ABSTRACT

The Potential Benefit of the United States Exporting Liquefied Natural Gas for Japan: Forecasting Liquefied Natural Gas Price Changes

Andrew Leistensnider

Director: Dr. Pham Hoang Van, Ph.D.

This paper estimated the change in price of liquefied natural gas (LNG) in world LNG markets and U.S. domestic markets if the U.S. were to start exporting LNG. We then calculated the estimated effect of such a change in the world price of LNG on the Consumer Price Index of Japan and the U.S. We considered what Japan's demand for LNG would be if it ended its nuclear energy program. This paper uses the price elasticity of world demand and U.S. demand for LNG to estimate future price changes in five year intervals from 2015 until 2035. We found that the world price of LNG would drop 4-8% at current supply conditions and 6-12% at high natural gas well recovery conditions. We found that the U.S. price of LNG would rise around 10% every five years at current supply conditions and around 20% every five years at high natural gas well recovery conditions. Japan would benefit from the U.S. exporting LNG and the U.S. would also benefit.

APPROVED BY DIRECTOR OF HONORS THESIS:

____

Dr. Pham Hoang Van, Department of Economics

APPROVED BY THE HONORS PROGRAM:

____

Dr. Andrew Wisely, Director

DATE: _________________________

THE POTENTIAL BENEFIT OF THE UNITED STATES EXPORTING LIQUEFIED NATURAL GAS FOR JAPAN: FORECASTING LIQUEFIED NATURAL GAS PRICE CHANGES

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements for the

Honors Program

By

Andrew Leistensnider

Waco, TX

May 2013

TABLE OF CONTENTS

ACKNOWLEDGEMENT

First I would like to thank Dr. Pham for being my thesis director and providing valuable insight throughout this project. Without his guidance this thesis would not have come to fruition and I am very grateful for his assistance. I would also like to thank Dr. Joseph McKinney and Dr. James West for serving on my thesis defense committee. They have always been kind, helpful, and supportive of my endeavors. I am very grateful for the Economics Department at Baylor for giving me an economic education that I am proud of and feel blessed to have received.

I would also like to thank my parents for their support and kind assistance throughout my undergraduate career. Without them none of this would have been possible and I feel blessed to have such loving parents.

Finally I would like to thank Yoshiko F. Gaines and Yuko Prefume in the Modern Foreign Language Department for their unwavering support and kind fellowship. They have always inspired my interest in Japan and helped guide me through my undergraduate career. They have served as role models to me with their kindness and care for their students and I only wish to one day be like them as an educator. I will greatly miss the conversations, laughs, and tea we have shared together.

CHAPTER ONE

The World, U.S., and Japanese Liquefied Natural Gas Markets

The United States has large reserves of natural gas it could potentially export in the world market. Though economic theory predicts that doing so would be beneficial for the U.S. economy, the U.S. has a trade restriction that effectively prevents exporting natural gas. This ban particularly prevents natural gas exports to overseas markets by liquefaction, or liquefied natural gas (LNG). There is currently a debate about exporting LNG in the U.S. because of concerns over the gains from trade, the U.S. political climate, and national security.

At the same time Japan is a major importer of LNG and would likely be interested in purchasing LNG from the U.S. because it is already a major trading partner. Japan is also considering ending its nuclear program in light of the massive earthquake and Tsunami on March 11th, 2011. If Japan were to do so, it would have a much greater need for LNG imports which the U.S. could supply if the U.S. were to lift its ban on LNG exports. If Japan were able to import LNG from the U.S. at a cheaper price, then Japan's economy could potentially start growing at a higher rate. The resulting increases in production could lead to lower prices of Japanese exports to the U.S., and a stronger economy for one of America's closest allies in East Asia. If Japan were able to end its nuclear program primarily through LNG imports, then it could serve as an example for developed countries that nuclear energy is not always necessary to power a modern developed economy.

Hence we argue that the ban on LNG exports should be lifted. In order to evaluate the merits of this decision, we will attempt to forecast the impact on world and U.S. prices of LNG if the U.S. were to lift its restriction on LNG exports and Japan were to end its nuclear program and demand greater quantities of LNG from the global market. Knowing this impact would help inform a decision about lifting the ban on U.S. LNG exports. The paper is divided into three main parts: an explanation of world, U.S., and Japanese LNG markets, the methodology of the price forecasting model, and the results and implications of the price forecasting.

This analysis has two key assumptions. First, for the high estimated ultimate recovery per well (HEUR), low estimated ultimate recovery per well (LEUR), and the demand shock case where Japan stops using nuclear power, all assumptions from the Annual Energy Outlook 2011 from the Energy Information Administration were used. These included assumptions about energy and environmental policies, baseline coal, oil, and natural gas prices, economic and energy demand growth, and technology availability and cost in the corresponding Annual Energy Outlook 2011 cases (NERA 5) (for the full list of EIA Annual Energy Outlook 2011 assumptions see Appendix). These assumptions about the supply and demand for liquefied natural gas allow us to make predictions about the world market for LNG while holding other pertinent factors constant.

Second, the global LNG market was assumed to be a single perfectly competitive market with Qatar as the one dominant supplier limiting its export capacity. For the purposes of this analysis, Qatar's decisions about exports were assumed to be fixed regardless of future U.S. exports (NERA 5). Other world LNG exporters are assumed to behave as competitors to the U.S., but were assumed to not adjust their exports in light of the new world price they are offered. It is beyond the scope of this analysis to consider alternative responses by other world LNG exporters to maximize their gains.

World LNG markets have been changing at an increasing rate recently and the possibilities in the industry are still not fully explored. In 2011 world LNG trade grew by 8% and the number of countries exporting it increased as well (International Gas Union 6). Global liquefaction capacity, though, rose by a much smaller amount and remains a limiting factor of the burgeoning industry (International Gas Union 6). Currently there are many exporters of LNG and Qatar is one dominant supplier (see APPENDIX B). The U.S. did actually export a very small amount of LNG in 2011. However, this is a negligible amount compared to the quantities exported by other natural gas producing countries. On the demand side, Japan is the world's largest importer with numerous smaller importers (see APPENDIX C). There is a collection of distinct regional markets for trading natural gas as opposed to a single global market (NERA 16). The location, availability of producing natural gas indigenously, pipeline infrastructure and prospects, accessibility to natural gas from other regions of the world, and rate of growth in natural gas demand all characterize each regional market (NERA 16). Some regions trade with other regions by pipelines while others act relatively autonomously (NERA 16). So a country's access to LNG depends on how the characteristics of their regional market.

