The Macroeconomic Impact of LNG Exports: Integrating the GPCM® Natural Gas Model and the PI⁺® Regional Model

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[2] PI$^+$ is a registered trademark of Regional Economic Models, Inc., and we use with permission.

Overview

The issue of liquefied natural gas (LNG) exports is a complicated, but important, one for the related industries, the consuming public, and policymakers throughout North America. Exporting LNG holds both positive and negative potential promises. On the positive side, LNG exports could increase energy interdependence between continents, foster wealth creation and capital investment in North American gas fields, and lower gas prices for consumers in foreign lands. However, on the downside, these exports may put upward pressure on retail prices in Canada, Mexico, and the United States for consumers in various sectors. Impacts will vary across regions of the continent and specific countries, concentrating benefits in areas of future exploration and costs in areas of high natural gas consumption at current times.

The economic and technical possibility of LNG exports from North America comes from the explosion of gas production from 2005 onwards. In 2005, the United States produced 18,051bcf of gas, a number that surged to 21,577bcf in 2009 (19.5% growth in four years) and continues to spike to the current day.[3] Low natural gas prices have recently slowed the rate of exploration and drilling for new wells;[4,5] conversely, these low prices have engendered considerations of LNG exports to exploit potential arbitrage between North American and foreign markets. This past summer, Chinese consumers paid over five times the price of North Americans for natural gas,[6] and LNG exports are one method for both economies to begin to close this gap. Elsewhere in Northeast Asia, Japan accounted for 48% of world imports of LNG in 2002, though China and India are growing much more quickly into the 2010s.[7]

Several projects are already proceeding for LNG exports in North America. These include the Sabine Pass facility in Cameron Parish, LA, owned by Cheniere Energy.[8] This project, originally built as an import terminal, will undergo reconversion to a "bidirectional" facility with a focus on exports. The new Sabine Pass allows exports from the Gulf Coast to anywhere in the world. Another major project is at Dominion Cove Point near Lusby, MD. This project received approval in 2011, and it will have legal permission to sell LNG to countries that have a free trade agreement with the United States.[9] On the Pacific Coast, Apache Canada is working on the Kitimat LNG facility, which has a close proximity to Canadian gas and Northeast Asian markets.[10]

[3] "United States: Country Analysis Brief," *United States Energy Information Administration* (EIA), accessed September 7, 2012, http://www.eia.gov/countries/country-data.cfm?fips=US#ng

[4] Carolyn Cui and Liam Pleven, "Gas Drilling Slows, Heating Up Prices," *Wall Street Journal*, accessed September 7, 2012, http://online.wsj.com/article/SB10001424052702303877604577380470571678552.html

[5] Andrew Maykuth, "Natural-gas prices force down number of Marcellus drilling rigs," *Philadelphia Inquirer*, accessed September 7, 2012, http://articles.philly.com/2012-07-08/business/32589447_1_natural-gas-prices-drilling-natural-gas

[6] Winnie Zhu and Dinakar Sethuraman, "China's Easy Grip on Gas Opening Door to North America Exports, *Bloomberg Businessweek*, accessed September 7, 2012, http://www.businessweek.com/news/2012-06-04/china-s-easing-grip-on-gas-opening-door-to-north-america-exports

[7] "The Global Liquefied Natural Gas Market: Status and Outlook," *United States Energy Information Administration* (EIA), accessed September 7, 2012, http://www.eia.gov/oiaf/analysispaper/global/importers.html

[8] "Sabine Pass Liquefaction," *Cheniere*, accessed on September 7, 2012, http://www.cheniere.com/lng_industry/sabine_pass_liquefaction.shtml

[9] "Dominion Cove LNG," *Dominion*, accessed on September 7, 2012, https://www.dom.com/business/gas-transmission/cove-point/index.jsp

[10] "Kitimat LNG," *Kitimat LNG Facility*, accessed on September 7, 2012, http://www.kitimatlngfacility.com/

These projects are not without their controversies. Critically, while prices for gas are low in the United States, the introduction of intercontinental demand to the North American market has the potential to increase prices for domestic consumers. This process, assuming it brings on price increases, will increase the cost of doing business and the cost of living for households. Several politicians have taken notice and spoken out against current or future LNG export facilities, most notably Congressman Ed Markey (D, MA-7) and Senator Ron Wyden (D, OR).[11] Markey has cited economic concerns about LNG exports, "America should exploit her competitive advantage with lower natural gas prices to create jobs in the United States, not export natural gas to create more profits for oil and gas companies."[12] Political concerns on the economic impact of LNG exports make this issue into a public policy discussion on its broader implications.

To date, three other studies have looked into the issue from the perspective of natural gas markets, each with some consideration of macroeconomic impacts. These include reports by the Brookings Institute,[13] Deloitte,[14] and the United States Energy Information Administration.[15] Other studies include those by the consulting firms ICF International and Navigant. Their product market impacts—price changes due to a demand shock from export/arbitrage through paths like Kitimat and Sabine Pass—varied depending on the model and some of the assumptions behind them. The Brookings Institute summarized the price results:

Figure 1.1 – This is the study comparison of market impacts based on "Average Price Impact from 2015-2035 of 6bcf/day of LNG exports" as compiled by the Brookings Institute's study.[16]

Study	Average price without exports ($/MMBtu)	Average price with exports ($/MMBtu)	Average price increase (percentage)
EIA	**$5.28**	**$5.78**	**9%**
Deloitte	**$7.09**	**$7.21**	**2%**
ICF	**$5.81**	**$6.45**	**11%**
Navigant	**$5.67**	**$6.01**	**6%**

Answering to the divergence of these results is not the purpose of this paper. There are many potential reasons for this between different model configurations, data inputs, and users' assumptions. However, none of these studies attempted to quantify the *macroeconomic impact* of LNG exports. There were some nods to it. The Deloitte study, for example, stated on economic impacts, "The price impact is less than $0.10/MMBtu in most downstream areas… it is highly unlikely that [these] would cause U.S. industry to be uncompetitive and lead to a

[11] Tyler Graf, "Wyden stands firm on no LNG exports at town hall meeting," *Daily Astorian*, accessed on September 7, 2012, http://www.dailyastorian.com/free/wyden-stands-firm-on-no-lng-exports-at-town-hall/article_0aad2b82-71f5-11e1-ba48-001871e3ce6c.html

[12] "Markey: Sabine LNG Export Facility Approval Would Help Export U.S. Manufacturing Jobs," *Congressman Ed Markey: Proudly Serving the 7th District of Massachusetts*, accessed on September 7, 2012, http://markey.house.gov/press-release/markey-sabine-lng-export-facility-approval-would-help-export-us-manufacturing-jobs

[13] Charles Ebinger, Kevin Massy, and Govinda Avasarala, "Liquid Markets: Assessing the Case for U.S. Exports of Liquefied Natural Gas," *The Brookings Institute*, May 2012, Policy Brief 12-01, accessed on September 7, 2012, http://www.brookings.edu/research/reports/2012/05/02-lng-exports-ebinger

[14] "Made in America: the Economic Impact of LNG Exports from the United States," *Deloitte*, accessed on September 7, 2012, http://www.deloitte.com/view/en_US/us/Industries/oil-gas/9f70dd1cc9324310VgnVCM1000001a56f00aRCRD.htm

