recent low natural gas prices we can expect US solar installation to slow down dramatically for the next four to five years. Although solar installation for the upcoming years may be bleak, the government has a few options to raise natural gas prices into the ideal $4 to $6 range. The government could set up carbon policy in the form of a cap and trade system or carbon tax to decrease carbon emissions and lift the price of gas. These forms of carbon policy would reduce total carbon emissions, and effectively raise the price on fossil fuels, specifically natural gas to the Goldilocks range from $4 to $6. The government could also help the US facilitate the exportation of natural gas. If the US eventually becomes a net exporter of natural gas, although this may not solve the global climate change problem, it could raise the price of natural gas to the Goldilocks range of $4 to $6.

**Conclusion**

This paper provides significant empirical evidence that the natural gas price three to five years ago leads to an increase in US solar installation. We also find that as the natural gas price gets extremely high, solar installation decreases. By finding the maximum in our quadratic regression equations we find that US solar installation is at its highest levels when natural gas price ranges from $4 to $6 per thousand cubic feet. This is consistent with the goldilocks theory that just the right price will lead to the highest level of solar output. Although the average natural gas price of the last fifteen years lies within the Goldilocks range we calculated, recent natural gas prices have been well below the Goldilocks range. We assume that because of the fall in natural gas prices the last five years, US solar installation will begin to decrease in the upcoming years ceteris paribus. If the government wants installed solar capacity to increase in the future, as an attempt to mitigate climate change, carbon policy must be created to increase the price of natural gas into the Goldilocks range. The government could also facilitate the exportation of natural gas, which would also increase natural gas prices into the Goldilocks range.

Because of the contemporary nature of this issue, future data will be able to create more robust models as these industries become more efficient. Since the government plays a large role in creating incentives for energy this study could also include variables representing government or state monetary incentives. Monthly installed solar capacity, instead of yearly, could also be used as the dependent variable to provide a more robust model. (All US renewable energy could also be used as a dependent variable to show the impacts of natural gas on renewable energy in its entirety. Continuously collecting data, and running the same regressions in the future may tell us how the solar industry has adapted to natural gas holding a significant role in the nations energy portfolio.

Works Cited

Archer, D. (2009). *Global warming: Understanding the forecast* (2nd Edition ed.,)

Environmental Law Institute (ELI). (2013). Retrieved September 20th, 2013, from http://www.eli.org/sites/default/files/docs/energy_subsidies_black_not_green.pdf

Five Star Equities. (2012). Renewable Energy Could Fall Victim to Low Natural Gas Prices Warns IEA. Retrieved September 25th, 2013, from http://www.marketwired.com/press-release/Renewable-Energy-Could-Fall-Victim-to-Low-Natural-Gas-Prices-Warns-IEA-1664780.htm

Habjanec, D. (2009). Fossil fuel facts. Retrieved October 5th, 2013, from http://interestingenergyfacts.blogspot.com/2009/09/fossil-fuels-facts.html

Lacey, S. (2012). Top three reasons cheap gas wont kill renewable energy. Retrieved October 5th, 2013, from http://thinkprogress.org/climate/2012/02/21/421319/top-three-reasons-cheap-natural-gas-wont-kill-renewable-energy/

Lacey, S. (2012). What do falling natural gas prices mean for renewables? Retrieved September 8th, 2013, from http://www.renewableenergyworld.com/rea/news/article/2012/01/what-do-falling-natural-gas-prices-mean-for-renewables

Lesser, A. (2012). How the natural gas craze will impact renewable energy. Retrieved 5th, October, from http://gigaom.com/2012/03/27/how-the-natural-gas-craze-will-impact-renewable-energy-2/

Lomborg, B. (2012). Green energy needs to be cheaper. Retrieved October 2nd, 2013, from http://www.slate.com/articles/health_and_science/project_syndicate/2013/08/green_energy_subsidies_for_solar_and_wind_power_aren_t_helping_let_s_invest.html

Mastrangelo, E. (2007). An analysis of price volatility in natural gas markets. *Energy Information Administration, Office of Oil and Gas.*

Moniz, E. J. (Director). (2013). *Secretary Moniz on Natural Gas and Renewables.* [Video/DVD] YouTube.

Moniz, E. J., Jacoby, H. D., Meggs, A., Armtrong, R., Cohn, D., Connors, S., Kaufman, G. (2011). The Future of Natural Gas.

Obama, B. (2013, June). *We Need to Act*. Speech presented at Georgetown University, Washington, DC.

Randall, T. (2013). 'We need to act': Transcript of obama's climate change speech. Retrieved October 5th, 2013, from http://www.bloomberg.com/news/2013-06-25/-we-need-to-act-transcript-of-obama-s-climate-change-speech.html

Stair, C. (2013, April 10). Telephone interview.

Stevens, B. (2012). Natural gas the perfect bridge to renewable energy part 2. Retrieved September 25th, 2013, from http://oilprice.com/Energy/Natural-Gas/Natural-Gas-the-Perfect-Bridge-to-Renewable-Energy-Part-2.html

Trabish, H. (2012). Getting natural gas, solar, and wind to play well together. Retrieved September 8th, 2013, from http://www.greentechmedia.com/articles/read/Getting-Natural-Gas-Solar-and-Wind-to-Play-Well-Together

U.S. Energy Information Administration (EIA). (2013). Retrieved September 20th, 2013, from http://www.eia.gov/