Natural gas is supplied based on a country's reserves and is a non-renewable energy source (Naturalgas.org). It is difficult to measure how much natural gas is available under the ground, and it involves a great deal of inference and estimation (Naturalgas.org). Natural gas is used in the industrial sector, which often uses natural gas as both a plant fuel and as a feedstock for many products such as fertilizer and pharmaceuticals (EIA Natural Gas Explained). Natural gas is also consumed by residential and commercial users for heating during winter months (EIA Natural Gas Explained). Natural gas also fuels many electric power plants that are operated to meet air-conditioning needs in the summer (EIA Natural Gas Explained). Natural gas is often stored in underground storage fields to help meet sharp increases in demand and prevent large fluctuations in prices if production fails to meet expected levels (EIA Natural Gas Explained). Because natural gas has uses for large-scale industries, it is important to consider how it is traded.

There are three ways a country can acquire natural gas. These methods are ranked by their relative ease. First there is indigenous production, which is the easiest way a country can acquire natural gas if it has large enough domestic reserves (NERA 16). Second is natural gas deliveries by pipeline connected to other regions, which is still relatively cheap but requires trade arrangements and geography to cooperate (NERA 16). And third is LNG shipments, which requires liquefaction, long-distance shipping, and re-gasification which can be quite expensive (NERA 16). Each region will meet its natural gas demand first with indigenous production, then pipeline deliveries, then LNG shipments.

In this analysis we will consider Japan and the U.S. in the global LNG market, which have their own unique characteristics, respectively. Although there are distinct regional markets for natural gas, we will assume that Japan is an importer from a single global market for LNG. Japan has no indigenous production and does not have any pipelines connecting it to regional suppliers, so it will import LNG from the global market. We will assume that the U.S. will be an exporter to a single global market for

LNG. Although the U.S. can export some of its natural gas via pipeline to Canada or Central and South America, for the purpose of this analysis we will consider only how the U.S. exports LNG to the single global market.

LNG is traded in the world market based on short-term demand, availability of supplies, and proximity of supply projects to markets (NERA 18). Most LNG is traded via long-term contracts lasting 10 or more years with dedicated reserves transported with dedicated vessels (NERA 18). There is also a world spot market for LNG, but the availability of reserves at any moment can vary greatly. The spot market for LNG has been growing steadily since the 1990s, particularly with more rapid growth in the last five years (International Gas Union 15). Spot trade only accounted for roughly 10% of total LNG traded before 2005 (International Gas Union 15). However, by 2011 it was more than 25% of global trade and is likely to continue growing (International Gas Union 15). The number of countries trading in the spot market has also increased. Nine countries were exporters in LNG spot markets in 2006 and by 2011 there were 21 (International Gas Union 16). Similarly for LNG importers in the spot markets, in 2006 there were only 13 and by 2011 there were 25 (International Gas Union 16). Hence interest in trading LNG in the spot market has been increasing in recent years.

Currently there is no futures market for LNG in the world. However, Japan has recently announced its intention to list the world's first futures contracts for LNG on the Tokyo Commodity Exchange within the next two years (Okada & Hong). According to Takashi Ishizaki, the director for the commerce policy division at the Ministry of Economy, Trade, and Industry, the futures will be for cash settlement in dollars and based on an index price for spot LNG cargoes delivered to Japan (Okada & Hong). The existence of such a futures market would allow consumers and producers to hedge against price swings and it would also challenge the current method of indexing LNG's price to oil (Okada & Hong). Because LNG is a relatively recently discovered and traded commodity, the markets and instruments for trading it are still evolving and adapting to new conditions.

If the U.S. began exporting LNG in the world market, it would be purchased at first based on short-term demand and the availability of supplies. The exact buyers of U.S. LNG are difficult to predict given how each one would respond to the change in world LNG prices. However, we will consider how Japan will react to such a change in world LNG prices.

The basis is the difference in price between two different natural gas market regional hubs (NERA 20). Even though we are assuming there is a single world market with a single world price for LNG, in reality there is a basis which reflects the difference in the pricing mechanisms for each regional market (NERA 20). The basis can be simply the cost of transportation between two market regions if the pricing for both market regions were set by the same mechanism (NERA 20). However, Japan and the U.S. have different pricing mechanisms for LNG. Japan indexes the LNG price to crude oil because it completely depends on LNG as its sources for natural gas (NERA 20). LNG prices in North America are set by competition between different North American supply sources of natural gas because of its limited LNG terminals for export or import (NERA 20). Hence there is a basis differential between Japan and the U.S. While this is the case in reality, for the purpose of this analysis we will abstract from basis differentials and consider only the effect of a supply shock to the single world price of LNG observed by all countries.

The U.S. is currently not exporting liquefied natural gas despite its relatively large reserves. It is still possible for U.S. firms to export LNG, but under the Natural Gas Act Section 3 (15 USC §717b), "exporting natural gas from the United States requires authorizations from the Department of Energy's Office of Fossil Energy and from FERC (Federal Energy Regulatory Commission)" (Ebinger et al. 13). The approval process includes multiple steps including the DOE determining if the export is deemed consistent with public interest and possible regulatory oversight from the U.S. Coast Guard or the Department of Transportation (Ebinger et al. 13). Environmental impacts are also a major consideration and must be documented and approved before export rights can be granted (Ebinger et al. 13). This law effectively prevents U.S. firms from exporting LNG. If this law were to be revised or removed, then U.S. firms could export LNG much more easily.

This law, though, has not been revised due to the current U.S. political climate. The U.S. currently has 2,543 trillion cubic feet (tcf) of technically recoverable natural gas (Loris). However, U.S. politicians and energy-intensive manufacturers have raised concerns that exporting LNG will decrease the domestic supply of natural gas and thus raise the domestic price significantly enough to be material (Loris). American businesses and energy consumers would have to pay a higher price for this commodity which is an input factor for many different things including electricity generation, home heating and cooling, and industrial applications (Loris). It would be politically unpopular for Congress to revise or remove the law, hence it has remained.

The top five natural gas producing states in order are Texas (7.1 tcf), Louisiana (3.0 tcf), Wyoming (2.2 tcf), Oklahoma (1.9 tcf), and Colorado (1.6 tcf) (EIA Frequently Asked Questions). These states would benefit from the potential price increase if the U.S. were to start exporting LNG. The natural gas industries in these states would expand and could potentially have positive spillover effects such as new technologies from the increased resources dedicated to natural gas production. The top five natural gas consuming states in order are Texas (3.6 tcf), California (2.2 tcf), Louisiana (1.4 tcf), New York (1.2 tcf), and Florida (1.2 tcf) (EIA Table F19). It is somewhat not surprising that two of the five largest natural gas producing states (Texas and Louisiana) are also two of the five largest natural gas consuming states. States will consume their own supplies before importing from other states in the union. While the natural gas industry in these states would benefit from the increase in prices from LNG exports, the other industries that use natural gas as an input factor and the major consuming states would be adversely affected. Government intervention would be necessary to redistribute the gains from trade out of the natural gas industry and into other industries. This would increase the overall welfare of the nation, rather than just the relatively few individuals in the natural gas industry. The feedback effects of an increase in the price of natural gas on the macroeconomy are not considered in this paper as they are beyond the scope of this partial equilibrium analysis.