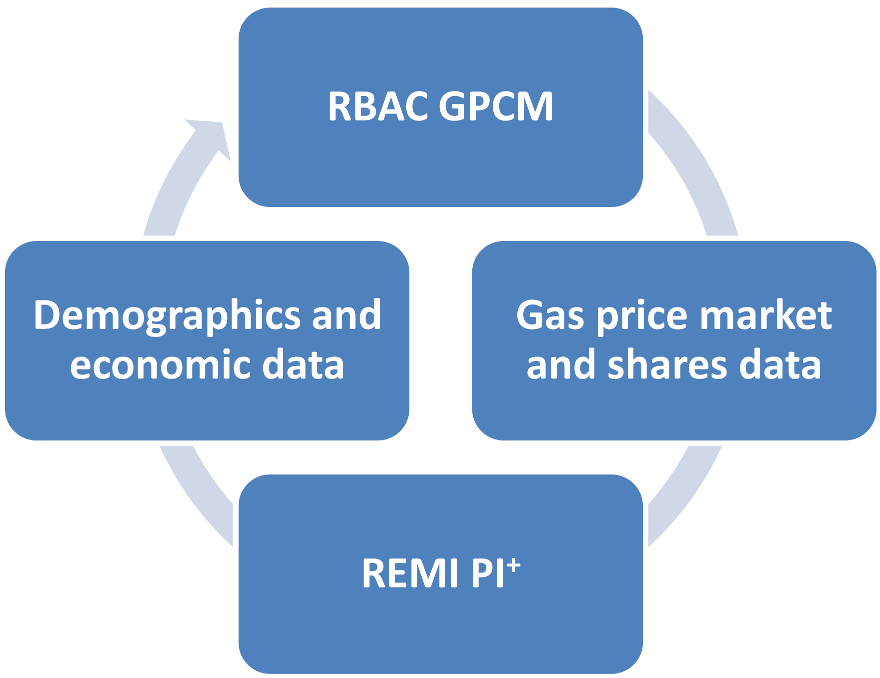
[15] "Effect of Increased Natural Gas Exports on Domestic Energy Markets: as requested by the Office of Fossil Energy," *United States Energy Information Administration* (EIA), January 2012, accessed September 7, 2012, http://www.eia.gov/analysis/requests/fe/pdf/fe_lng.pdf

[16] Ebinger et al, p. 33

loss of jobs."[17] Furthermore, "The U.S. has lower gas prices than most industrialized countries… An increase in gas prices of less than 2% is unlikely to change the U.S. competitiveness in global markets."[18] The Brookings Institute concluded, "LNG exports are likely to be a net benefit to the U.S. economy, although probably not a significant contributor in terms of total U.S. GDP."[19] These results could, however, go into another model to describe the macroeconomic implications of LNG exports, including results of job creation, gross domestic product growth, and changes in real personal income.[20]

Here, we present an integration to do just that. Using complimentary models, PI+ of Regional Economic Models, Inc. (REMI) of Amherst, MA and GPCM of RBAC, Inc. of Sherman Oaks, CA, we modeled the economic impact of LNG exports on regional development and natural gas markets to 2025. This presents a "closed system" amid the two perspectives—gas market-oriented and economy-oriented—to model the issues discussed but never examined in full detail by the previous literature. Additionally, our study will include "macroeconomic feedback" iteration between the two models, because price/cost changes will change regional development, which will, in turn, change demand for fuel, and continuing within a loop:

Figure 1.2 – This shows the iterations between PI+ and GPCM models, including the types of information passed from one to the other through the "closed loop" analysis.



The remainder of this study consists of an overview of the two models and a description of the data that passes between the two of them in the loop. After that, we report results on three LNG export simulations: 0bcf/day (low), 3bcf/day (medium or expected), or 6bcf/day (high). These results will include a look at the economic and demographic implications of the policy for households and businesses, including breakdowns by fifty states of

[17] Deloitte, p. 13
[18] Ibid.
[19] Ebinger et al, p. 36
[20] Some other models do realize some degree of these effects. For instance, the EIA study discusses the macroeconomic component of the NEMS energy model on p. 5. They do not include, however, jobs impacts or regional information, concentrating their analysis on gross domestic product (due to the model's capabilities).

the United States (plus the District of Columbia), NAICS industries,[21] SOC occupations,[22] and the implications to total employment and gross domestic product (GDP). There will be similar results in the natural gas market and prices after accounting for macroeconomic feedbacks. In addition, we will make adjustments to capital gains income—and therefore total national wealth and consumer spending—and industry reinvestment in oil and gas extraction based on the anticipated revenue from LNG arbitrage. This will present a more comprehensive economic impact from the policy and scope of LNG exports in the next fifteen years.

Methods

REMI PI+

REMI PI+, formerly Policy Insight®, is a regional economic model that takes a macroeconomic approach to analysis of sub-national policies. The model includes four quantitative methodologies, and it looks at policies on a year-to-year basis from given inputs. The geography of the model is theoretically to the county-level; however, for this analysis, we used a fifty-one region model (which includes all fifty states and the District of Columbia) with 169 industrial sectors.[23] This corresponded to the geography and output data from the GPCM natural gas model. Raw data sources include the Bureau of Economic Analysis (BEA),[24] Bureau of Labor Statistics (BLS),[25] U.S. Census Bureau,[26] the Energy Information Administration (EIA),[27] and the Research Seminar in Quantitative Economics (RSQE)[28] at the University of Michigan.[29] The structure of the model includes macroeconomic components, the business perspective on the economy towards labor and capital, the household perspective towards the labor market and costs, other market concepts, government spending, and a measurement of competitiveness and market shares between regions and industries.

Methodologies

The four quantitative methodologies in REMI include **input-output** (IO) tabulation, **econometric** estimation, **computable general equilibrium** (CGE) theory, and **New Economic Geography** (NEG) theory. Input-output tables

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[21] "North American Industrial Classification System," *United States Census Bureau*, accessed on September 7, 2012, http://www.census.gov/eos/www/naics/

[22] "Standard Occupational Classification," *United States Department of Labor: Bureau of Labor Statistics* (BLS), accessed on September 7, 2012, http://www.bls.gov/SOC/

[23] This corresponds, roughly, to the four-digit NAICS classification. There are some aggregations, particularly in the retail sector. Please see "Industries for PI+ v. 1.2 Models," *Regional Economic Models, Inc.*, accessed on September 7, 2012, http://www.remi.com/download/documentation/pi+/pi+_version_1.2/NAICS_Industries_for_PI+_-_Hierarchical_v1.2.pdf

[24] "U.S. Economic Accounts," *United States Department of Commerce: Bureau of Economic Analysis* (BEA), accessed on September 7, 2012, http://www.bea.gov/

[25] "U.S. Bureau of Labor Statistics," *United State Department of Labor: Bureau of Labor Statistics* (BLS), accessed on September 7, 2012, http://www.bls.gov/

[26] "United States Census Bureau," *United States Department of Commerce: United States Census Bureau*, accessed on September 7, 2012, http://www.census.gov/#

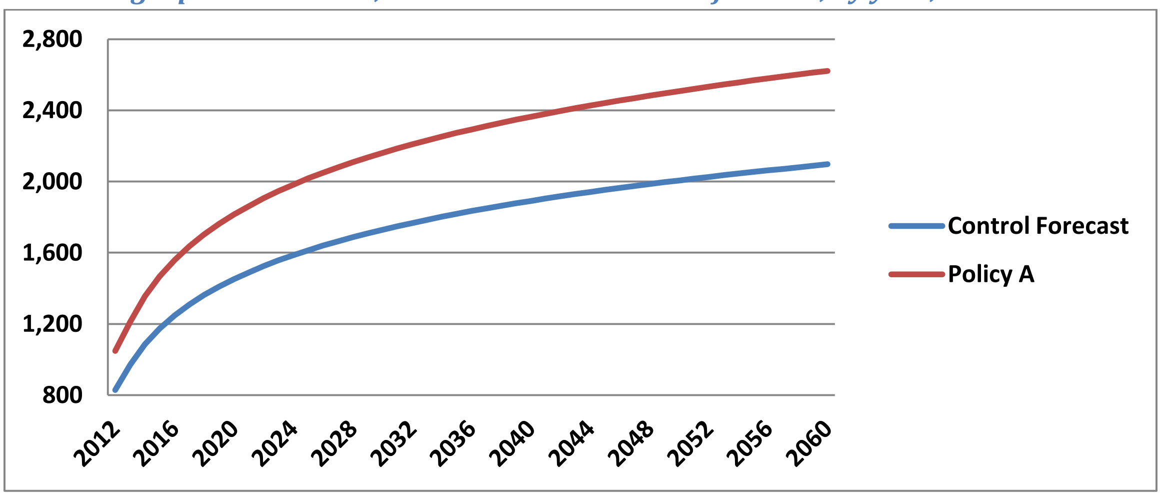
[27] "Independent Statistics & Analysis," *United States Energy Information Administration* (EIA), accessed on September 7, 2012, http://www.eia.gov/

[28] "RSQE Forecasts," *Research Seminar in Quantitative Economics* (RSQE), accessed on September 7, 2012, http://rsqe.econ.lsa.umich.edu/

[29] For full description of data sources and estimation procedures for REMI, please see, "Data Sources and Estimation Procedures," *Regional Economic Models, Inc.*, accessed on September 7, 2012, http://www.remi.com/download/documentation/pi+/pi+_version_1.3/Data_Sources_and_Estimation_Procedures.pdf

capture inter-industry relationships and transactions, supply chains, and multiplier effects between different industries and regions. Econometrics uses statistics to estimate behavior and time parameters in the economy, including price elasticities, wealth effects, the strength of migratory flows within the United States,[30] and the time "lags" for an economy to return to stability after an exogenous shock. The CGE component of the model handles the long-term situation, in which markets—including those for labor, housing, and products—have a chance to "clear" in response to changes over time. NEG quantifies agglomeration and clustering effects by industry and regions, which increases labor pooling, productivity, and competitiveness.

