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# Obstacles to International Trade in Natural Gas

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## Abstract

Obstacles to international trade in natural gas include factors such as transportation costs, non-competitive pricing, thin markets, risk, restrictive contracts, and government trade restraints. These obstacles are currently quite substantial, however, there is evidence that they are loosening. This paper estimates the impact that these obstacles have on trade and what the effect of eliminating them would be. This is accomplished by comparing actual natural gas trade to an econometrically-estimated counterfactual case where there are no obstacles to trade. Our model estimates that the volume of international trade in natural gas would slightly more than double if these obstacles did not exist. Current natural gas net exporting countries would greatly reduce domestic consumption. By contrast consumption would increase slightly in countries with no current natural gas consumption. However, the bulk of the consumption increases would occur in large economies that currently have to import most of their natural gas.

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United States International Trade Commission

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# Table of Contents



## Figures



## Tables

# Introduction

Natural gas is traded internationally, but this trade is constrained by many obstacles. Transporting natural gas requires the construction of specialized pipelines or port facilities costing billions of dollars. In addition to these transportation costs, natural gas trade faces substantial obstacles in the form of non-competitive pricing, thin markets,[1] risk, restrictive contracts, and government trade policies. As a result, the global natural gas market is regionally segmented: in 2014, 74 percent of natural gas was consumed in the same country where it was produced.[2] Because of this segmentation, there are large differences in gas prices across regions, as regions that import their gas pay the costs the obstacles impose. For example, in 2014 the average price of natural gas was $16/MMBtu in Japan and $9 in Europe (regions that import all or most of their gas), but only $4 in the United States (which has very large domestic production).[3]

However, some of these obstacles to international trade may be weakening. Competitive practices in natural gas markets are becoming more widespread: in 2005, 31 percent of the natural gas consumed worldwide had its price set in competitive wholesale markets, but this increased to 43 percent in 2014.[4] In addition, natural gas markets are thickening, reducing transaction costs.

Distant regions can trade natural gas by converting it into liquefied natural gas (LNG), and the volume of LNG trade increased by more than 50 percent between 2006 and 2014.[5] From 2000 to 2014, the number of countries exporting LNG increased from 6 to 26, while spot and short-term contracts have increased from 5 percent of total LNG trade to 27 percent.[6] Furthermore, increased natural gas production from competitive North American markets is likely to reinforce both of these trends.

One can easily predict that these trends will increase international natural gas trade, but how large is this potential expansion? And how much of it will consist of currently-consuming countries expanding their natural gas consumption, as opposed to the creation of new national markets? This paper answers these questions by developing an econometric model of world natural gas consumption and using it to conduct a counterfactual analysis of what world natural

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[1] Thin markets are those with few transactions. Thick markets have many transactions. Perfectly competitive markets have infinite thickness. Market thickness is important because thin markets increase transaction costs.
[2] International Gas Union, *Wholesale Gas Price Survey - 2015*, 14–15.
[3] BP, *BP Statistical Review of World Energy 2015*, 27.
[4] International Gas Union, *Wholesale Gas Price Survey - 2015*, 26.
[5] BP, *BP Statistical Review of World Energy 2007*; BP, *BP Statistical Review of World Energy 2015*.
[6] International Gas Union, *World LNG Report 2015 Edition*, 15.

gas trade would look like if all obstacles to international natural gas trade were removed. By comparing this counterfactual scenario to actual natural gas trade (where trade costs do in fact exist), this paper can estimate the impact that these obstacles have on natural gas trade.

Our model estimates that the volume of international trade in natural gas would slightly more than double if all obstacles to trade were eliminated. The extra exports come from current natural gas net exporters reducing their share of world consumption from 34.1 percent to 21.6 percent. Consumption would increase slightly in countries with no current natural gas consumption, rising from 0 to 2.0 percent of world consumption. However, the bulk of the consumption increase would occur in large economies that already have to import most of their natural gas. Their share of world gas consumption increases from 64.4 to 72.2 percent. In terms of specific countries, the countries with the largest increase in net exports are the United States (up 8,250 billion cubic feet (bcf)), Russia (7,872 bcf), and Iran (4,600 bcf), and the countries with the largest increase in net imports are China (10,466 bcf), Japan (2,190 bcf), and Germany (2,170 bcf). Several countries shift from net importer of natural gas to net exporter, including Argentina, Kuwait, Mexico, Thailand, Ukraine, the United Arab Emirates, the United States, and Venezuela. On the other hand, Colombia, Denmark, and Kazakhstan shift from being a net exporter to a net importer.

Our paper is organized into five sections. Section 2 provides background information on international trade in natural gas. It contains an overview of natural gas trade flows, discusses the law of one price, describes the main obstacles to natural gas trade, and then explains how these obstacles are weakening. Section 3 presents the data sources and description of the model that is used to estimate the potential expansion of natural gas trade if all constraints were removed. Section 4 reports our results, the econometric estimates of model parameters and simulation estimates of unconstrained trade flows. Section 5 provides concluding remarks.

# Background Information

## Overview

Commerce in natural gas has both domestic and international aspects. In 2014, 74 percent of natural gas was consumed in the same country where it was produced, 17 percent was exported via pipelines, and 9 percent was exported via LNG.[7] [8] Major international natural gas flows include pipeline exports from Russia to Europe, LNG exports from the Middle East to Europe and Asia, and LNG trade between Asian countries.

Each of these regional markets is unique. North America is an extremely integrated and competitive region, with 99 percent of the gas consumed there sold in competitive wholesale markets.[9] However, North America does not trade much with other regions: although it consumed 949 billion cubic meters (bcm) of natural gas, North America imported only 11.6 bcm of natural gas from other regions and exported only 0.4 bcm.[10] Much of the European market is similarly integrated,[11] but outside of the United Kingdom, its natural gas markets are less competitive. In the European Union in 2013, each country's largest gas importer had on average 65.6 percent of the domestic market.[12] In East Asia, gas import markets are also frequently dominated by a few organizations,[13] and vertically integrated state-owned companies own 79 percent of the LNG terminals in operation, under construction, or planned through 2017.[14] In the rest of the world, natural gas markets are highly fragmented and there are substantial obstacles to natural gas trade between countries.[15] Nevertheless, throughout the world, most consuming countries are supplied with natural gas by several different source countries.[16]

[7] International Gas Union, *Wholesale Gas Price Survey - 2015*, 14–15.
[8] Natural gas is liquefied as part of the process of transporting it overseas by tanker. In this process, the natural gas is first transported via pipeline to a specialized export facility. At the facility, the natural gas is cooled until it turns into a liquid (LNG) and then loaded onto a specialized tanker ship. The ship travels to the destination port where there is another specialized facility capable of converting the LNG back to a gas. The gas is then transported to consumers via the destination country's pipeline network.
[9] International Gas Union, *Wholesale Gas Price Survey - 2015,* 17.
[10] BP, *BP Statistical Review of World Energy 2015*, 23, 28.
[11] International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities," 46.
[12] Eurostat, "Natural Gas Market Indicators."
[13] International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities," 31.
[14] Ibid., 29.
[15] International Gas Union, *World LNG Report 2015 Edition*, 16.
[16] A notable exception would be Eastern European countries that are dependent on the Russian state-controlled natural gas company Gazprom for almost all of their gas.