It is likely that if the U.S. were to export LNG, Japan would be a major importer. While it is the third-largest net importer of crude oil in the world, Japan is the world's largest importer of liquefied natural gas (EIA Japan 1). In 2011 Japan held about 33% of the global market for liquefied natural gas (EIA Japan 7). After the Great East Japan

Earthquake on March 11th, 2011, the country was forced to immediately shutdown 12,000 megawatts of electric generating capacity at four nuclear power stations (EIA Japan 1). In the following months Japan lost all of its nuclear capacity due to scheduled maintenance and new government restrictions on nuclear power plant operations (EIA Japan 1). As a result, Japan is increasing its demand for liquefied natural gas as a substitute for nuclear power. Japan's LNG imports rose 12% in 2011 and IHS Cambridge Energy Research Associates estimated that total natural gas imports increased by a monthly average of 18% annually from April 2011 through February 2012 (EIA Japan 7). So with Japan's increased demand for LNG, it would likely seek to import from the U.S.

Japan as a modern economy has always been dependent on energy imports. It has traditionally been an importer of oil, iron ore, coal, and other raw materials, and an exporter of manufactured goods such as consumer electronics, steel, ships, and automobiles (Ito 296). During the late 1980s Japan's share of fuels in imports declined sharply (Ito 296). Half of Japan's imports were mostly crude oil and some other fuels in 1980, and by 1987 it was down to 27 percent (Ito 296). The share of fuel imports dropped because of two factors. Fuel consumption (volume) per unit of GNP was declining due to energy-saving measures and the yen appreciated sharply, which caused the share of machinery, transportation equipment, and other industrial goods in imports to increase, and thus the share of fuel to decrease (Ito 296). Japan still imports large amounts of energy, but following the two oil crises in the 1970s, Japan diversified its energy sources to include nuclear energy, natural gas and coal (Federation of Electric). Part of this diversification effort included expanding its nuclear energy program, but in light of the March 11th earthquake, efforts to expand the nuclear program have ceased. Because it still desires a diversified source of energy, and now a safe and stable source, Japan is switching to natural gas as a source of energy.

Japan favors the use of LNG over other fossil fuels to replace nuclear energy. Because of the current government carbon-abatement policies and the government's pledge to lower greenhouse gas emissions, LNG is receiving more government support than oil or other fossil fuels (EIA Japan 8). After the Great East Japan Earthquake, Japan replaced its lost nuclear capacity with spot cargo LNG constituting roughly 20% of total LNG imports in 2011 (EIA Japan 7). The number of LNG-powered electric stations is also increasing in Japan. Roughly 26% of electricity was generated from LNG in 2010 and LNG accounted for 43% of the fossil fuel mix for generating electricity in 2011 (EIA Japan 11). Japan will most likely continue to prefer LNG over other fossil fuels for electricity generation in the years to come.

Japan imports LNG from a variety of distributors around the world, none of which constitute more than 20% of the market share (see APPENDIX D) (EIA Japan 8). Japan is only 16% energy self-sufficient and has few domestic energy resources (EIA Japan 1). Because Japan is an island and has few prospects for pipelines to connect it to other regions (such as Russia or China), Japan is solely reliant on LNG shipments from abroad (NERA 17). However Japan was in negotiations with Russia in 2009 to increase gas imports to Japan via a proposed pipeline or more LNG shipments (EIA Japan 8). Japan is also heavily involved in overseas exploration of LNG, particularly in Australia. Japanese electric and gas companies have signed contracts with various Australian LNG ventures, most significantly the Chevron-led Gorgon project (EIA Japan 8). The Japanese companies Mitsui and Mitsubishi Corporation also purchased a 15% stake in Australia's

Browse LNG project in 2012 (EIA Japan 8). Japanese energy companies currently have stakes in five major LNG exploration projects in Australia (EIA Japan 9). Japan will continue to pursue LNG interests abroad and potentially be interested in importing from the U.S. at lower prices.

The Japanese import tariff on LNG is zero (Customs and Tariff). In fact, Japan has one of the lowest applied tariff rates in the world (Global Trade). Only certain products including leather goods, certain processed foods, and some manufactured goods have relatively high tariff rates (Global Trade). Only Japan's average agricultural import tariff is relatively high for industrialized countries (Global Trade). So a change in the world price of LNG would not be obscured by any import tariff.

CHAPTER TWO

Methodology of the Price Forecasting Model

We will use the price elasticity of world demand for LNG, the existing world demand for LNG, and the estimated amount of U.S. exports of LNG into the world market to estimate the percentage change in the world price of LNG. Similarly, we will also use the price elasticity of U.S. demand for LNG, the existing U.S. demand for LNG, and the estimated amount of U.S. exports of LNG out of the U.S. to estimate the percentage change in the U.S. price of LNG. This relationship is given by the following equation:

$$\frac{\frac{\Delta Qd}{Qd}}{\frac{\Delta P}{P}} = \mathcal{E}d$$

which is the price elasticity of demand equation. We can rewrite this equation as:

$$\frac{\frac{\Delta Qd}{Qd}}{\mathcal{E}d} = \frac{\Delta P}{P}$$

which isolates the percentage change in price of LNG, which we are solving for.

We will use NERA's Global Natural Gas Model (GNGM) to estimate the price elasticity of demand for LNG ($\mathcal{E}d$), the existing demand for LNG (Qd), and the estimated amount of U.S. exports of LNG (ΔQd)for both the U.S. and world markets. The GNGM is a partial-equilibrium model that estimates the production, consumption, and trade of natural gas by major world natural gas consuming and/or producing regions (NERA 20). The model maximizes the sum of consumers' and producers' surplus less transportation costs, subject to re-gasification, liquefaction, and pipeline capacity constraints and mass balancing constraints (NERA 95). The model is calibrated to match the Energy Information Administration's International Energy Outlook 2011 and Annual Energy Outlook 2011 reference cases for the U.S. supply of natural gas (NERA 95). These are the same conditions which our first key assumption must match for the HEUR, LEUR, and References scenarios. The GNGM assumes no limits on either LNG liquefaction capacity additions outside the U.S. or world LNG shipping capacity, except for the U.S. and Qatar (NERA 35). Qatar's LNG exports were limited to 4.64 tcf while U.S. export limits varied based on different scenarios considered (NERA 29). So our calculations in this analysis will be based on the assumptions of the GNGM model.

The GNGM model is a partial-equilibrium analysis model and thus has limitations compared to a general-equilibrium model. The GNGM model can estimate the production, consumption, and trade of natural gas and provides the supply and demand estimates of natural gas necessary for predicting the change in LNG prices in the U.S. and world markets. However, it does not take into account the feedback effects of natural gas production and consumption on the U.S. macroeconomy, as a general-equilibrium model would. So the GNGM model is somewhat limited, but the data requirements are lower and the model is more transparent.