Figure 2.1 – This illustrates the fundamental methodology of the REMI model. It generates a "control" or "baseline" forecast and then compares it to an alternative policy situation, such as gas price changes and reinvestments involving the natural gas industry. The y-axis shows different economic or demographic indicators, and the x-axis shows the forecast, by year, out to 2060.

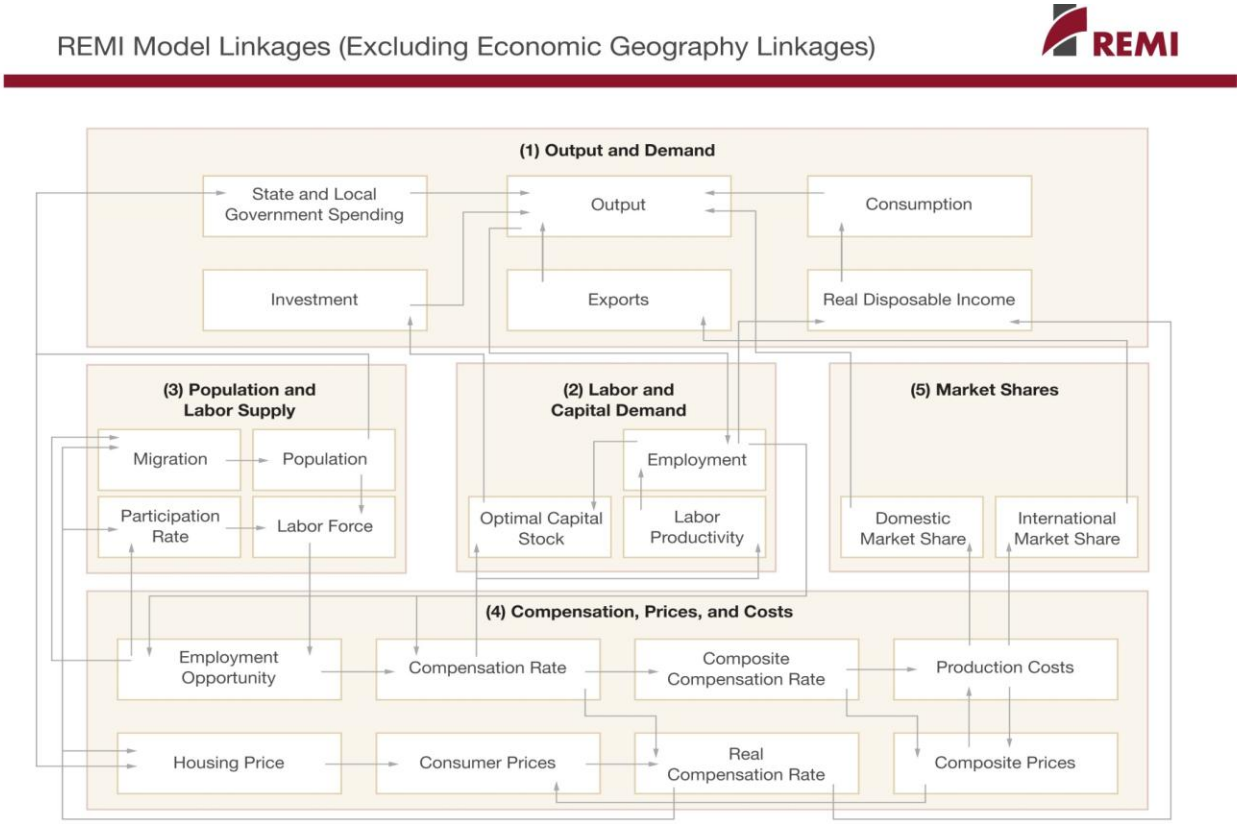


Model Structure

PI$^+$ is built on a five block structure. Those blocks are, respectively, (1) **Output and Demand**, (2) **Labor and Capital Demand**, (3) **Population and Labor Supply**, (4) **Compensation, Prices, and Costs**, and (5) **Market Shares**. Block 1 is the final demand of the economy by sub-national region, including consumption, investment, net exports, and government spending. Block 2 is where industries, needing to produce to match the demand in Block 1, receive their orders and make decisions about acquiring factors of production for inputs. These include labor inputs, capital, and fuel (including natural gas, electricity, and petroleum products). Block 3 is the household component of the model, which includes demographic concepts like births, survivals, and migration, as well as labor force participation and adjustments to final demand based on age and region. Block 4 "brings the two together" with labor market concepts, housing and costs of living, and production costs for businesses. These come together in Block 5 for market shares, which measure how competitive a region and an industry is versus its competitors. In practice, this is a measurement of how well a region can export its wares and prevent the importation of similar wares into its area. These concepts all form variables, which we change for the simulation on LNG exports and their economic impact by region.

[30] Sinan Hastorun and Ted Cangero, "Re-Estimating the REMI Migration Equation Coefficients to Correct for Endogeneity," *Regional Economic Models, Inc.*, accessed September 7, 2012, http://www.remi.com/download/documentation/pi+/pi+_version_1.3/Reestimating_The_REMI_Migration_Equation_Coefficients_to_Correct_for_Endogeneity.pdf

Figure 2.2 – This is the REMI model structure for PI+ v. 1.3 in block and flowchart form.



RBAC GPCM

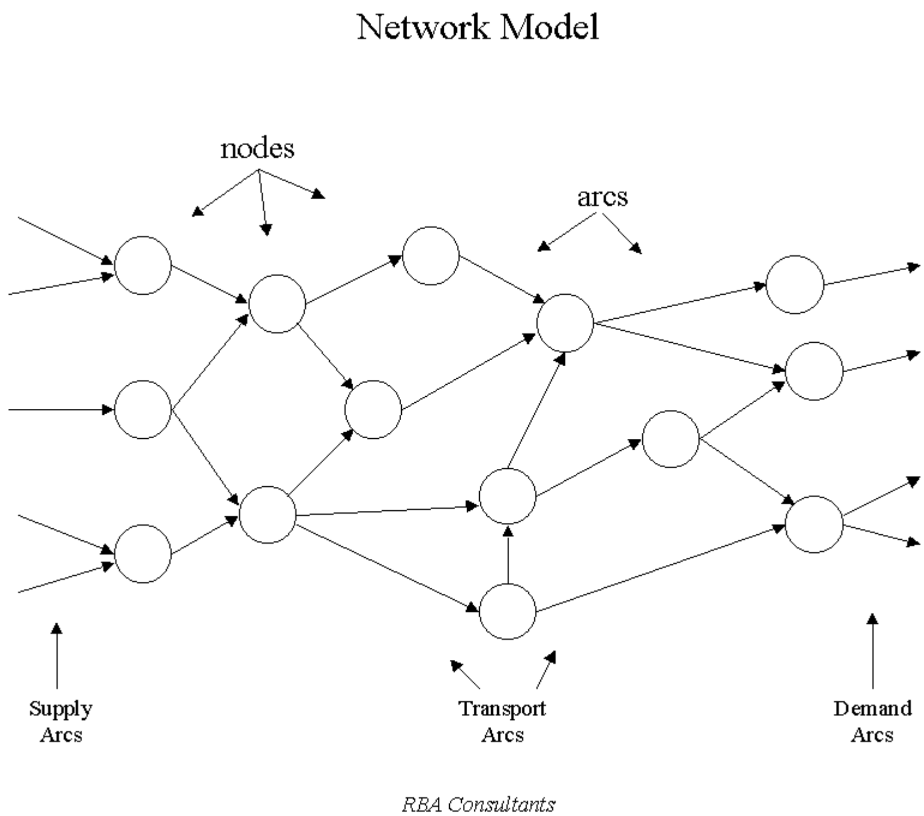
GPCM is a model of an integrated natural gas market such as the one in North America. It is a network model consisting of points where natural gas is produced, bought, sold, stored, and consumed. These points are called “nodes” in a network model. It consists of paths through these various points representing the pipeline grid, which delivers gas from producing areas to consumers. Each point-to-point component of a path in a network model is called an “arc.” The questions that GPCM answers are: given a set of assumptions about supply in producing areas and demand in consuming areas, plus knowledge about the capacity and cost of transportation and storage in the grid, what set of prices at the nodes and flows on the arcs is consistent with a relatively free and competitive market for natural gas.