# The Law of One Price

The Law of One Price provides a useful framework for examining the impact of the various trade obstacles. Essentially, the more trade obstacles there are in a region, the larger the price difference can be between that region and the rest of the world. More formally, the Law of One Price is an arbitrage condition that describes the pricing at different geographic locations of an (otherwise) identical good. It says that in a competitive market with no transportation costs or obstacles to the movement of goods, arbitrage will cause the prices of the commodity at different locations to converge over time.[17] The crude oil market provides an excellent example of this, as the market is competitive, there are few obstacles to oil movement, and transportation costs are very low. As shown in Figure 1, shocks may move the price of oil up or down but the prices in all locations move together.[18]

However, when the assumptions underlying the Law of One Price are not satisfied, the price of a single commodity can vary greatly depending on its location. This is the case in natural gas markets: natural gas has a very different price depending on whether it is sold in the United Kingdom, the United States, or Japan, and these price differentials are persistent over time (see Figure 2).[19] This occurs because trade obstacles are large in natural gas markets and if they impose costs that are larger than the price differentials between two regions, arbitrage between the regions is uneconomical and their prices can become uncorrelated.

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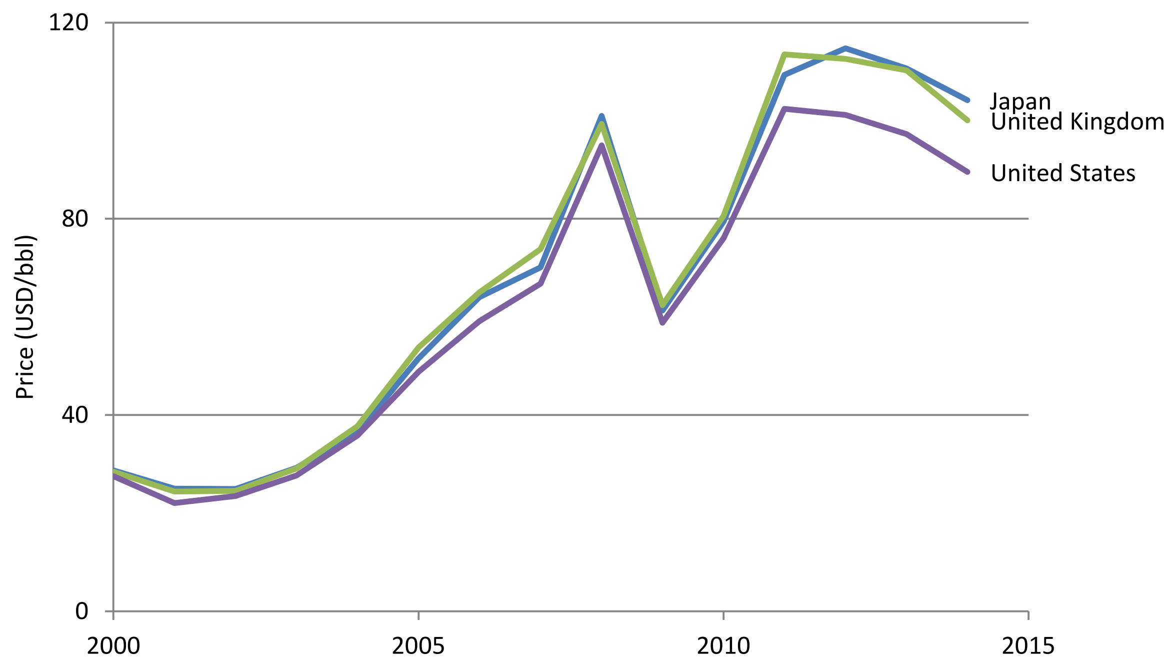
[17] Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 46–47.

[18] One exception is the disconnect between U.S. and foreign crude oil prices after 2010. For a detailed explanation see Barbe, *Emerging International Trade Issues for Fossil Fuels*.

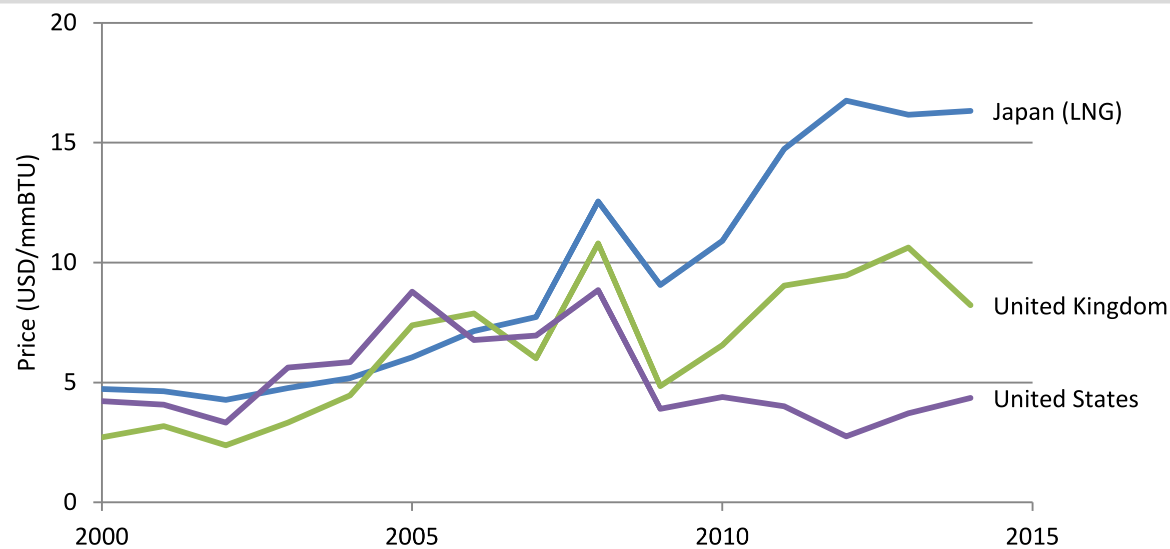
[19] Statistical analysis has rejected the Law of One Price in the international natural gas market. See Siliverstovs et al., “International Market Integration for Natural Gas? A Cointegration Analysis of Prices in Europe, North America and Japan”; Neumann, “Linking Natural Gas Markets - Is LNG Doing Its Job?”; Li, Joyeux, and Ripple, “International Natural Gas Market Integration”; Geng, Ji, and Fan, “A Dynamic Analysis on Global Natural Gas Trade Network.”

**Figure 1:** Crude oil import prices in difference countries




Source: International Energy Agency, Energy Prices and Taxes: Quarterly Statistics: First Quarter 2015, 11. (See Appendix table B.1)

**Figure 2:** Natural gas prices in difference countries




Source: BP, BP Statistical Review of World Energy 2015. (See Appendix table B.2)

# Obstacles to International Natural Gas Trade

Natural gas prices have not converged because there are substantial impediments to trade at each stage in the supply chain: from acquiring natural gas, to transporting it to the destination country, to selling it in the destination country.[20] The six main obstacles to natural gas trade are transportation costs, non-competitive pricing, thin markets, risk, restrictive contracts, and government restraints.[21] This section describes each of these obstacles.