This also applies to the estimates for the percentage change in LNG based on the price elasticity of demand for LNG. This paper is a partial-equilibrium analysis and thus does not account for the feedback effects of a change in the price of LNG on the world market for LNG, the U.S. economy, or the Japanese economy. However, the data requirements are much lower for a partial-equilibrium analysis and it allows us to analyze the percentage change in the world and U.S. price of LNG is a more transparent way than if we used a general-equilibrium model. However, many assumptions must be used in a partial-equilibrium analysis to hold all other relevant factors constant. Hence this analysis is not as robust as possible since many of the underlying assumptions cannot be relaxed. But for the purpose of estimating the percentage change in LNG prices to help inform policy decisions and general investment decisions, a partial-equilibrium analysis is more than sufficient.

For world price elasticity of demand for LNG, all regions are assumed to have a short run demand elasticity of -0.10 in 2010 and a long run demand elasticity of -0.20 in 2035 (NERA 90). The U.S. demand elasticity, though, is derived based on average delivered price and consumption fluctuations (NERA 90). Also, in this model the estimated amount of U.S. exports of LNG (ΔQd) represents the change in quantity of LNG available in that year with respect to the starting year (2010). This does not represent that change from the previous selected year where the changes compound (e.g. change from 2020 to 2025), but instead represents the additional quantity available in that year with respect to the starting year; it shows how much LNG is being exported in that year alone.

Before we calculate the estimated percentage change in price of LNG, we need to consider the behavior of other LNG suppliers in response to the U.S. entering the world market. The potential entry of a new supplier can have multiple effects, but we will assume that existing suppliers produce at previously planned levels with the hope of discouraging the new potential supplier from entering the market. When existing suppliers do not change their production levels, prices may possibly decrease below acceptable levels to the new entrant, in this case the U.S. This is consistent with our second key assumption that the single dominant supplier in the world LNG market (Qatar) would not change its production levels in response to the U.S. entering.

Because this analysis focuses on Japan's response to the U.S. exporting LNG, we will consider the special case where Japan has an increased demand for LNG. This special case is called the Demand Shock Case, in which we assume that Japan converts all its nuclear power generation to natural gas-fired generation (NERA 24). The incremental demand could only be served by additional LNG imports because Japan lacks domestic natural gas resources and pipeline accessibility (NERA 24). There are other possibilities as well, such as if both Japan and South Korea convert their nuclear demand to natural gas, or if no new liquefaction projects are started in Australia, Southeast Asia, or Africa. However, for this analysis we will only consider Japan's Demand Shock Case.

This analysis will consider three possible scenarios for U.S. natural gas production. Because there is uncertainty about the recovery rate of natural gas wells, we must consider different possible scenarios for how much natural gas the U.S. would have available for export as LNG. The cases are as follows:

1) Reference Scenario: based on the Energy Information Administration's estimation of current U.S. natural gas production capacity in the Annual Energy Outlook 2011.
2) HEUR Scenario: the High Shale Estimated Ultimate Recovery (HEUR) Scenario reflects a more optimistic assumption about U.S. natural gas supply

prospects, with the estimated ultimate recovery per shale gas well for undrilled wells assumed to be 50 percent higher than the Reference Scenario.

3) LEUR Scenario: the Low Shale Estimated Ultimate Recovery (LEUR) Scenario reflects a less optimistic assumption about U.S. natural gas supply prospects, with the estimated ultimate recovery per shale gas well for undrilled wells assumed to be 50 percent lower than the Reference Scenario.

These are the three scenarios which will be tested for the Demand Shock Case.

Finally the LNG export quota trajectories starting in 2015 must be considered. The rate at which LNG is exported can be either 'Low' at 6 Bcf/d or 'High' at 12 Bcf/d (NERA 26). The rate at which LNG exports accelerate to 'Low' or 'High' can be either 'Slow' where it is phased in at a rate of 1 Bcf/d per year or 'Rapid' where it is phased in at a rate of 3 Bcf/d per year (NERA 26). This gives a total of four possible combinations of the velocity and acceleration of the export quota trajectory.

1) Low/Slow ('LS'): 6 Bcf/d, phased in at a rate of 1 Bcf/d per year.

2) Low/Rapid ('LR'): 6 Bcf/d phased in at a rate of 3 Bcf/d per year.

3) High/Slow ('HS'): 12 Bcf/d phased in at a rate of 1 Bcf/d per year.

4) High/Rapid ('HR'): 12 Bcf/d phased in at a rate of 3 Bcf/d per year.

For this analysis, we will consider only the (2) 'Low/Rapid' and (4)'High/Rapid' trajectories. Because of redundancy in values and a smaller impact on the percentage change in quantity demanded of LNG, we will disregard the 'Low/Slow' and 'High/Slow' trajectories. This gives us a total of 6 possible outcomes for the 1 Case, 3 Scenarios, and 2 Trajectories (see APPENDIX J).

Some of the values from this tabular data were bound by upper limits. Though they are theoretically possible, the U.S. LNG export capacity binds when the optimal level of exports as determined by the model exceeds the LNG export capacity level (NERA 39). Values bound by upper limits will appear purple in the table (see APPENDIX G and APPENDIX H).

CHAPTER THREE

Results and Implications of the Price Forecasting Model

As theory would predict, the world price of LNG decreases while the U.S. domestic price of LNG increases. In the Reference Scenario, there is no difference between the Low/Rapid and High/Rapid trajectories for U.S. LNG exports (see APPENDIX E and APPENDIX F). The changes in world and U.S. price are identical in both cases so we can consider the Reference Scenario as a whole regardless of export trajectory. The largest decrease in world price occurs in 2015, which is the soonest predicted change in our model. The decreases then fluctuate between the initial 7.53% decrease in 2015 and the final 4.06% decrease in 2035. Because there are still many major exporters of LNG in the world market, the impact of U.S. exports on world prices is not as large as the impact on domestic prices.

U.S. LNG prices would increase by 11.29% in 2015 and the highest increase would be observed in 2025 with a 13.56% increase. These price increases are larger than the world price decreases and would have a material effect on the U.S. economy. Historically, the U.S. natural gas wellhead price has been steadily decreasing since 1986, but then began to rise greatly leading up to the 2008 global financial crises (EIA Natural Gas). After 2008 the price of LNG imports plummeted and has been decreasing back down to historic lows (EIA Natural Gas). If the U.S. were to begin exporting LNG into the global market, the domestic natural gas wellhead price would increase at around 10% every five years, with other factors held constant. This would be greatly beneficial for

U.S. natural gas producers (Texas, Louisiana, Wyoming, Oklahoma, and Colorado), but detrimental to U.S. households, industries, and other states that use natural gas as an input factor.

As for the High Shale Estimated Ultimate Recovery Scenario (HEUR), there are noticeable differences between the Low/Rapid and High/Rapid trajectories. Almost all of the world price decreases were greater than in the Reference Scenario. However, almost all of the U.S. price increases were smaller than in the Reference Scenario. This comes from changing the quantity supplied in the U.S. market under the HEUR Scenario, which has a mitigating effect on the U.S. price increase from LNG exports. As for the world market, because even more LNG is being exported, the supply is greater and hence the price decrease is even greater than the Reference Scenario.