Methodologies

GPCM calculates these answers by using the basic principles of equilibrium economics. For the gas market, this means that supply and demand must be in balance. This balance must exist at every point in the market—that is, at every node in the model. A balance, or equilibrium, occurs when the price differential between any two points in the network balances with the cost of moving gas between those two points, and, therefore, there is no reason to increase or decrease the amount of gas flowing between the two points. At supply points, this would mean that there is no reason to increase (or decrease) production because the amount produced is equal to the amount demanded at that price. At demand points, there is also no reason to increase (or decrease) the amounts of gas demanded because supply and demand are in balance at the market price.

GPCM uses a step-by-step, iterative method to compute this equilibrium solution. It starts with a trial “solution” which has no gas flowing in the network. From this beginning point, it scans through the various possible supplies, demands, and pathways from supply points to demand points, and finds the one which has the greatest price/cost differential. It then creates a new trial "solution," moving the maximum amount it can from a low cost producer along a low cost pathway to a consumer who is willing to pay a high price. At this early point in the solution process, prices are low at that supply point, high at the demand point, and at intermediate levels at the various transportation points used to move gas from the supply to the demand point.

Figure 2.3 – This is a representation of the spatial nature of GPCM. The diagram includes the model's nodes, arcs, and the connections representing the North American natural gas market.

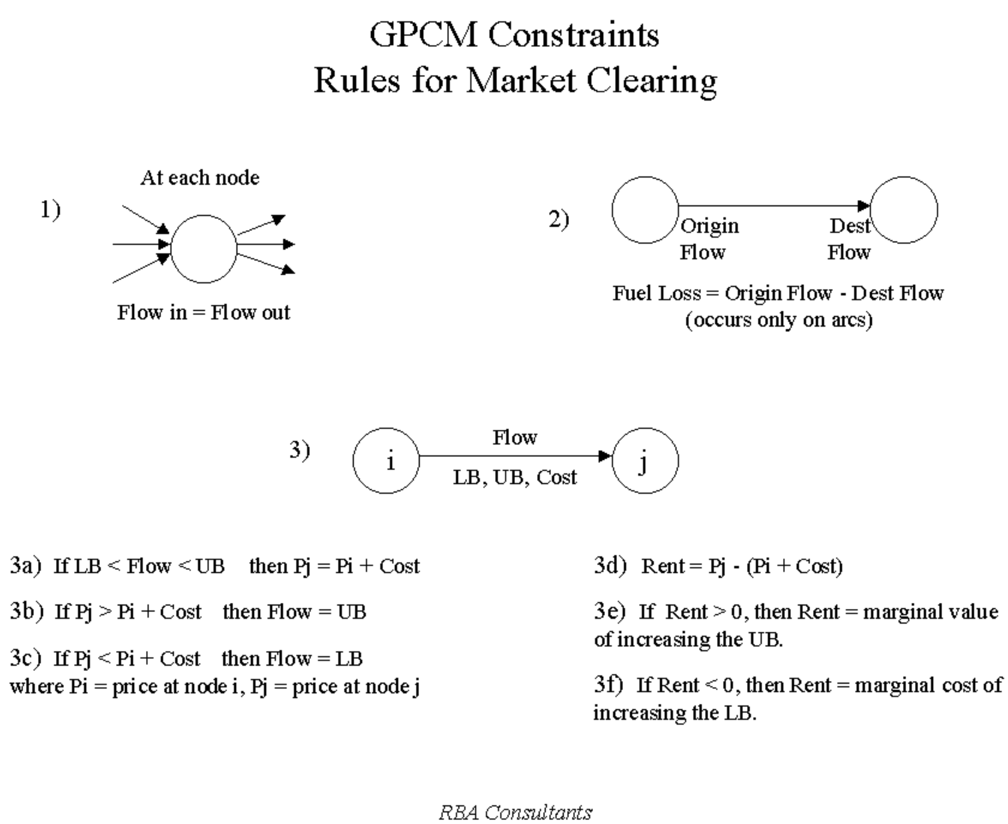


The algorithm then looks for another, similar situation where a profitable flow from producer to consumer can take place. Iteratively, GPCM must compute an implied price at points in the transportation network. As the capacity of each pathway fills, the price of transporting along that path increases, reflecting the operation of supply and demand for transportation. Since more gas is demanded at various supply points, higher cost producers can sell their gas, and the price at these points goes up. The consumers willing to pay higher prices find contentment to their preferences, and the market tries to yet satisfy those customers not willing to pay so much. From there, prices at the demand points come down.

GPCM continues to look for opportunities to move gas from suppliers to consumers that have an economic benefit associated with them. This is exactly analogous to the process that current gas traders and marketers use to make money for their firms. If they find a way to move gas from one market point to another at a cost less than the price differential between those points, they will do so. This process can also involve time. In other words, they might want to buy gas at a certain point during one period, store it, and then sell it at the same or a different price later. If the relative price between these two space-time points is greater than the cost, then the trader will try to make the deal. GPCM computes prices and flows over both space and time, including storage injections and withdrawals as well as production, pipeline transportation, and delivery to customers. Its algorithm uses the same "thought process" that traders and marketers use to conduct business in the competitive North American market for natural gas.

The GPCM algorithm will always converge to a solution where the price and flow variables are consistent with an economic equilibrium, per the mathematicians behind the model's functional structure. This means that all of the arbitrage opportunities discussed will clear, and the system will balance at every point and period of time. The model is consistent with industry and private behavior. The only instances where price differentials between two points will be different from the cost of transportation and/or storage will involve "congested" paths between those points where there is no more capacity left to sell. In those instances, GPCM would like to take advantage of the potential for additional economic benefit, but there is not enough physical capacity to do so. This is very important information, because the solution is actually an alert for locations where additional capacity might be needed in the present or future. The difference between the price differential and the cost is a measure of the economic value of additional capacity between those two points.

Figure 2.4 – This shows the model's rules for an economically-efficient solution.



Model Integration Methodology

For this integration, we distilled from the two models the main pieces of forecasts and impact information they can provide each other. For the network model, this included forecasted macroeconomic and regional growth projections and demand for natural gas. This took the form of gross domestic product growth, and gross manufacturing product (GMP) growth, demographic data, output of electrical power generation, and changes to personal income. PI⁺ forecasts these numbers in its regional baselines and simulations, and the economic model then changes these forecasts in response to shocks. For instance, if gas prices were to plummet in a state, then businesses and households would seek to relocation there to take advantage of the lower cost of doing business and cost of living. These, in turn, however, will influence future population and economic activity in the state, which will change the demand forecast inside of the network model.

GPCM provided market forecasts and information for the REMI model. These included prices by sectors (commercial, industrial, residential, and utility), which we then converted into relative prices. These relative prices drive the competitiveness measurements in REMI PI⁺. First, we updated the REMI regional baselines for all fifty states and the District of Columbia to include the gas model's forecast for prices and relative prices out to 2025. This new baseline included 3bcf/day of LNG export—this is to account for the fact that Sabine Pass and Dominion Cove Point are already approved by regulators and planned for reconversion in the next few years. We also included the growing demand for natural gas powered vehicles (NGVs) to the REMI baseline from GPCM, owing to the lack of such demand in the original PI⁺ build. The alternative price scenarios for the two models include a 0bcf/day export case and an aggressive export program of 6bcf/day of LNG. The former should generate lower domestic prices and the latter should generate higher domestic gas prices (from the exogenous demand shift to the right) when compared to the baseline.