## Transportation Costs

Transportation costs are perhaps the largest obstacle to natural gas trade. International natural gas trade is costly on both the intensive (marginal costs) and extensive (fixed costs) margins.[22] Large fixed costs inhibit firms from entering the market and therefore can create market power. Marginal costs for LNG are also high, limiting arbitrage's ability to eliminate price differentials. Natural gas requires specialized infrastructure to transport: either pipelines for overland transportation or import and export terminals for transporting LNG overseas. In particular, the fixed costs of constructing LNG terminals and gas pipelines are high: an LNG import terminal constructed by Cheniere in Louisiana in 2008 cost $2 billion.[23] Medlock estimates that for hypothetical LNG exports from the low-price United States to high-price Japan during 2011–2020, transportation costs would comprise 56 percent of the landed cost.[24] And this is assuming that the arbitrage is technically feasible: there are significant technical compatibility challenges to matching LNG, tankers, and shore import facilities.[25]

## Non-competitive Pricing

Natural gas prices are determined by different methods in different markets. However, these pricing mechanisms can be broadly classified into competitive or non-competitive mechanisms, depending on whether prices are set by competitive markets or by bilateral agreements with

[20] For a detailed discussion on the obstacles to arbitrage of liquefied natural gas in particular, see Zhuravleva, *The Nature of LNG Arbitrage: An Analysis of the Main Barriers to the Growth of the Global LNG Arbitrage Market*.
[21] Many issues fall into more than one of these six areas.
[22] The extensive margin describes whether there is any trade at all or no trade. The intensive margin refers to changes in the level of existing trade.
[23] Helman, "How Cheniere Energy Got First In Line To Export America's Natural Gas."
[24] Medlock, *U.S. LNG Exports: Truth and Consequence*, 30.
[25] Zhuravleva, *The Nature of LNG Arbitrage: An Analysis of the Main Barriers to the Growth of the Global LNG Arbitrage Market*, 13.

few buyers and sellers, monopolies, or the government.[26] Non-competitive pricing can restrict trade by setting natural gas prices inefficiently high or low.[27] Both competitive and non-competitive pricing mechanisms are seen in different natural gas production, import, and wholesale markets, depending on their geographic region and also the stage of the supply chain (production, import, or wholesale) at which the transaction occurs. However, non-competitive pricing predominates. In 2014, competitive pricing set the price for 42.5 percent of the natural gas consumed worldwide.[28] Competitive pricing was the most common type of wholesale pricing for natural gas in North America (99 percent) and Europe (61 percent) in 2014, but it is rare in the rest of the world, where oil-index pricing or government regulated pricing is the norm.[29] The situation is similar regardless of the source of supply, as worldwide, competitive pricing is only used for 42 percent of both imports and production consumed domestically.[30] [31]

# Thin Markets

Many key natural gas markets are thin, which inhibits trade by increasing transaction costs. In particular, it can be hard to match buyers and sellers of LNG liquefaction capacity and pipeline capacity, and these problems are particularly severe in certain regions.

For LNG, the issue is that construction of an LNG export terminal begins only after a contract has been signed with a customer who will commit to buying the gas.[32] As a result, there is little excess liquefaction capacity. Although global liquefaction capacity utilization averaged only 83 percent from 2010 through 2014,[33] the unused capacity was typically due to military conflict, technical problems, or non-existence of natural gas for liquefaction. This means that it is very difficult for anyone to actually utilize this “excess” capacity.

The situation is similar for pipelines: they are only constructed in response to a long-term contract with a customer.[34] Although pipelines typically have greater excess capacity than LNG

[26] There is a substantial taxonomy dividing pricing mechanisms into various groups. The International Gas Union splits gas pricing into market and non-market mechanisms. Market pricing mechanisms can be further subdivided into one of four categories. These categories are: (1) gas-on-gas competition, where prices are indexed based on prices in competitive gas spot or future markets and on bilateral agreements in markets with many buyers and sellers (When we refer to “competitive pricing,” we mean this category), (2) netback from final product, where gas prices are linked to that of ammonia, (3) oil indexation, linking the price of gas to the price of oil, and (4) bilateral monopoly, where prices are decided in negotiations between a monopoly seller and a monopsony buyer. For more information, see International Gas Union, *Wholesale Gas Price Survey - 2015*, 26.
[27] Inefficiently high prices encourage imports and discourage exports. Inefficiently low prices do the opposite.
[28] International Gas Union, *Wholesale Gas Price Survey - 2015*, 26.
[29] Ibid., 17–20.
[30] Ibid., 16.
[31] Ibid., 14.
[32] Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 49–50.
[33] International Gas Union, *World LNG Report 2015 Edition*, 20.
[34] Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 49–50.

facilities, their origin and destination are fixed.[35] This means that if an arbitrager wants to export to a particular high price market, he is limited to exports from countries with extant pipeline connections to the market.

Markets may be thin to the point of non-existence in some regions. Many Asian countries with high natural gas prices cannot be reached by pipelines at all and can only be supplied via LNG. Other regions, like the Baltic states, have no LNG import facilities and pipeline connections only to a single supplier, making arbitrage impossible without the supplier's consent.[36]

# Risk

While the difficulty of acquiring supplies would hinder arbitrage in any market, this situation is especially problematic for natural gas due to the riskiness of arbitrage. When transporting the gas to the destination country, the minimum transaction size of LNG arbitrage is very large (a shipload of LNG) and it can take weeks for it to arrive at its destination.[37] Given the volatility of gas prices, it is possible for there to be a significant shift in relative prices while the gas is in transit, and the resulting loss is amplified by the size of the shipment. This means that arbitraging LNG is very risky, and under-developed risk management markets make it hard to insure against these risks.[38] This increases the price differential necessary for the risk-adjusted rate of return to provide a sufficient incentive to undertake the arbitrage. The problem is even greater for new natural gas pipelines, as instead of weeks, their approval and construction can take years.

# Restrictive Contracts

The fifth major constraint is the restrictive nature of many LNG contracts. Liquefied natural gas trade is primarily conducted through contracts that are long-term, contain take-or-pay clauses, and prohibit resale.[39] While some of these terms are responses to price and volume risk, the hold-up problem,[40] or energy security needs, they also can hinder competition.[41] [42] For

[35] Ibid.
[36] Ibid., 49.
[37] Ritz, "Price Discrimination and Limits to Arbitrage: An Analysis of Global LNG Markets," 330.
[38] Ibid.
[39] For a more detailed description of the structure of a typical LNG contract, see Leidos, *Global Natural Gas Markets Overview: A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 11.
[40] The holdup problem refers to how bargaining power between two agents can change after an investment is made. For example, a natural gas supplier might promise to sell gas at a low price in order to attract an investor to build an LNG plant near them. However, once the plant is built, the gas supplier now has an incentive to charge the plant a high price. For a detailed description of the holdup problem, see Krishna, "The Hold-up Problem."
[41] Dorigoni, Graziano, and Pontoni, "Can LNG Increase Competitiveness in the Natural Gas Market?"; Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 46.

example, take-or-pay clauses commit buyers to a minimum annual purchase. In European markets, this is typically 85 percent of the contracted quantity.[43] These clauses and the contract's long duration result in vendor lock-in. Similarly, resale prevention clauses directly prohibit arbitrage.[44]