For the Low/Rapid trajectory, the world price decreases are slightly larger than the Reference Scenario, varying from about 4.3% to 7.2%. The greatest world price decrease occurs in 2025 at 13.20%. From 2025 to 2035 they then gradually decrease from about 13% to 8.5%. The largest value is observed in 2025 probably because it will take some time for long term LNG contracts to be formed and the U.S. to tap into its newfound rapidly recovering natural gas reserves.

The U.S. price increases are smaller than the Reference Scenario. The highest value is again observed in 2025 at 13.56% in the High/Rapid trajectory, which is equivalent to the U.S. price increase in the same year in the Reference Scenario. Hence the U.S. price increases in the HEUR Scenario will always be less than or equal to the price increases in the Reference Scenario. The price increase by 2025 would be about 10% to 13.5% and by 2035 it would return to about 10%. Even though this is the

High/Rapid trajectory and hence the greatest price increases of the ameliorated HEUR Scenario, they are still substantial. The likelihood of the HEUR Scenario actually occurring, though, is difficult to predict. However, the HEUR scenario is still reasonable because there are binding restrictions on U.S. LNG exports based on production capacity. None of the Reference Scenario export values reached their upper bound, while all but one (2020 ΔQ HR) of the HEUR Scenario exports values had to be bounded by an upper limit (see APPENDIX G and APPENDIX H).

Finally in the HEUR Scenario with a High/Rapid trajectory there are remarkably larger price changes than the Reference Scenario. In this case we can see the amplifying effects of the HEUR Scenario on world prices. The world price of LNG would decrease by nearly 13% by 2020. The initial price change in 2015 would only be about 6.7%, which is actually a little less than the Reference Scenario value of about 7.5%. However where the Reference Scenario values gradually decrease for both the Low/Rapid and High/Rapid trajectories, HEUR Scenario values vary a lot in comparison. The price increases in the HEUR Scenario with the Low/Rapid trajectory are remarkably smaller than the Reference Scenario. In this situation, price increases start rather high at 11.29% in 2015, but then never go above 6.78% for the next 20 years. This situation would represent the most optimal scenario and trajectory for the U.S. and Japan because the U.S. price increase would be the smallest and the world price increase would be the largest.

In the Low Shale Estimated Ultimate Recovery Scenario, the supply of U.S. natural gas is more costly and thus there are no U.S. LNG exports in the Demand Shock Scenario (NERA 41). Hence the LEUR Scenario was omitted from the calculation and we only considered the Reference and HEUR Scenarios.

We will use the Consumer Price Index (CPI) to guide our consideration of the implications of these price fluctuations. According to the Organisation for Economic Cooperation and Development, 7.8% of Japan's Consumer Price Index is composed of energy expenditures in 2012 (OECD). Energy expenditures have remained at 7.8% since 2010 and were at 7.3% from 2005 to 2009 (see APPENDIX I) (OECD). Energy is a fairly large component of Japan's CPI relative to other components. If Japan were to switch completely from nuclear power and substitute with cheaper LNG imports from the U.S., then the energy component of Japan's CPI could increase even more. This would also make Japan's endeavor to end domestic nuclear power use much more feasible.

At the current level of energy expenditure, Japan's CPI would drop by .59% as a result of a 7.53% decrease in the world price of LNG. That means that by 2015, Japan's CPI could drop by roughly .60% as a result of the U.S. exporting LNG (assuming Reference Scenario). This would be the lower bound of Japan's CPI decreasing, because other factors still exist and could influence a change in Japan's CPI. The maximum effect a drop in world LNG prices could have on Japan's CPI would be in the HEUR Scenario with the high recovery trajectory by 2025. The lower bound of the decrease would be 1.03%, which is rather sizable for a fluctuation in a country's CPI.

In comparison, energy consumption is 9.7% of U.S. CPI in 2012 and has been steadily increasing from 7.6% in 2008 (see APPENDIX I) (OECD). U.S. consumers use more energy than Japanese consumers because it is more abundant and cheaper, but given the potential increases in U.S. domestic natural gas prices, there could be a significant decrease in U.S. energy consumption.

At the current level of energy expenditure, the U.S.'s CPI would increase by as much as roughly 1.1% as a result of an 11.29% increase in the U.S. price of LNG by 2015 assuming the Reference Scenario. This is fairly sizable and would certainly create political turmoil if taxpayers had to take on this increased energy cost while U.S. natural gas firms enjoy the benefits of trade. In the most extreme case, the U.S. CPI would increase by up to 1.32% as a result of the increase in U.S. LNG price in the Reference Scenario with the high recovery trajectory by 2025. This would most certainly get the attention of taxpayers in firms and households and would most likely prompt some kind of adjustment from the government. But because this is the maximum effect an increase in U.S. LNG prices can have on the CPI if all other things are held equal, it is difficult to predict what the changes could actually be.

CHAPTER FOUR

Conclusion

Overall Japan would benefit from the U.S. exporting LNG and remarkably the U.S. would also benefit. The resulting price changes from removing the ban on LNG exports are consistent with what economic theory would predict. This same economic theory predicts that the removal of a trade barrier would decrease the dead weight loss resulting from the trade barrier. There would be an increase in the consumer surplus in the importing Japanese market and an increase in the producer surplus in the exporting U.S. market. This would be a more efficient outcome where both parties could benefit. The benefits that come from export expansion more than outweigh the losses from reduced capital and wage income to U.S. consumers, thus exporting LNG would have a net economic benefit despite the higher domestic natural gas prices (NERA 1). Because the gains of trade in this case would be concentrated in the natural gas industry, the U.S. government may consider redistributing these gains for the sake of making the decision to allow LNG exports more politically popular. Perhaps the gains from trade could be taxed and transferred to other parts of the economy for a more equitable outcome.

Given the potential benefits of the U.S. exporting LNG, abolishing the Department of Energy restrictions on LNG exports could be beneficial to the U.S. and major LNG importers. The U.S. has a comparative advantage in producing relatively capital-intensive goods because of its large capital stock. Based on the Heckscher-Ohlin theory, the U.S. should be exporting capital-intensive goods such as LNG. Doing so could help bring the U.S. balance of payments closer to equilibrium and possibly help reduce the trade deficit. The U.S. would be exporting on the world market, and so Japan would not be the only possible trading partner. The U.S. could also export to South Korea, the United Kingdom, Spain, and even possibly China and India, all of which are major importers of LNG.

Abolishing the DOE restrictions on LNG exports could also help Japan. Lower energy prices would help the Japanese economy recover in light of the relatively recent earthquake and tsunami on March 11th, 2011. Lower energy costs would also help the reconstruction efforts in northeastern Japan which are still underway and are not scheduled to end for at least another 5 years. Lower energy prices could also stimulate certain industries in Japan which could in turn help boost the Japanese economy out of its 20 year recession. Because Japan exports many high-technology manufactured products to the U.S., stimulating the Japanese economy with lower energy prices could have positive feedback effects for the U.S.