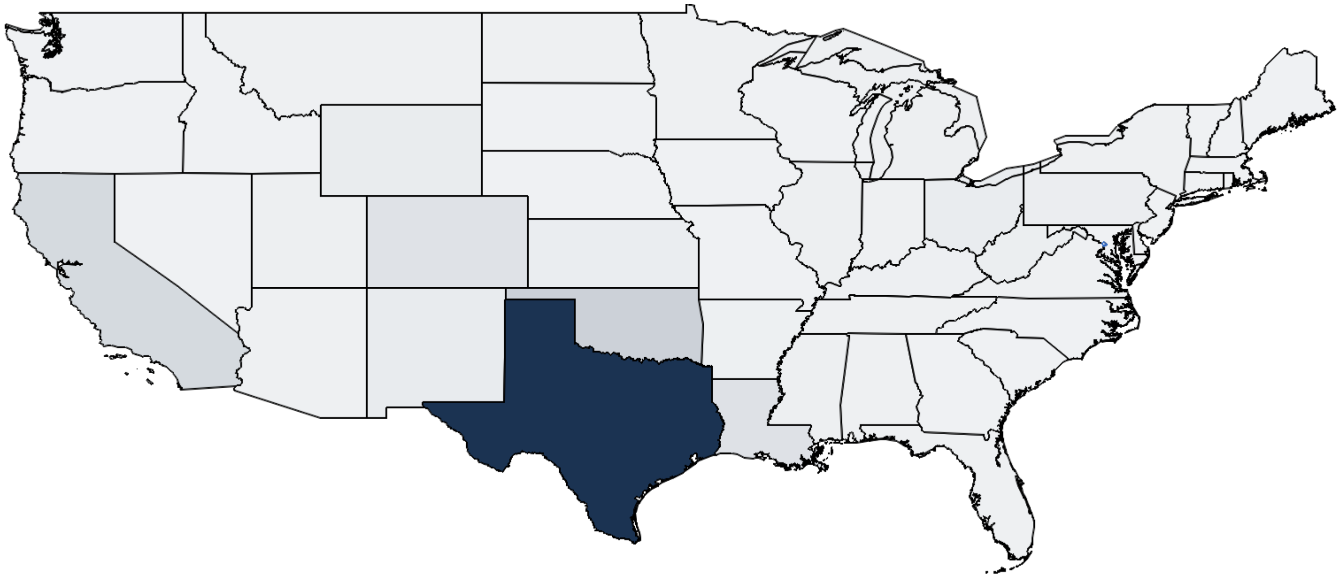
Figure 2.5 – This table summarizes the major pieces of data passing between the two models. We ran three iterations between the two for the purposes of this study on LNG exports.

Data from PI⁺ into GPCM	Data from GPCM into PI⁺
• **Gross domestic product ($)** • **Gross manufacturing product ($)** • **Population (persons)** • **Disposable personal income ($)** • **Electrical power generation (GW-h)**	• **Natural gas prices for commercial, industrial, residential, and utility sectors** • **Demand for natural gas-fueled vehicles** • **Production information for natural gas** • **Volume information for LNG exports**

Furthermore, we expanded the scope of this economic impact study by including other considerations in the economic simulations. LNG exports should, at least in the short-run, turn a profit for private firms.[31] These profits can have their own consequences. These might include changes to the financial sector (due to changing institutional savings rates, capital costs, and self-financing of projects from profits), direct reinvestment of producer surplus into oil and gas exploration and drilling, and increased shareholder income, household wealth, and therefore consumption. According to historical data,[32,33] firms in the oil and gas industry tend to reinvest profits at a rate of between 70% and 80%. Hence, for our purposes, we assumed a 25% rate of stock repurchase and dividends out of LNG export profits, and boosted those variables accordingly in the economic model. The other 75% went to increased oil and gas exploration throughout the various regions of the United States at the same underlying rate of investment in the REMI economic forecast.

[31] Margaret Ryan, "LNG Exports from US to Asia Seen as Profitable – for a Limited Time," *AOL Energy*, accessed on September 7, 2012, http://energy.aol.com/2012/08/30/lng-exports-from-the-us-to-asia-seen-as-profitable-for-a-limit/
[32] "Putting Earnings into Perspective: Facts for Addressing Energy Policy," *American Petroleum Institute*, accessed on September 7, 2012, http://tinyurl.com/cqvormb
[33] Daniel J. Weiss, Jackie Weidman, and Rebecca Leber, "Big Oil's Banner Year: Higher Prices, Record Profits, Less Oil," *Center for American Progress*, accessed on September 7, 2012, http://www.americanprogress.org/issues/green/news/2012/02/07/11145/big-oils-banner-year/

Figure 2.6 – This map shows the underlying distribution of oil and gas extraction in the REMI data for 2012. Extraction concentrates on the darkened states of Texas, Oklahoma, California, and Colorado, but this map will change over time with newer gas plays opening up all over the country.



To find a profit margin for LNG, we considered the cost of shipping, liquefaction, and the potential arbitrage margins with importers in Europe and Asia. Liquefaction costs will average approximately $2.92/mcf in the near future, and transportation costs to Britain or Japan range between $1.07/mcf to $2.15/mcf.[34] Averaging these figures and projected costs of feed gas costs is complicated. However, a conservative assumption leads to an average profit margin of around $2/mcf for LNG exports in the immediate future.[35] Maintaining this level of export is also an open question. Price differentials between continents are high at the current moment, but the exportation of technological knowhow and expertise will spur shale oil and gas development in the rest of the world. In China, for example, Sinopec began drilling nine shale gas wells near Chongqing in the central part of the country earlier this year. [36] These wells should produce between 11bcf and 18bcf from June through December of 2012.[37] This effect could expand supply of gas throughout the world, and depress the demand or need for North American LNG exports from lack of a price differential later in the 2010s.

These considerations allow the models to take account of both the upsides and downsides of LNG exports, and their potential impacts on the macroeconomy. The results report the combined outputs of the PI$^+$ and GPCM models in their two fields: the impacts to the product markets as well as to the overall economy. There are many important considerations and issues for policymaking over LNG; however, with the given models and assumptions, these results quantify the major economic factors involved in it. The model integration leads to a combined and consistent forecast with the same assumptions between the two.

[34] Kenneth B. Medlock III, "U.S. LNG Exports: Truth and Consequences," *Rice University: James A. Baker III Institute for Public Policy*, accessed on September 7, 2012, http://bakerinstitute.org/publications/US%20LNG%20Exports%20-%20Truth%20and%20Consequence%20Final_Aug12-1.pdf

[35] Ibid., p. 30

[36] John Daly, "It's Official – China Embraces Oil Shale and Fracking," *Oil Price*, accessed on September 7, 2012, http://oilprice.com/Energy/Natural-Gas/Its-Official-China-Embraces-Oil-Shale-and-Fracking.html

[37] Ibid.

Results

The results for the LNG simulations will take different forms here, based on the simulation case and if it is a macroeconomic result or a natural gas price result. The three simulations include:

- 3bcf/day case (the baseline)
- Alternative cases of 0bcf/day (no exports) and 6bcf/day (rapid exports)

Between these, there are two potential sets of comparisons: between the three of them, or between the three of them *using the 3bcf/day scenario as a baseline or zero-line*. We will label those clearly throughout the results, depending on the most logical way to display the data.

Economic results will include the following categories of indicators:

- Employment concepts
    - **Total employment**
    - **Private, non-farm employment**
    - Employment impacts by **occupational** category
- Macroeconomic concepts
    - **Gross domestic product** (nationally)
    - **Real disposable personal income** (nationally, per capita)
    - Impacts to specific **industries**
- Geographic distributions
    - **Graphical** interface

We report natural gas prices in a similar manner, including their Henry Hub prices and geographic distribution after the addition or subtraction of LNG exports and macroeconomic feedbacks.

These results constitute a potential impact of the policy on the American economy, *and we do not mean to recommend for the exportation of LNG from North America in either direction*. One of the main considerations here, as well, is the scale of the impact of these projects on the economy in comparison to a United States of over 314 million people and $15.3 trillion annual gross domestic product in 2012.[38] In keeping with this, we will include some discussion of the proportions and sensitivities of these impacts compared to the baseline growth of the United States economy expected over the next fifteen years.

Natural Gas Price Impacts

We will report the impacts to the gas markets first, though we will not compare them with different sources from previous in the literature here.[39] Increased exports have an effect on domestic natural gas prices at Henry Hub and in regions from 2018 to 2025. We changed LNG exports from a baseline of 3bcf/day to the levels in the scenarios, modeling projects starting in 2015 and running at capacity in 2018.

[38] "United States," *Central Intelligent Agency World Factbook*, accessed on September 7, 2012, https://www.cia.gov/library/publications/the-world-factbook/geos/us.html

[39] Please see Robert Brooks, "Using GPCM to Model LNG Exports from the US Gulf Coast," *RBAC, Inc.*, accessed on September 7, 2012, http://www.rbac.com/press/LNG%20Exports%20from%20the%20US.pdf

Figure 3.1 – This shows the Henry Hub price from the GPCM simulation runs under various scenarios after iterations. The differences in price then drove the simulations for the economic model.