## Government Restraints on Trade

Finally, governments impose a number of trade restraints on both the import and export side of natural gas markets. These may include direct restraints such as import or export tariffs, or indirect restraints that restrict third-party access to necessary infrastructure (for example, import and export terminals or pipelines).[45] [46] Furthermore, many wholesale markets are dominated by state-owned companies that themselves can limit access to infrastructure.[47]

# Trade Obstacles are Falling

While the constraints on international trade in natural gas are currently quite significant, they are less severe than they once were. In particular, competition in natural gas markets is increasing as competitive gas-on-gas pricing expands and LNG markets become thicker, and the emergence of U.S. supply onto world LNG markets will only reinforce this trend. New business models have been developed to help manage risk, and competition-restricting practices are diminishing because of increased use of short-term contracts and more flexible long-term contracts. The use of competitive pricing mechanisms is increasing in world gas markets. In 2005, 31 percent of the natural gas consumed worldwide had its price set by gas-on-gas competition in wholesale markets, but this increased to 43 percent in 2014.[48]

The thickness of LNG markets has also greatly increased over the last decade. The volume of LNG trade has increased by more than 50 percent from 2006 to 2014.[49] And this increase has occurred despite an increase in costs: average unit costs for LNG liquefaction plants rose from $321 per metric ton in 2000-2006 to $851 in 2007-2014.[50] [51] The number of countries

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[42] For a review of the factors that cause these contract terms, see von Hirschhausen and Neumann, "Long-Term Contracts and Asset Specificity Revisited: An Empirical Analysis of Producer-Importer Relations in the Natural Gas Industry."

[43] Rogers, *The Impact of a Globalising Market on Future European Gas Supply and Pricing: The Importance of Asian Demand and North American Supply*, 4.

[44] International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities," 69.

[45] Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 50.

[46] For further discussion of third-party access in particular countries, see International Energy Agency, *Natural Gas Information 2015*, VI.32, VI. 44; International Energy Agency, *Energy Policies of IEA Countries: The Republic of Korea 2012*, 27; Tang, "China's Natural Gas Imports and Prospects," 24.

[47] International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities," 29.

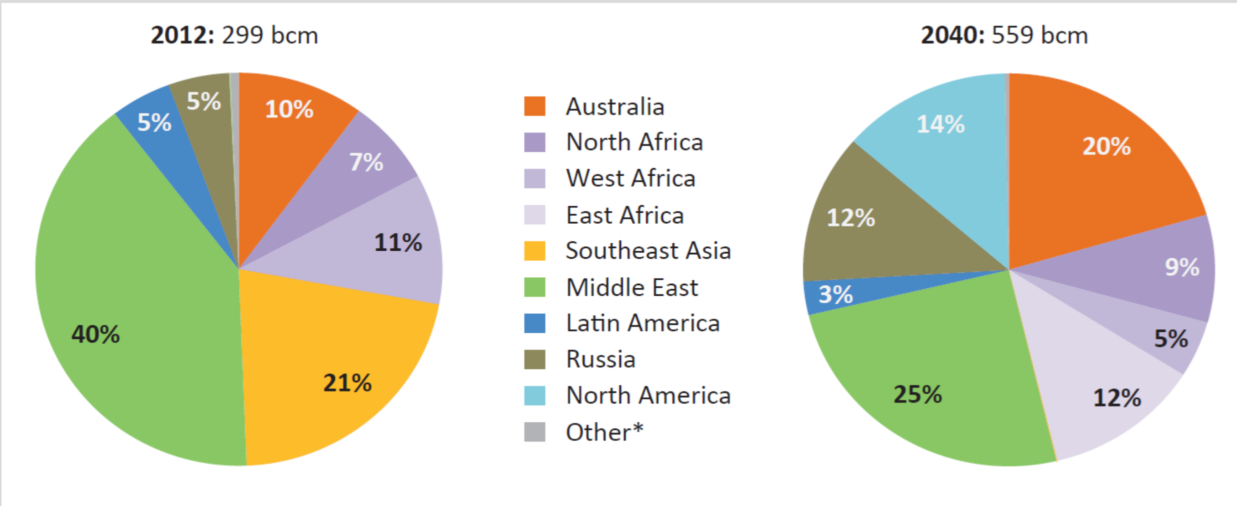
[48] International Gas Union, *Wholesale Gas Price Survey - 2015*, 26.

[49] BP, *BP Statistical Review of World Energy 2007*; BP, *BP Statistical Review of World Energy 2015*.

[50] International Gas Union, *World LNG Report 2015 Edition*.

participating in LNG trade has increased as well. In 2000, LNG spot markets had 6 exporters and 8 importers, but that increased to 26 exporters and 28 importers in 2014.[52] The International Energy Agency projects that LNG supply will diversify further as more countries begin exporting LNG outside of their region and the volume of that trade nearly doubles from 2012–2040 (see Figure 3).

**Figure 3:** Inter-regional LNG exports by source




Source: International Energy Agency, "World Energy Outlook 2014," 163.
Note: "Other" includes OECD Europe and Other Developing Asia.

Moving forward, expanding U.S. natural gas production and exports will increase the competitiveness of natural gas markets by increasing market thickness and promoting competition. U.S. natural gas production increased by 28 percent from 2008 to 2014, and was 20 percent of world gas production in 2013.[53] [54] The United States is forecast to begin net gas exports in 2017.[55] This will reduce the market share of other exporters. In particular, Russia's market share in natural gas for Western Europe (Europe excluding former Soviet Union countries) is projected to decline from 27 percent in 2009 to 13 percent by 2040.[56] Since North American gas is almost entirely priced via gas-to-gas competition in wholesale markets,[57]

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[51] For more discussion of possible capital costs increases for LNG plants, see International Energy Agency, "World Energy Investment Outlook," 73.
[52] International Gas Union, *World LNG Report 2015 Edition*, 15.
[53] Energy Information Administration, "Dry Natural Gas Production"; Energy Information Administration, "International Energy Statistics."
[54] However, in the short term, these large and unexpected natural gas production increases caused a divergence of natural gas prices between the United States and the rest of the world.
[55] Energy Information Administration, *Annual Energy Outlook 2015*, Data Table 13.
[56] Medlock, Jaffe, and Hartley, *Shale Gas and US National Security*, 13.
[57] International Gas Union, *Wholesale Gas Price Survey - 2015*, 17.

increasing North American exports will increase the volume and share of gas that is competitively priced. This will in turn reduce both the ability of incumbent exporters to markup price over costs and to impose contract terms that act as barriers to competition.
Risk and financing problems are also better handled by new business models. For example, in contrast to long-term contracts, LNG suppliers are now retaining a portion of their own production to sell where they choose, or selling it to third party aggregators who have a portfolio of different sources and destinations. Both cases allow the LNG to be resold under short or medium term contracts.[58] And in the United States, LNG export terminals under construction are not planning to directly sell the LNG they produce, but instead sell the option to use their liquefaction capacity.[59] This lowers capital costs by unbundling the financing of the liquefaction project from the destination or marketing arrangements for the LNG.