Further research could examine the actual likelihood of the Demand Shock Case used in this analysis occurring or the potential impact of U.S. exporting LNG on other countries. Game theoretic approaches could consider how other countries would respond by the U.S. entering the world LNG export market. Regression analysis could include finding the relationship between LNG production and technological advancement, export restrictions and economic growth, or LNG imports and heating costs for firms and households.

APPENDICES

APPENDIX A

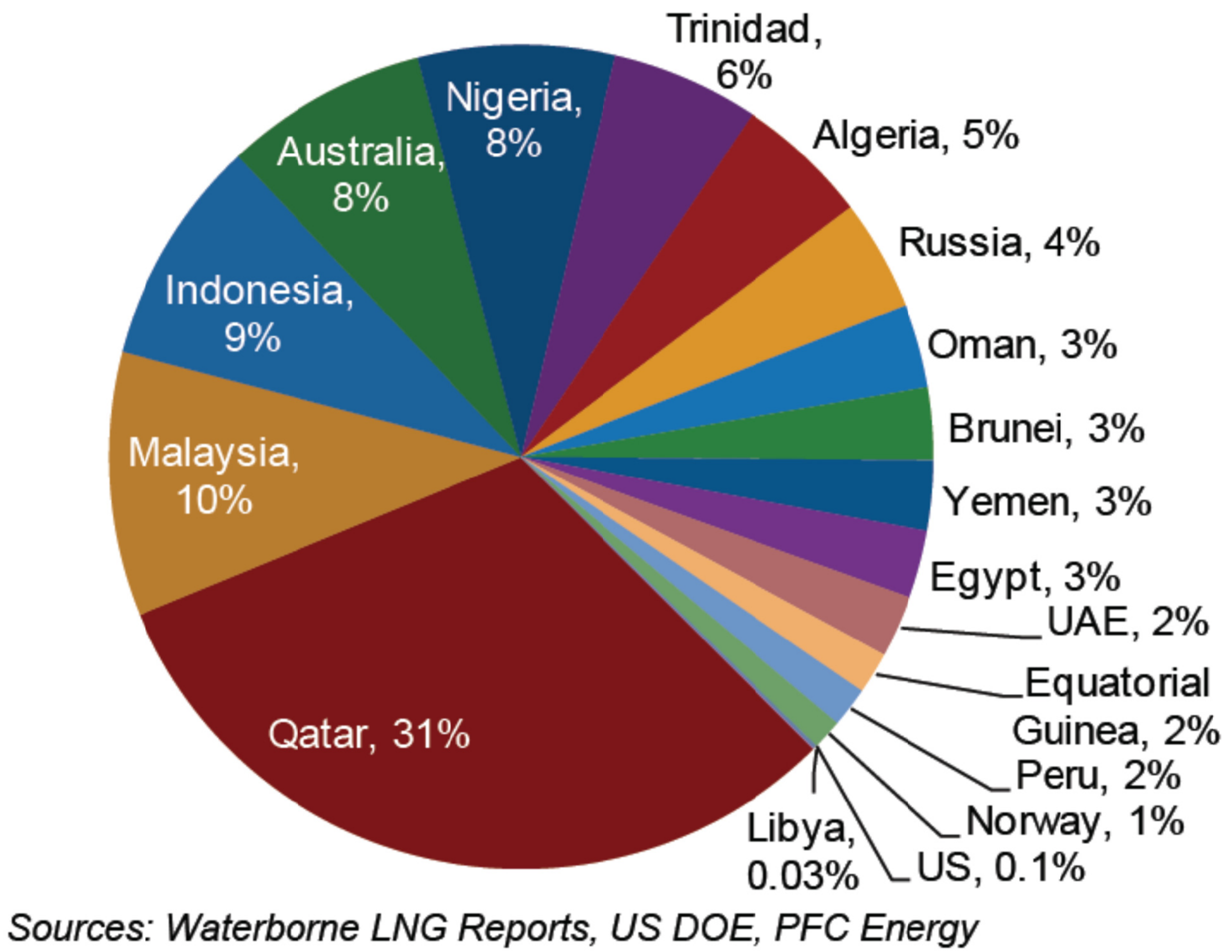
EIA Annual Energy Outlook 2011 Assumptions

1) Current laws remain unchanged.
2) Increased estimates for U.S. shale gas resources drive increased U.S. production, lower prices, and lower imports of natural gas.
3) Industrial natural gas demand recovers, reversing recent trend
4) Non-hydro renewable and natural gas are the fastest growing electricity generation sources, but coal remains the dominant fuel because of the large amount of existing capacity.
5) Oil imports fall due to increased domestic production – including biofuels –and greater fuel efficiency
6) U.S. carbon dioxide emissions rise slowly, but do not pass 2005 levels again until 2027

Source: http://www.eia.gov/neic/speeches/newell_12162010.pdf

APPENDIX B

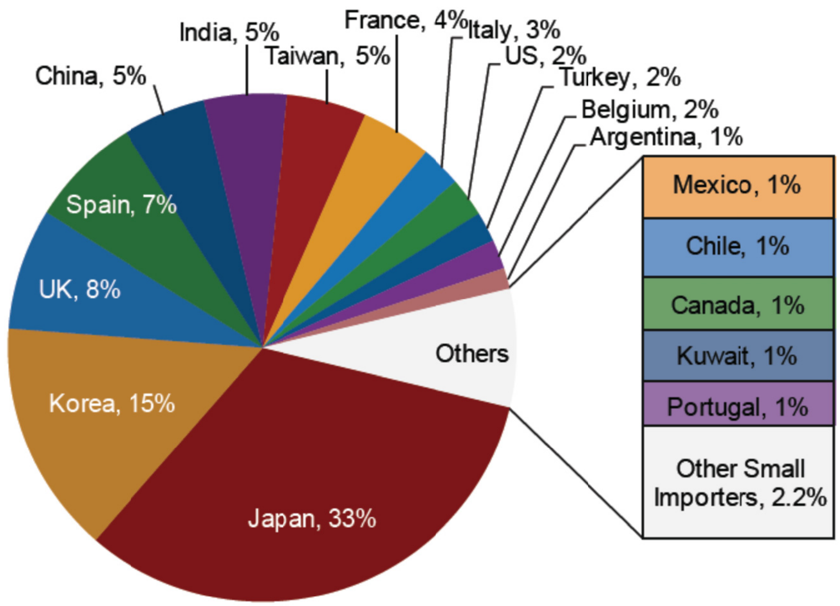
World LNG Exporters by Country, 2011



Source: http://www.igu.org/gas-knowhow/publications/igu-publications/LNG%20Report%202011.pdf