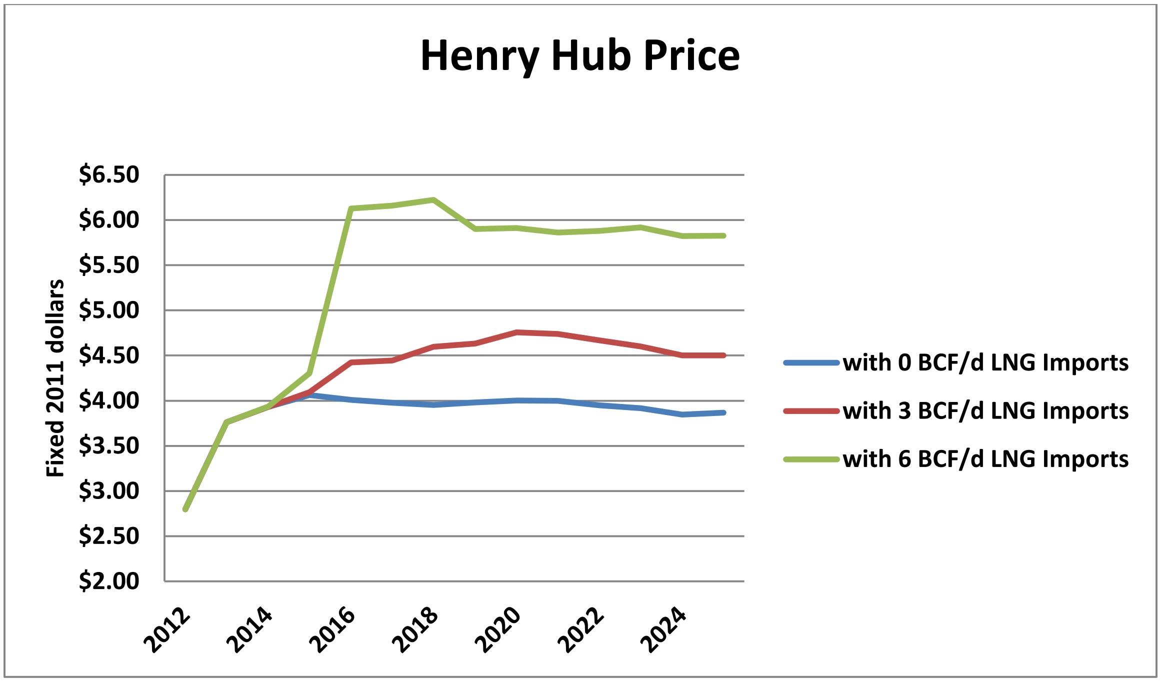


Figure 3.2 – This shows the market point price and basis from Henry Hub for the 0bcf/day export scenario. Exports on the Gulf Coast put stronger prices on Louisiana and Texas markets, which create the spikes above and some of the patterns in regional pricing situations below.

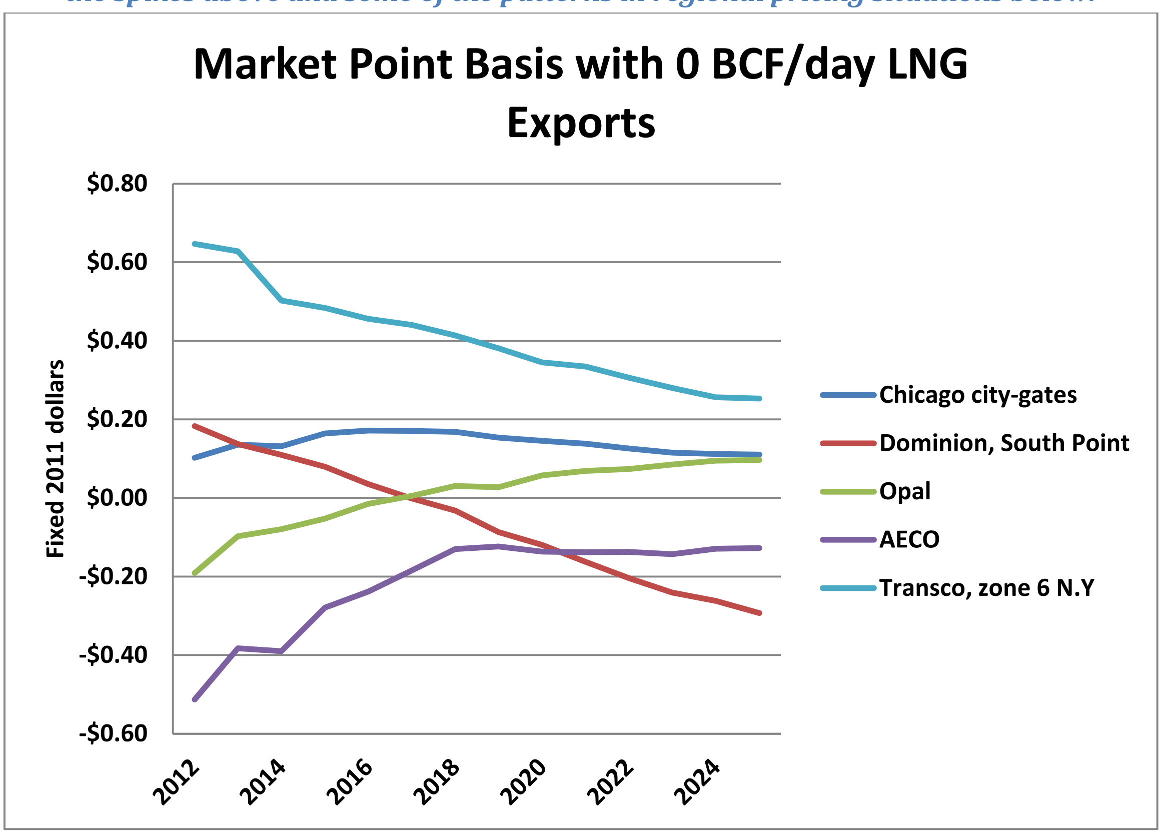


Figure 3.3 – The same for the 3bcf/day baseline scenario in the PI+ and GPCM runs.