Changes in LNG contracting are also reducing their competition-restricting aspects and increasing market thickness. Spot and short-term contracts have increased from 5 percent of total LNG trade in 2000 to 27 percent in 2014,[60] and their prevalence is predicted to continue to increase.[61] Nonetheless, there is a glut of tankers and ongoing shipbuilding is expected to further increase oversupply until at least 2017, when Australian and U.S. exports are forecast to ramp up.[62] Both of these situations lead to a thicker LNG market which, when combined with importer demand for shorter contract durations, further lowers the barriers to entry for LNG traders.[63] In addition to the increased prevalence of short-term contracts, long-term contracts are becoming more flexible in terms of their destination, quantities purchased, pricing, and price review provisions.[64] This flexibility has allowed Middle East gas headed to Europe to instead be diverted to the currently much higher priced Asian-Pacific countries.[65]

While these trends are leading towards convergence in natural gas prices, it may still be many years before the Law of One Price holds in natural gas.[66] For example, the International Energy Agency predicts that the price of Japanese natural gas will fall from 4.4 times the U.S. price in 2013 but still be 1.9 times the U.S. price by 2040.[67] Market liberalization (which is only a part of

[58] Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 12.
[59] International Energy Agency, "World Energy Investment Outlook," 73.
[60] International Gas Union, *World LNG Report 2015 Edition*, 15.
[61] Hartley, *The Future of Long-Term LNG Contracts*, 6.
[62] International Gas Union, *World LNG Report 2015 Edition*, 42.
[63] Ibid., 46.
[64] Hartley, *The Future of Long-Term LNG Contracts*, 7; International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities," 70; Leidos, *Global Natural Gas Markets Overview : A Report Prepared by Leidos , Inc ., Under Contract to EIA*, 49.
[65] International Gas Union, *World LNG Report 2015 Edition*, 13.
[66] For a description of reforms necessary for a competitive natural gas market to develop in Asia, see International Energy Agency, "Developing a Natural Gas Trading Hub in Asia: Obstacles and Opportunities."
[67] International Energy Agency, "World Energy Outlook 2014," 51.

eliminating trade obstacles) is a slow process: in the United States and the United Kingdom, the transition from regulatory pricing and long-term contracts to market-based pricing took many years.[68] Thus, the scenario modeled in this paper should not be thought of as short-term forecast, but analysis of the long-term trajectory of one of the determinants of natural gas trade (trade obstacles).

[68] Stern and Rogers, *The Transition to Hub-Based Gas Pricing in Continental Europe*, 34.

# Methodology

In order to understand what trade would look like if all trade obstacles were removed and consumption was determined by local demand and world supply factors, one must first understand what these factors are. Therefore this analysis begins by econometrically estimating a demand function for natural gas consumption in each country in the world. These demand functions are then used to provide a simple counterfactual calculation of national consumption levels and the volume of international trade that would occur if trade were completely unconstrained.

With unconstrained trade, prices in each country depend on the global supply of natural gas, not local supplies. Our hypothesis is that absent all costs and obstacles to trade, there would be substantially more international trade in natural gas, with less consumption in producing countries that currently have low prices, and more consumption in non-producing, geographically-isolated countries.

## Model

We calculate counterfactual consumption levels using a simple econometric model. First, each country's demand function for natural gas is estimated using

$$\ln C_{jt} = \alpha \ln RGDP_{jt} + \beta \ln POP_{jt} + \gamma \, HDD_{jt} + \delta \, CDD_{jt} + \theta + \varepsilon_{jt} \qquad (1)$$

where, for country $j$ in year $t$, $\ln C_{jt}$ is the natural log of the quantity of natural gas consumed, $\ln RGDP_{jt}$ is the natural log of real gross domestic product, $\ln POP_{jt}$ is the natural log of population, $HDD_{jt}$ is heating degree days,[69] and $CDD_{jt}$ is cooling degree days, $\theta$ is a constant, and the error term is $\varepsilon_{jt}$. Note that the constant absorbs the impact of average world natural gas prices over the time period, while the error term contains the effect of omitted variables such as the difference between world average prices and the price of gas in country $j$ in year $t$. The parameters of equation (1) are estimated using all countries with non-zero consumption of natural gas (countries which currently consume no gas are excluded from the regression).

In the counterfactual scenario (denoted with a superscript *), we assume all obstacles to trade are eliminated and therefore all countries face the same price for natural gas. In addition, prior non-consumers of natural gas now follow the demand function estimated for consumers. We

[69] Heating and cooling degree days are not in logs because the dataset includes some zero values for these variables.

also assume that there is no change in production in any of the countries in the counterfactual, so that where $Y_{jt}$ is natural gas production in country $j$ in year $t$.

$$Y_{jt}^{*} = Y_{jt} \tag{2}$$

More formally, natural gas consumption in the counterfactual scenario is calculated by taking equation (1), and modifying it in two ways. First, we set $\varepsilon_{jt} = 0$, which means that no country's prices differ from the world prices. We then set world prices equal to the value that equates world gas supply and demand. This means that we set the value of the constant to $\theta^{*}$ so that

$$\sum\nolimits_{k} C_{jt}^{*} = \sum\nolimits_{k} Y_{jt}^{*} \tag{3}$$

where $C_{jt}^{*}$ is consumption in country $j$ in year $t$ in the counterfactual scenario and $\Sigma_j$ is the sum over all countries indexed by $j$. This implies that

$$\ln C_{jt}^{*} = \alpha \ln RGDP_{jt} + \beta \ln POP_{jt} + \gamma\, HDD_{jt} + \delta\, CDD_{jt} + \theta^{*} \tag{4}$$

As a result of (1) and (4), $C_{jt}^{*}$ and $\hat{C}_{jt}$ differ by a constant proportion and thus by (3),

$$\frac{C_{jt}^{*}}{\sum_k C_{kt}^{*}} = \frac{\widehat{C_{jt}}}{\sum_k \widehat{C_{kt}}} \tag{5}$$

By substituting equation (4) into (5) and rearranging, we can calculate counterfactual consumption as a function of estimated or observed parameters,

$$C_{jt}^{*} = \frac{\left(RGDP_{jt}\right)^{\alpha}\left(POP_{jt}\right)^{\beta} exp\left(\gamma\, HDD_{jt} + \delta\, CDD_{jt}\right)}{\sum_j \left(RGDP_{jt}\right)^{\alpha}\left(POP_{jt}\right)^{\beta} exp\left(\gamma\, HDD_{jt} + \delta\, CDD_{jt}\right)} \sum\nolimits_{j} C_{jt}^{*}. \tag{6}$$

Finally, the counterfactual consumption levels from equation (6) are used to calculate counterfactual net exports as

$$\mathrm{NX}_{\mathrm{jt}}^{*} = \mathrm{Y}_{\mathrm{jt}}^{*} - \mathrm{C}_{\mathrm{jt}}^{*} \tag{7}$$

# Data Sources and Summary Statistics

Data on the production and consumption of natural gas in billions of cubic feet (bcf) are taken from the International Energy Statistics of the U.S. Energy Information Administration (EIA). The EIA data cover the 13 years from 2000 to 2012. Data on each country’s heating and cooling degree days are taken from the Global Degree Days Database of the King Abdullah Petroleum

Studies and Resource Center, specifically items "ESI.hdd.14.9C" and "ESI.cdd.14.9C". Country gross domestic product and nominal GDP per capita (used to calculate population) are taken from the International Monetary Fund's World Economic Outlook Database. Nominal GDP for all countries is deflated to real GDP using the U.S. GDP Deflator in the *Economic Report of the President*.[70] Table 1 lists summary statistics for these data sets. Appendix Table A.1 lists the 144 countries in the model.