APPENDIX C

World LNG Importers by Country, 2011



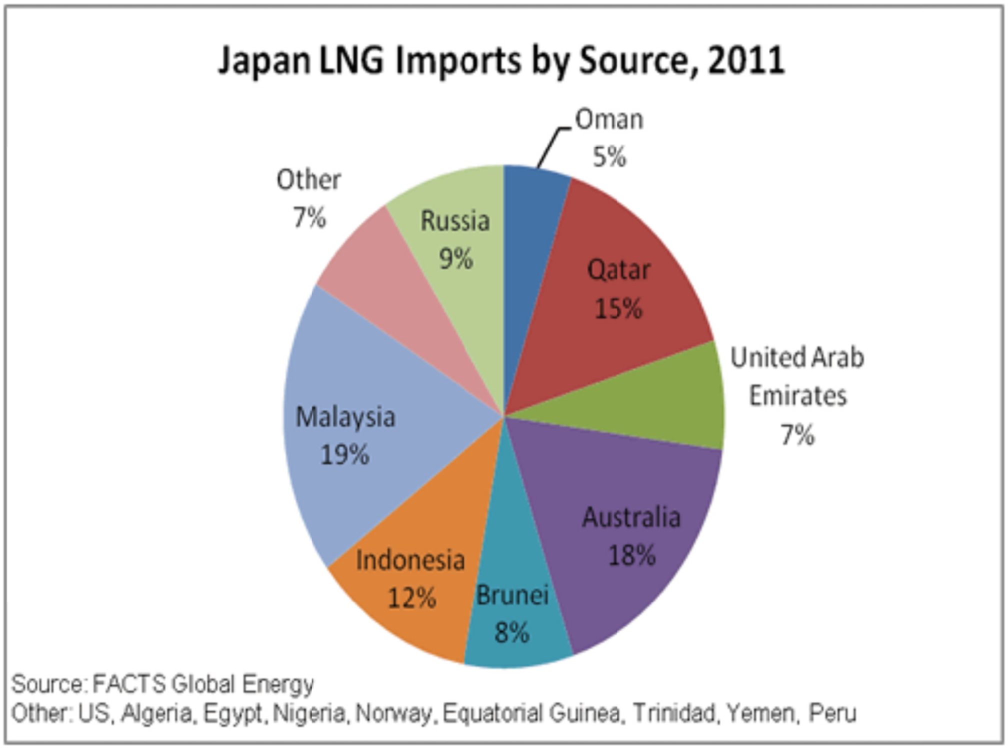
**"Small Importers" includes imports to the United Arab Emirates (Dubai), Greece, the Dominican Republic, Thailand, Brazil, the Netherlands and Puerto Rico. Each of these countries imported less than 1% of global LNG volumes in 2011.*

Sources: Waterborne LNG Reports, US DOE, PFC Energy

Source: http://www.igu.org/gas-knowhow/publications/igu-publications/LNG%20Report%202011.pdf

APPENDIX D

Japan LNG Imports by Source, 2011



Source: http://www.eia.gov/cabs/Japan/pdf.pdf

APPENDIX E

Reference Scenario Table World

World	2010	2015	2020	2025	2030	2035
ΔQLR	-	1.020	0.980	1.430	1.190	1.370
ΔQHR	-	1.020	0.980	1.430	1.190	1.370
Q	112.900	123.100	133.200	144.400	157.000	168.700
ε	-0.100	-0.110	-0.130	-0.150	-0.170	-0.200
ΔQLR/Q	-	0.008286	0.007357	0.009903	0.00758	0.008121
ΔQHR/Q	-	0.008286	0.007357	0.009903	0.00758	0.008121
ΔP/P (LR)	-	-7.53%	-5.66%	-6.60%	-4.46%	-4.06%
ΔP/P (HR)	-	-7.53%	-5.66%	-6.60%	-4.46%	-4.06%

APPENDIX F

Reference Scenario Table U.S.

U.S.	2010	2015	2020	2025	2030	2035
ΔQLR	-	-1.020	-0.980	-1.430	-1.190	-1.370
ΔQHR	-	-1.020	-0.980	-1.430	-1.190	-1.370
Q	23.800	25.100	25.300	25.100	25.900	26.500
ε	-0.330	-0.360	-0.390	-0.420	-0.460	-0.500
		-	-	-	-	-
ΔQLR/Q	-	0.040637	0.038735	0.056972	0.045946	0.051698
		-	-	-	-	-
ΔQHR/Q	-	0.040637	0.038735	0.056972	0.045946	0.051698
ΔP/P (LR)	-	11.29%	9.93%	13.56%	9.99%	10.34%
ΔP/P (HR)	-	11.29%	9.93%	13.56%	9.99%	10.34%

APPENDIX G

HEUR Scenario World

World	2010	2015	2020	2025	2030	2035
ΔQLR	-	1.100	2.190	2.190	2.190	2.190
ΔQHR	-	1.100	3.940	4.380	4.380	4.380
Q	112.900	150.169	234.916	221.280	252.329	253.423
ε	-0.100	-0.110	-0.130	-0.150	-0.170	-0.200
ΔQLR/Q	-	0.00733	0.00932	0.0099	0.00868	0.00864
ΔQHR/Q	-	0.00733	0.01677	0.01979	0.01736	0.01728
ΔP/P (LR)	-	-6.66%	-7.17%	-6.60%	-5.11%	-4.32%
ΔP/P (HR)	-	-6.66%	-12.90%	-13.20%	-10.21%	-8.64%

APPENDIX H

HEUR Scenario U.S.

U.S.	2010	2015	2020	2025	2030	2035
ΔQLR	-	-1.100	-2.190	-2.190	-2.190	-2.190
ΔQHR	-	-1.100	-3.940	-4.380	-4.380	-4.380
Q	23.800	27.069	101.716	76.880	95.329	84.723
ε	-0.330	-0.360	-0.390	-0.420	-0.460	-0.500
ΔQLR/Q	-	-0.040637	-0.02153	-0.028486	-0.022973	-0.025849
ΔQHR/Q	-	-0.040637	-0.038735	-0.056972	-0.045946	-0.051698
ΔP/P (LR)	-	11.29%	5.52%	6.78%	4.99%	5.17%
ΔP/P (HR)	-	11.29%	9.93%	13.56%	9.99%	10.34%

APPENDIX I

Energy Consumption Component of CPI as a Percentage of Total Expenditures

	1998	1999	2000	2001	2002	2003	2004	2005
Japan	6.5%	6.5%	6.8%	6.8%	6.8%	6.8%	6.8%	7.3%
U.S.	6.3%	7.0%	7.7%	6.6%	6.7%	7.1%	8.0%	9.1%

	2006	2007	2008	2009	2010	2011	2012
Japan	7.3%	7.3%	7.3%	7.3%	7.8%	7.8%	7.8%
U.S.	8.7%	9.8%	7.6%	8.6%	9.1%	9.4%	9.7%