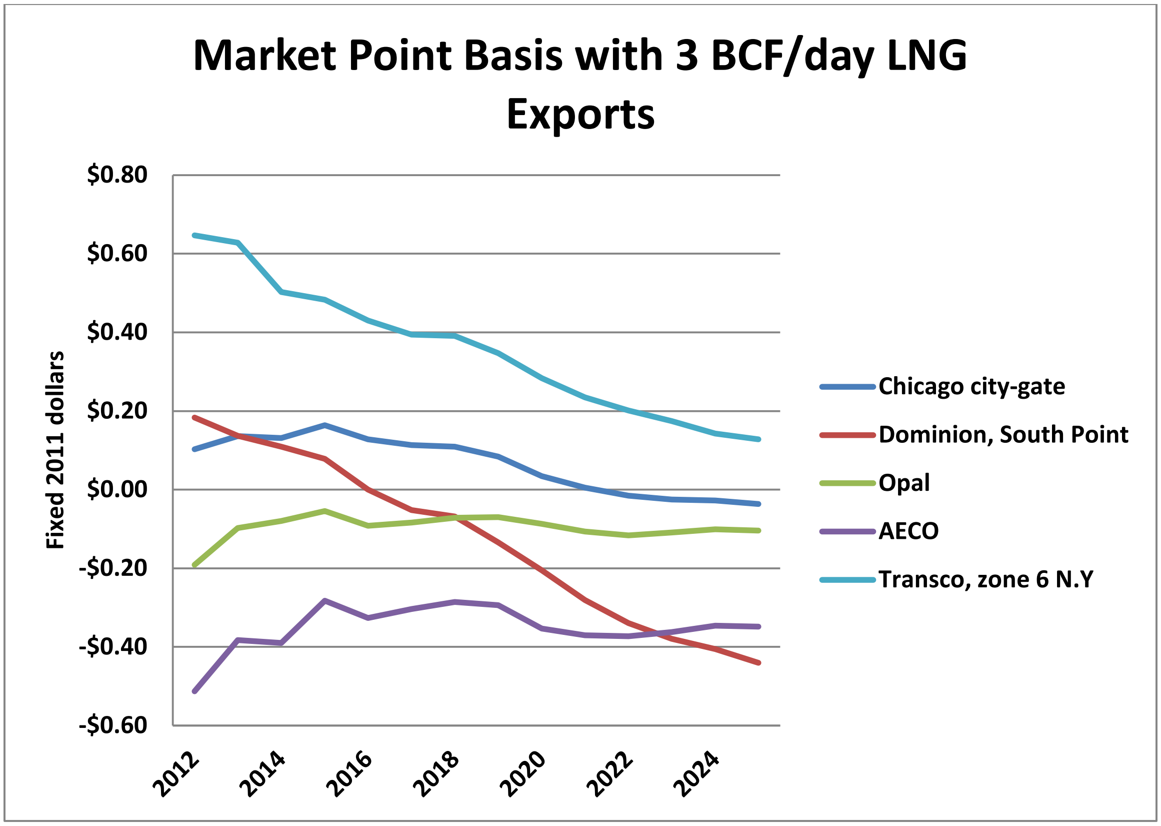
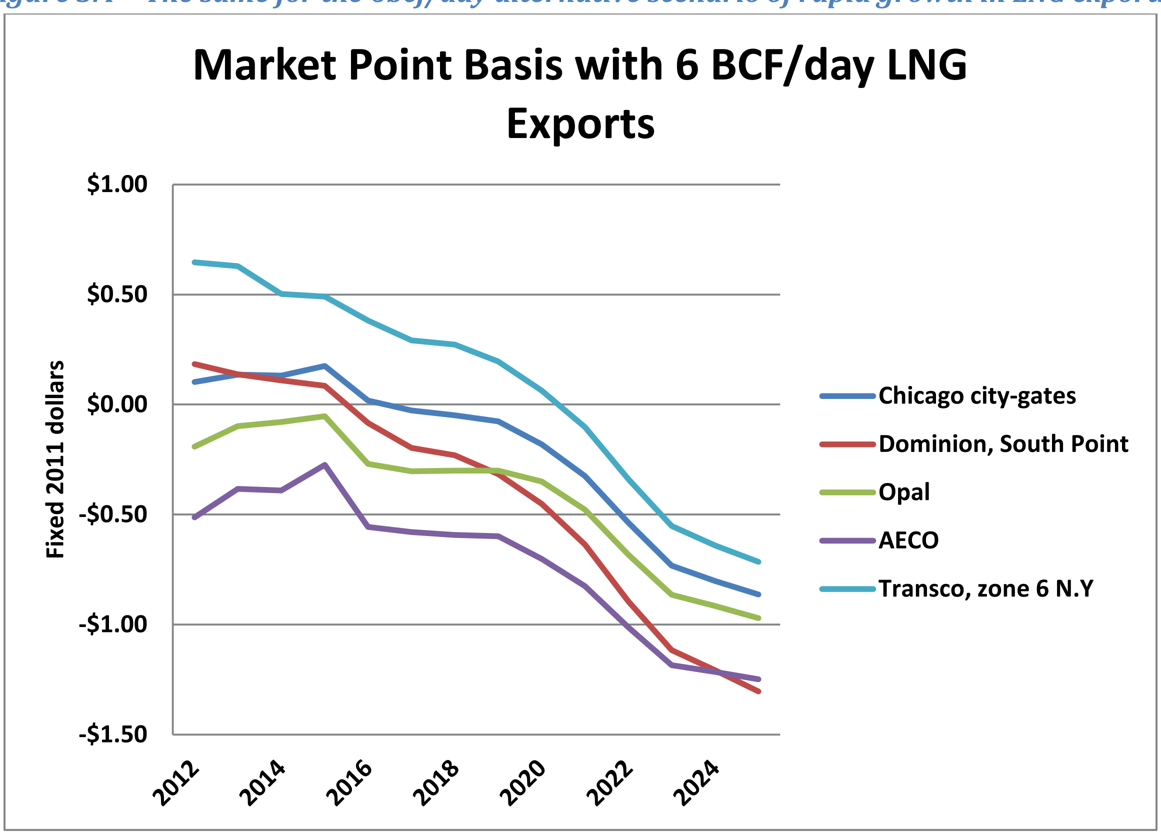


Figure 3.4 – The same for the 6bcf/day alternative scenario of rapid growth in LNG exports.

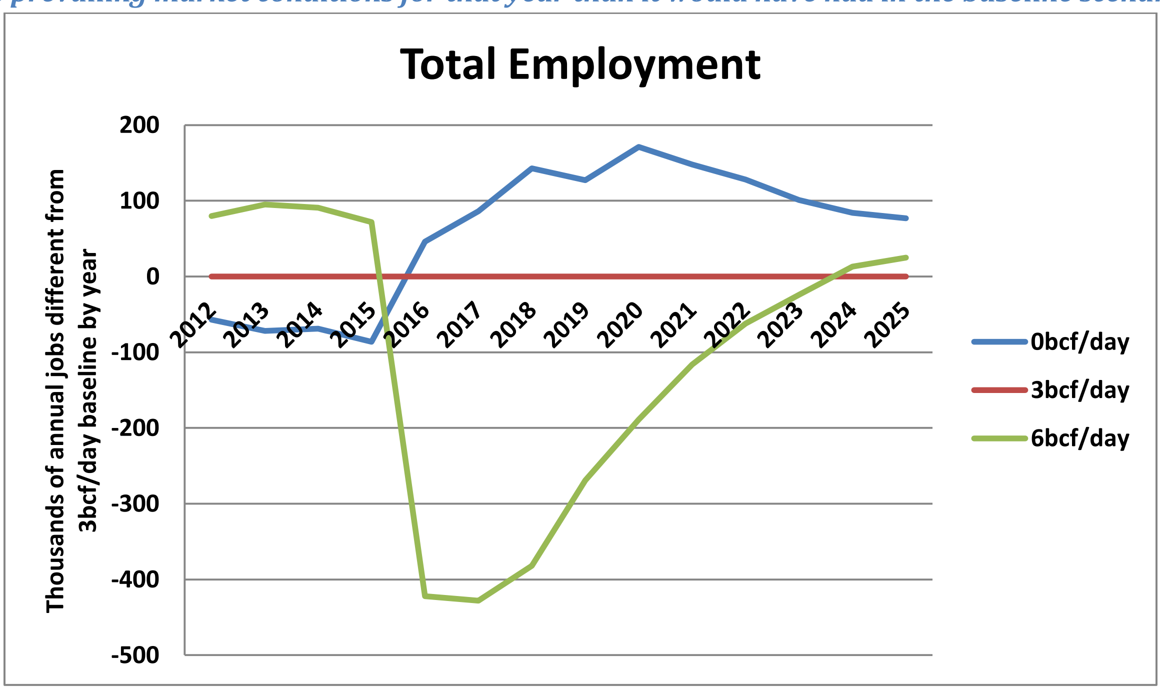


These prices changes will influence economic development by region and industry. For example, areas that use larger amounts of natural gas in daily household or economic processes (mostly in the Midwest) will be more sensitive to swings in natural gas price changes, while other regions that are more dependent on other fuels (from either petroleum-based products, bio-fuels, or electricity) will not "feel" it as much. The same is true of certain industries, because manufacturers often use a large amount of liquid fuels for inputs, while service-based industries do not often use much energy or use mostly electricity. In addition, the ability of the states' economies to switch between different fuel choices will influence their sensitivity. There is still a downstream effect from price changes to the gas inputs for utilities, but not a direct impact.

Employment Impacts

Unsurprisingly, increased natural gas prices in the Unites States of 5% to 10% (depending on the region, the year, and the scenario) increases business costs in the country to the point of a loss of employment. However, the United States' economy is a dynamic one, and impacts vary across states depending on their preexisting fuel mixtures, industry combinations, household preferences, and the rate they tend to prospect for natural gas and receive dividend income or additions to total wealth from producers' surpluses. There is also a time effect to reaction to natural gas prices as markets clear and industries have a chance to relocate their production to low-cost areas and to integrate different fuel inputs.

Figure 3.5 – This shows the total employment impact of LNG exports by year. Do note: these report "job-years" in a year-to-year basis, not a net job creation concept.[40] In practice, this means that, for example, 300 jobs over the baseline in year x means that the labor market has 300 more openings at the prevailing market conditions for that year than it would have had in the baseline scenario.