**Table 1:** Data summary statistics

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Natural gas consumption (bcf) | 826 | 2,623 | 0.00 | 25,533 |
| Log real GDP in billion USD | 4.27 | 2.01 | -0.09 | 9.69 |
| Log population in billions | -4.33 | 1.42 | -7.82 | 0.30 |
| Thousand heating degree days | 6.22 | 7.28 | 0.00 | 31.32 |
| Thousand cooling degree days | 7.29 | 5.20 | 0.07 | 17.56 |

## Omitted Price Variable

One notable variable that is missing from equation (1) is the price of natural gas. The effect of price is instead in the error term, $\varepsilon_{jt}$. This assumption is made because price data are not publically available for most countries. While there is a literature that uses detailed price data from developed countries to conduct time series analysis on the determinants of natural gas prices[71] or the relationship between prices at different natural gas trading hubs,[72] such prices are only relevant for a small section of the international gas market. In 2014, only 42 percent of internationally traded gas was priced based on benchmark prices at trading hubs, while 51 percent were priced using oil-indexed prices in non-public contracts, and the remaining 7 percent reflect agreements between bilateral monopolists.[73] In addition to these problems with internationally traded gas, price data is even scarcer for domestically consumed gas, which is especially problematic because worldwide, 74 percent of gas is consumed in the country in which it was produced.[74] In short, outside of a few established natural gas hubs in developed countries, price data is not publically available.

As a result, for our analysis of world natural gas trade, this paper utilizes a methodology that does not require country-specific price data. This is done by identifying the non-price

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[70] Statistical Tables in Appendix B, available on-line at https://www.whitehouse.gov/administration/eop/cea/economic-report-of-the-President/2015.
[71] Nick and Thoenes, "What Drives Natural Gas Prices? — A Structural VAR Approach"; Brown and Yücel, "What Drives Natural Gas Prices?"
[72] Siliverstovs et al., "International Market Integration for Natural Gas? A Cointegration Analysis of Prices in Europe, North America and Japan"; Neumann, "Linking Natural Gas Markets - Is LNG Doing Its Job?"; Li, Joyeux, and Ripple, "International Natural Gas Market Integration"; Geng, Ji, and Fan, "A Dynamic Analysis on Global Natural Gas Trade Network."
[73] International Gas Union, *Wholesale Gas Price Survey - 2015*, 16.
[74] Ibid., 14–15.

determinants of natural gas demand and assuming that once they are controlled for, any differences in gas consumption across countries or time periods is due to differences in gas prices (including any transport or trade costs). This assumption allows us to estimate the effect of price equalization on trade without explicit price data.

However, note that the econometric estimates are potentially biased if omitted factors (such as price) are correlated with the demand factors that are included in equation (1), since the effect of the omitted variable would be combined with the effect of the included factors. This would occur under the plausible scenario where natural gas transportation infrastructure is endogenous: infrastructure is more likely to be built to transport gas to a country that has high demand for gas. Unfortunately, the aforementioned data constraints mean that we are not able to eliminate this potential source of bias.

# Results

## Econometric Estimates

Table 2 reports OLS estimates of the regression coefficients in equation (1), as well as their robust standard errors. All of the estimated coefficients are as economic theory predicts: gas use increases with GDP, population, and heating and cooling demands. Results are statistically significant at the 1 percent level.

**Table 2:** Econometric estimates, dependent variable: log of natural gas consumption

| Explanatory Variables | Point Estimate | Robust Standard Error |
|---|---|---|
| Log of real GDP | 0.739 | 0.033 |
| Log of population | 0.145 | 0.040 |
| Heating degree days (in thousands) | 0.089 | 0.010 |
| Cooling degree days (in thousands) | 0.087 | 0.015 |
| Constant | 1.225 | 0.387 |

Note: Number of observations: 1,284. $R^2$ = 0.5159.

## Changes in Consumption

The changes in the volume of national consumption, from actual $C_{jt}$ to counterfactual $C_{jt}^*$ , range across the countries from a decrease of 8,249 bcf (billion cubic feet) to an increase of 10,465 bcf (see Appendix Table A.1 for full results). In countries with prices currently below the counterfactual single global price, there is a reduction in consumption. These are generally countries with relatively high production and current consumption levels. Appendix Table A.1 reports the average change in consumption levels within four types of countries based on their actual production and consumption in 2012.[75] These types are: (1) countries with no consumption, (2) countries that consume natural gas but are not producers, (3) countries that produce natural gas but are net importers, (4) and countries that produce natural gas and are also net exporters.

[75] Given our assumption in equation (4) that global supply is fixed, the average (consumption weighted) percentage change in consumption of all countries and also the global sum of the changes in consumption are both equal to zero.

**Table 3:** Natural gas consumption by country type

| | Consumption (as percent of world consumption) | | |
|---|---|---|---|
| **Country Type** | **Actual** | **Unconstrained Trade** | **Difference** |
| No consumption | 0.0 | 2.0 | 2.0 |
| Consumers only | 1.6 | 4.2 | 2.7 |
| Producers (but net importers) | 64.4 | 72.2 | 7.9 |
| Net exporters | 34.1 | 21.6 | -12.5 |

Note: Percentages do not add up to 100% due to rounding.

The main increase in consumption is not in the (typically small) economies that currently have no consumption of natural gas; it is in large economies that are producing natural gas but are currently net importers. Gas consumption in "no consumption" countries increased to only 2 percent of world consumption. However, countries that are producers but net importers increased their share of world gas consumption from 64.4 percent to 72.2 percent. In contrast, the main decrease in consumption is in countries that are currently producing natural gas and are also net exporters. Their share of world consumption falls from 34.1 percent to 21.6 percent. The specific countries with the largest decreases in consumption are the United States (-8,250 bcf), Russia (-7,872 bcf), and Iran (-4,600 bcf). The specific countries with the largest increases in consumption are China (+10,466 bcf), Japan (+2,190 bcf), and Germany (+2,170 bcf).

## Changes in Imports and Exports

Since production is fixed in our counterfactual calculations, the countries with the largest increases in net exports are the same as the countries with the largest decreases in consumption (the United States, Russia, and Iran), and likewise the countries with the largest decreases in net exports are the same as the countries with the largest increases in consumption (China, Japan, and Germany).[76] Several countries shift from net importer of natural gas to net exporter, including Argentina, Kuwait, Mexico, Thailand, Ukraine, the United Arab Emirates, the United States, and Venezuela. Other countries shift from net exporter to net importer (including Colombia, Denmark, and Kazakhstan). Finally, this analysis calculates the sum of the net exports of the countries that are net exporters as a measure of the total volume of world trade in natural gas.[77] This total volume approximately doubles, from 24 percent of world consumption for the 2012 actual data to 50 percent for the counterfactual.