Source: http://stats.oecd.org/Index.aspx?DataSetCode=MEI_CPI_WEIGHTS

Maximum Potential Impact on Japanese CPI

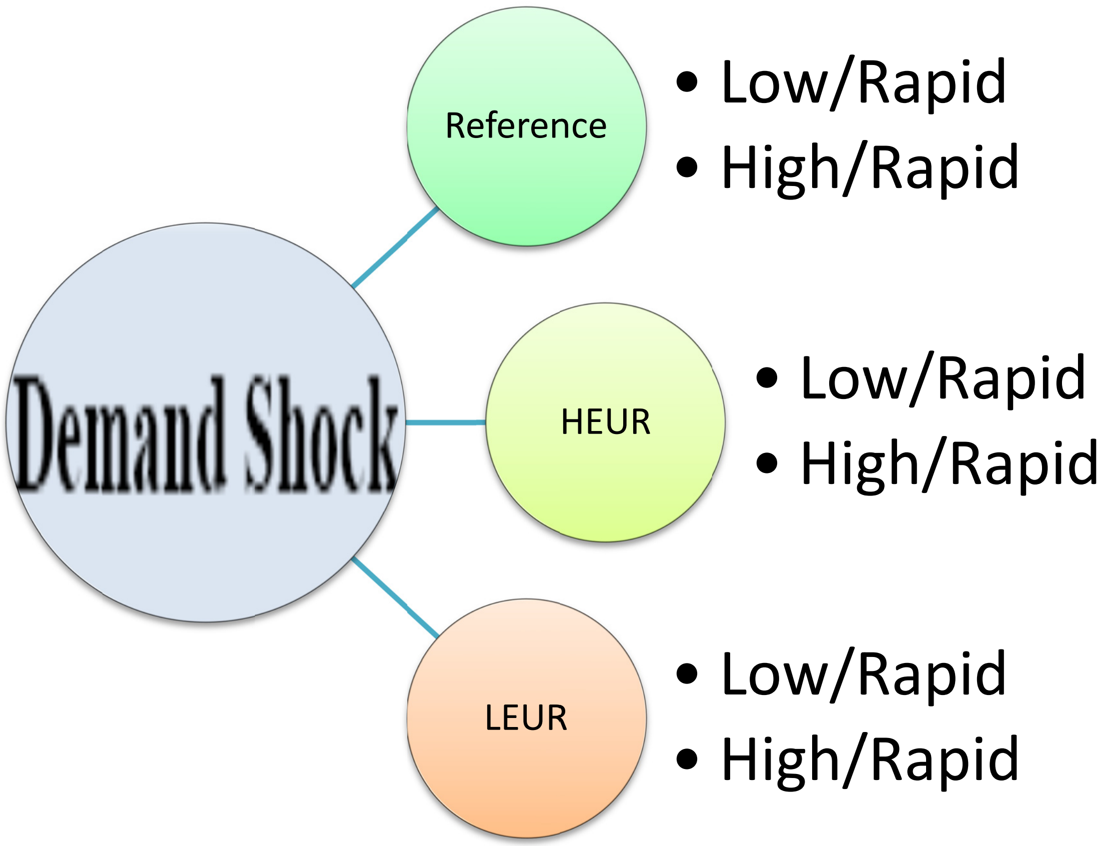
Japan	2015	2020	2025	2030	2035
Ref. HR/LR	-0.59%	-0.44%	-0.51%	-0.35%	-0.32%
HEUR LR	-0.52%	-0.56%	-0.51%	-0.40%	-0.34%
HEUR HR	-0.52%	-1.01%	-1.03%	-0.80%	-0.67%

Maximum Potential Impact on U.S. CPI

U.S.	2015	2020	2025	2030	2035
Ref. HR/LR	1.09%	0.96%	1.32%	0.97%	1.00%
HEUR LR	1.09%	0.54%	0.66%	0.48%	0.50%
HEUR HR	1.09%	0.96%	1.32%	0.97%	1.00%

APPENDIX J

Diagram of Total Cases, Scenarios, and Trajectories



REFERENCES

Customs and Tariff Bureau of Japan. *Japan's Tariff Schedule Section V Chapter 27: Mineral Products.* 1 January 2011. <*http://www.customs.go.jp/english/tariff/2011/data/i201101e_27.htm*>

Ebinger, C., Massy, K., & Avasarala, G. *Evaluating the Prospects for Increased Exports of Liquefied Natural Gas from the United States.* Energy Security Initiative at the Brookings Institute. January 2012. <http://www.brookings.edu/~/media/research/files/papers/2012/1/natural%20gas%20ebinger/natural_gas_ebinger_2.pdf>

Energy Information Administration. *Country Analysis Briefs: Japan*. 4 June 2012. <*http://www.eia.gov/cabs/Japan/pdf.pdf*>

Energy Information Administration. *Frequently Asked Questions. 2012.* <http://www.eia.gov/tools/faqs/faq.cfm?id=46&t=8>

Energy Information Administration. *Natural Gas Explained: Factors Affecting Natural Gas Prices.* 29 June 2012. <http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_factors_affecting_prices>

Energy Information Administration. *Table F19: Natural Gas Consumption Estimates.* 2011.< http://www.eia.gov/state/seds/sep_fuel/html/pdf/fuel_use_ng.pdf>

Energy Information Administration. *U.S. Natural Gas Wellhead Price.* 28 February 2013. <http://www.eia.gov/dnav/ng/hist/n9190us3m.htm>

Federation of Electric Power Companies of Japan. *Japan's Energy Supply Situation and Basic Policy.* 2013. <http://www.fepc.or.jp/english/energy_electricity/supply_situation/>

Global Trade International Trade Resources. *Japan Import Tariffs.* 6 January 2010. <http://www.globaltrade.net/international-trade-import-exports/f/business/text/Japan/Trade-Policy-Japan-Import-Tariffs.html>

International Gas Union. *World LNG Report 2011.* 2011. <http://www.igu.org/gas-knowhow/publications/igu-publications/LNG%20Report%202011.pdf>

Ito, Takatoshi. *The Japanese Economy.* Cambridge, MA: The MIT Press, 1992. Print.

Loris, N. *U.S. Natural Gas Exports: Lift Restrictions and Empower the States.* The Heritage Foundation. 11 February 2013. <http://www.heritage.org/research/reports/2013/02/us-natural-gas-exports-lift-restrictions-and-empower-the-states>

National Economic Research Associates. *Macroeconomic Impacts of LNG Exports from the United States.* 3 December 2012. <http://www.fossil.energy.gov/programs/gasregulation/reports/nera_lng_report.pdf>

NaturalGas.org. *Resources: U.S. Natural Gas Resource Estimates.* 2011 <http://www.naturalgas.org/overview/resources.asp>

Okada, Y. & Hong, C. H. "Japan to start world's first LNG futures within two years." *Financial Post*. 01 April 2013. <http://business.financialpost.com/2013/04/01/japan-to-start-worlds-first-lng-futures-within-two-years/>

Organisation for Economic Cooperation and Development. *National CPI Weights.* 2013. <http://stats.oecd.org/Index.aspx?DataSetCode=MEI_CPI_WEIGHTS>