[76] In the counterfactual calculation, the level of production is held fixed, so the change in net exports is by definition equal to minus one times the change in consumption levels.
[77] This is equivalent to the sum of the net imports of the countries that are net importers.

# Conclusion

This paper has examined the impact of obstacles to international gas trade by estimating how trade would change if all such obstacles were eliminated. It estimates that the volume of international trade in natural gas would slightly more than double. Current natural gas exporters and major producers (for example, the United States, Russia, and Iran) would greatly reduce their consumption. Consumption would increase slightly in countries with no current natural gas consumption, but the bulk of the new consumption would occur in large economies that currently have to import most of their natural gas (for example, China, Japan, and Germany).

However, our model has simplified the factors that drive international trade, and there are many ways it could be improved upon in future work. For example, by incorporating price data into the analysis, trade costs could be directly quantified. Furthermore, an explicit model of natural gas supply would allow us to examine the effect of price changes on global production levels, instead of assuming constant production levels in the counterfactual calculations.

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# Appendix A
# Tables

**Appendix A.1**: Consumption, Production, and Net Exports of Natural Gas in 2012, in Billions of Cubic Feet

| Country | Type | Actual Consumption | Actual Production | Actual Net Exports | Change in Consumption |
|---|---|---|---|---|---|
| Albania | No consumption | 0 | 0 | 0 | 35 |
| Algeria | Net Exporter | 1323 | 3053 | 1730 | -942 |
| Angola | Producer | 27 | 27 | 0 | 181 |
| Argentina | Producer | 1641 | 1329 | -312 | -825 |
| Armenia | Consumer only | 87 | 0 | -87 | -32 |
| Australia | Net Exporter | 1258 | 1977 | 720 | -101 |
| Austria | Producer | 319 | 67 | -252 | 739 |
| Azerbaijan | Net Exporter | 379 | 607 | 227 | -168 |
| Bahrain | Producer | 481 | 481 | 0 | -418 |
| Bangladesh | Producer | 772 | 772 | 0 | -260 |
| Belarus | Producer | 739 | 8 | -731 | -450 |
| Belgium | Consumer only | 631 | 0 | -631 | 23 |
| Benin | No consumption | 0 | 0 | 0 | 38 |
| Bolivia | Net Exporter | 131 | 644 | 513 | -62 |
| Bosnia and Herzegovina | Consumer only | 8 | 0 | -8 | 45 |
| Botswana | No consumption | 0 | 0 | 0 | 31 |
| Brazil | Producer | 1071 | 598 | -473 | 1797 |
| Brunei Darussalam | Net Exporter | 107 | 426 | 319 | -59 |
| Bulgaria | Producer | 108 | 3 | -106 | 43 |
| Burkina Faso | No consumption | 0 | 0 | 0 | 49 |
| Burundi | No consumption | 0 | 0 | 0 | 7 |
| Cambodia | No consumption | 0 | 0 | 0 | 73 |
| Cameroon | Producer | 6 | 6 | 0 | 73 |
| Canada | Net Exporter | 3057 | 5070 | 2012 | 1464 |
| Central African Republic | No consumption | 0 | 0 | 0 | 11 |
| Chad | No consumption | 0 | 0 | 0 | 46 |
| Chile | Producer | 181 | 44 | -137 | 432 |
| China | Producer | 5074 | 3666 | -1408 | 10466 |
| Colombia | Net Exporter | 332 | 421 | 90 | 144 |
| Costa Rica | No consumption | 0 | 0 | 0 | 149 |
| Cote d’Ivoire | Producer | 57 | 57 | 0 | 59 |
| Croatia | Producer | 115 | 68 | -47 | 25 |
| Czech Republic | Producer | 296 | 9 | -287 | 267 |
| Denmark | Net Exporter | 137 | 205 | 67 | 298 |
| Dominican Republic | Consumer only | 45 | 0 | -45 | 150 |
| Ecuador | Producer | 18 | 18 | 0 | 99 |
| Egypt | Net Exporter | 1882 | 2141 | 259 | -1422 |
| El Salvador | No consumption | 0 | 0 | 0 | 60 |
| Equatorial Guinea | Net Exporter | 76 | 243 | 167 | -38 |
| Eritrea | No consumption | 0 | 0 | 0 | 15 |

| Country | Type | Actual Consumption | Actual Production | Actual Net Exports | Change in Consumption |
|---|---|---|---|---|---|
| Estonia | Consumer only | 24 | 0 | -24 | 81 |
| Ethiopia | No consumption | 0 | 0 | 0 | 90 |
| Finland | Consumer only | 130 | 0 | -130 | 821 |
| France | Producer | 1523 | 19 | -1504 | 1687 |
| Gabon | Producer | 3 | 3 | 0 | 48 |
| Georgia | Producer | 63 | 0 | -63 | 20 |
| Germany | Producer | 3001 | 462 | -2539 | 2170 |
| Ghana | Consumer only | 22 | 0 | -22 | 144 |
| Greece | Producer | 154 | 0 | -154 | 257 |
| Guatemala | No consumption | 0 | 0 | 0 | 126 |
| Guinea | No consumption | 0 | 0 | 0 | 27 |
| Guinea-Bissau | No consumption | 0 | 0 | 0 | 6 |
| Haiti | No consumption | 0 | 0 | 0 | 46 |
| Honduras | No consumption | 0 | 0 | 0 | 54 |
| Hong Kong | Consumer only | 102 | 0 | -102 | 460 |
| Hungary | Producer | 358 | 79 | -279 | -16 |
| India | Producer | 2080 | 1448 | -632 | 1888 |
| Indonesia | Net Exporter | 1329 | 2559 | 1230 | 1035 |
| Iran | Net Exporter | 5511 | 5649 | 138 | -4600 |
| Iraq | Producer | 23 | 23 | 0 | 428 |
| Ireland | Producer | 167 | 8 | -159 | 96 |
| Israel | Producer | 90 | 88 | -2 | 196 |
| Italy | Producer | 2646 | 304 | -2342 | 56 |
| Japan | Producer | 4472 | 168 | -4303 | 2190 |
| Jordan | Producer | 25 | 8 | -17 | 43 |
| Kazakhstan | Net Exporter | 387 | 416 | 30 | 790 |
| Kenya | No consumption | 0 | 0 | 0 | 95 |
| Korea | Producer | 1793 | 37 | -1756 | 256 |
| Kuwait | Producer | 642 | 548 | -94 | -377 |
| Kyrgyz Republic | Producer | 15 | 0 | -15 | 109 |
| Lao P.D.R. | No consumption | 0 | 0 | 0 | 33 |
| Latvia | Consumer only | 52 | 0 | -52 | 70 |
| Lebanon | No consumption | 0 | 0 | 0 | 80 |
| Lesotho | No consumption | 0 | 0 | 0 | 9 |
| Liberia | No consumption | 0 | 0 | 0 | 13 |
| Libya | Net Exporter | 202 | 430 | 228 | -69 |
| Lithuania | Consumer only | 117 | 0 | -117 | 48 |
| Macedonia | Consumer only | 4 | 0 | -4 | 32 |
| Madagascar | No consumption | 0 | 0 | 0 | 32 |
| Malawi | No consumption | 0 | 0 | 0 | 16 |
| Malaysia | Net Exporter | 1104 | 2176 | 1073 | -352 |

| Country | Type | Actual Consumption | Actual Production | Actual Net Exports | Change in Consumption |
|---|---|---|---|---|---|
| Mali | No consumption | 0 | 0 | 0 | 44 |
| Mauritania | No consumption | 0 | 0 | 0 | 16 |
| Mexico | Producer | 2422 | 1671 | -751 | -1130 |
| Moldova | Consumer only | 123 | 0 | -123 | -84 |
| Mongolia | No consumption | 0 | 0 | 0 | 192 |
| Morocco | Producer | 38 | 2 | -36 | 161 |
| Mozambique | Net Exporter | 27 | 154 | 127 | 23 |
| Namibia | No consumption | 0 | 0 | 0 | 30 |
| Nepal | No consumption | 0 | 0 | 0 | 65 |
| Netherlands | Net Exporter | 1626 | 2843 | 1216 | -645 |
| New Zealand | Producer | 164 | 162 | -2 | 0 |
| Nicaragua | No consumption | 0 | 0 | 0 | 36 |
| Niger | No consumption | 0 | 0 | 0 | 32 |
| Nigeria | Net Exporter | 244 | 1190 | 946 | 866 |
| Norway | Net Exporter | 174 | 4156 | 3983 | 1440 |
| Oman | Net Exporter | 715 | 1035 | 319 | -570 |
| Pakistan | Producer | 1462 | 1462 | 0 | -820 |
| Panama | No consumption | 0 | 0 | 0 | 119 |
| Papua New Guinea | Producer | 4 | 4 | 0 | 44 |
| Paraguay | No consumption | 0 | 0 | 0 | 68 |
| Peru | Producer | 418 | 418 | 0 | -151 |
| Philippines | Producer | 99 | 99 | 0 | 803 |
| Poland | Producer | 640 | 219 | -421 | 643 |
| Portugal | Consumer only | 160 | 0 | -160 | 59 |
| Qatar | Net Exporter | 1257 | 5523 | 4267 | -995 |
| Romania | Producer | 476 | 375 | -101 | 65 |
| Russia | Net Exporter | 15711 | 21764 | 6053 | -7872 |
| Rwanda | No consumption | 0 | 0 | 0 | 17 |
| Saudi Arabia | Producer | 3508 | 3508 | 0 | -2597 |
| Senegal | Producer | 1 | 1 | 0 | 56 |
| Sierra Leone | No consumption | 0 | 0 | 0 | 24 |
| Singapore | Consumer only | 331 | 0 | -331 | 230 |
| Slovak Republic | Producer | 187 | 5 | -181 | 101 |
| Slovenia | Producer | 31 | 0 | -31 | 119 |
| South Africa | Producer | 164 | 42 | -122 | 349 |
| Spain | Producer | 1144 | 2 | -1142 | 568 |
| Sri Lanka | No consumption | 0 | 0 | 0 | 225 |
| Sudan | No consumption | 0 | 0 | 0 | 174 |
| Swaziland | No consumption | 0 | 0 | 0 | 10 |
| Sweden | Consumer only | 40 | 0 | -40 | 1035 |
| Switzerland | Producer | 127 | 0 | -126 | 1656 |

| Country | Type | Actual Consumption | Actual Production | Actual Net Exports | Change in Consumption |
|---|---|---|---|---|---|
| Taiwan | Producer | 602 | 13 | -589 | 432 |
| Tajikistan | Producer | 7 | 1 | -7 | 66 |
| Tanzania | Producer | 33 | 33 | 0 | 33 |
| Thailand | Producer | 1796 | 1458 | -338 | -912 |
| The Gambia | No consumption | 0 | 0 | 0 | 5 |
| Togo | No consumption | 0 | 0 | 0 | 22 |
| Trinidad and Tobago | Net Exporter | 787 | 1428 | 641 | -721 |
| Tunisia | Producer | 130 | 66 | -64 | -38 |
| Turkey | Producer | 1598 | 22 | -1576 | 34 |
| Turkmenistan | Net Exporter | 868 | 2492 | 1624 | -748 |
| Uganda | No consumption | 0 | 0 | 0 | 51 |
| Ukraine | Producer | 1856 | 694 | -1162 | -1209 |
| United Arab Emirates | Producer | 2235 | 1854 | -381 | -1696 |
| United Kingdom | Producer | 2752 | 1452 | -1300 | -133 |
| United States | Producer | 25533 | 24058 | -1475 | -8250 |
| Uruguay | Consumer only | 2 | 0 | -2 | 76 |
| Uzbekistan | Net Exporter | 1861 | 2222 | 360 | -1642 |
| Venezuela | Producer | 869 | 803 | -66 | -248 |
| Vietnam | Producer | 296 | 296 | 0 | 143 |
| Yemen | Net Exporter | 34 | 270 | 236 | 61 |
| Zambia | No consumption | 0 | 0 | 0 | 53 |
| Zimbabwe | No consumption | 0 | 0 | 0 | 34 |

# Appendix B
# Data Tables for Figures

**Appendix B.1:** Crude oil import costs in USD/bbl (average unit value, CIF)

| Year | Japan | United Kingdom | United States |
|---|---|---|---|
| 2000 | 28.72 | 28.45 | 27.54 |
| 2001 | 25.01 | 24.45 | 22.07 |
| 2002 | 24.96 | 24.58 | 23.52 |
| 2003 | 29.26 | 29.13 | 27.66 |
| 2004 | 36.59 | 37.75 | 35.86 |
| 2005 | 51.57 | 53.79 | 48.82 |
| 2006 | 64.03 | 65 | 59.17 |
| 2007 | 70.09 | 73.8 | 66.77 |
| 2008 | 100.98 | 99.34 | 94.97 |
| 2009 | 61.29 | 62.39 | 58.83 |
| 2010 | 79.43 | 80.6 | 76.02 |
| 2011 | 109.3 | 113.49 | 102.43 |
| 2012 | 114.75 | 112.62 | 101.16 |
| 2013 | 110.61 | 110.27 | 97.25 |
| 2014 | 104.16 | 100.07 | 89.55 |

**Appendix B.2:** Natural Gas Prices in USD/MMBtu

| Year | Japan (LNG) | United Kingdom | United States |
|---|---|---|---|
| 2000 | 4.72 | 2.71 | 4.23 |
| 2001 | 4.64 | 3.17 | 4.07 |
| 2002 | 4.27 | 2.37 | 3.33 |
| 2003 | 4.77 | 3.33 | 5.63 |
| 2004 | 5.18 | 4.46 | 5.85 |
| 2005 | 6.05 | 7.38 | 8.79 |
| 2006 | 7.14 | 7.87 | 6.76 |
| 2007 | 7.73 | 6.01 | 6.95 |
| 2008 | 12.55 | 10.79 | 8.85 |
| 2009 | 9.06 | 4.85 | 3.89 |
| 2010 | 10.91 | 6.56 | 4.39 |
| 2011 | 14.73 | 9.04 | 4.01 |
| 2012 | 16.75 | 9.46 | 2.76 |
| 2013 | 16.17 | 10.63 | 3.71 |
| 2014 | 16.33 | 8.22 | 4.35 |