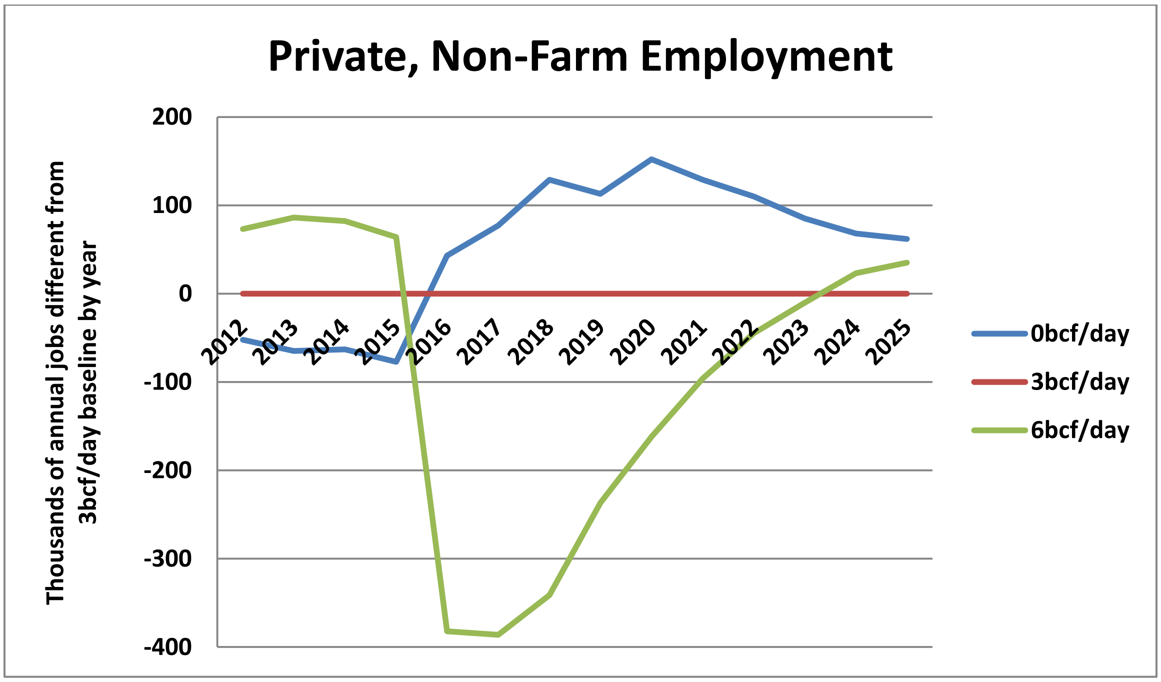


The story on jobs is mixed by years and the scenario. Initially, the higher rate of investment, capital construction, and other "preparation" for LNG exports generates a positive economic impact from expanding the 3bcf/day

[40] Tim Fernholz, "What the Heck is a Job-Year," *The American Prospect*, accessed on September 7, 2012, http://prospect.org/article/what-heck-job-year

case to the 6bcf/day case. These are lost in the 0bcf/case where some factor prevents export of LNG from the United States. In the longer-term, the situation "flips," where the increased demand on the natural gas grid from exports in the 3bcf/day or 6bcf/day simulations raises prices and depresses the economy over the 0bcf/day simulation. Additionally, the initial uptick in shareholder income and increased oil and gas exploration is nsot enough to swing the jobs numbers back positive. However, in greater time, the dynamic readjustment of the economy from higher-costs areas to lower-cost areas, changes in household spending patterns, and increases in these incomes cause these simulations to converge back towards the baseline, making the outlying impact of LNG exports much less than the big swings of the first decade.

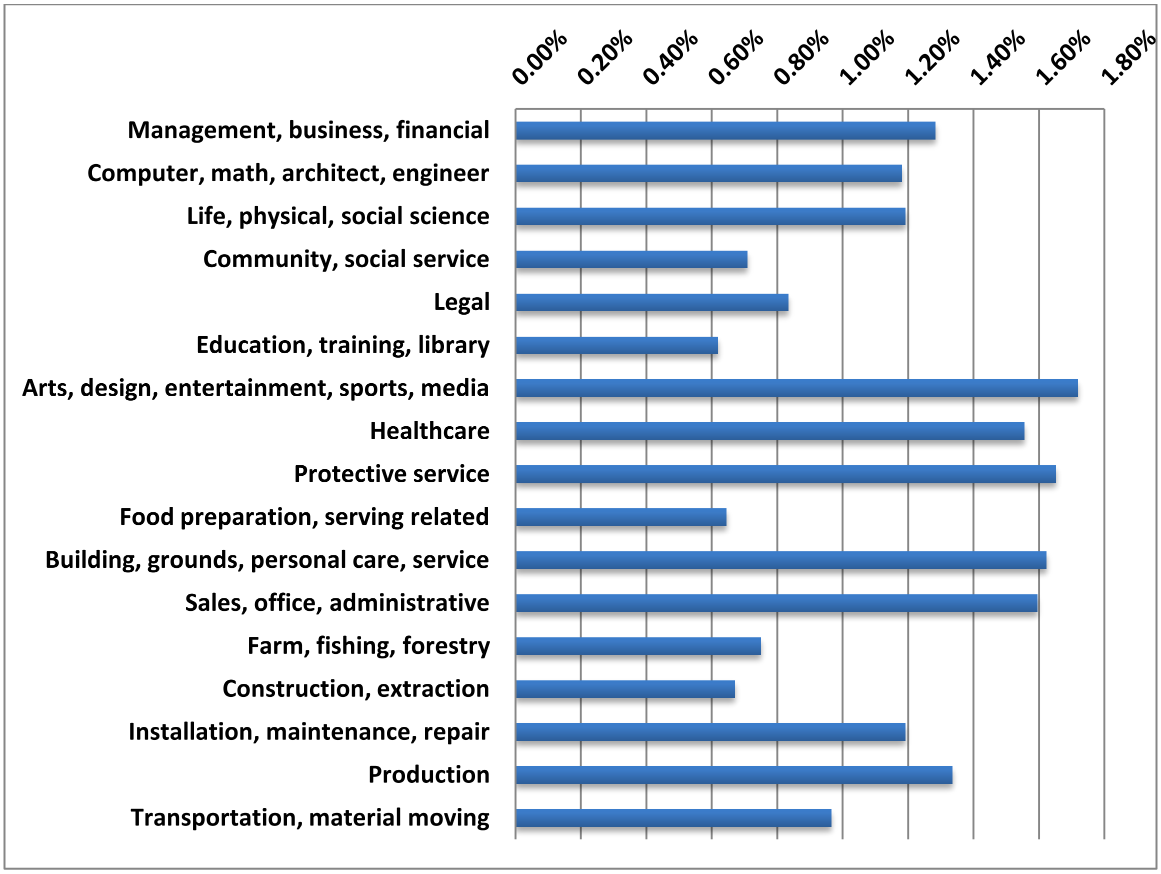
Figure 3.6 – This is the same graph as Figure 3.5, but it now includes only jobs in private, non-farm NAICS sectors. REMI PI+ calculates anticipated public sector employment based on the growth in tax bases and demand for government services, but this shows only private industries here. The overall patterns of the impacts are similar given the relationship of the private economy to tax revenue.



These job impacts are not uniform in terms of their occupations and their socioeconomics. Different industries and regions undergo different impacts from LNG exports and within them there are different types of impacts to the sorts of labor categories demanded. For instance, a large bank hires a full socioeconomic cross section of workers, including top executives, financial professionals, administrative and legal staffs, and maintenance personnel for their space. The model illustrates this by mapping occupational categories to NAICS codes with data from the BLS about what occupations differing industries typically employ.

LNG exports have a broad socioeconomic impact, though it concentrates in trades related to manufacturing, production, or construction over service-based trades. Broad categories in service industries like community service, legal trades, and education have smaller impacts from LNG exports in the relative sense. On the other hand, white collar jobs related to manufacturing industries and production trades see the largest hit. There are no categories of workers that do not have an impact though, so all classifications of workers could expect changes from changing natural gas prices and LNG exports.

Figure 3.7 – This table shows the average percentage impact of LNG exports between the 6bcf/day case and the 0bcf/day case from 2012 to 2025 for occupations. For example, for management, business, and financial, the gains in jobs-years over the time period is +0.103% for switching from the larger export scenario to the 0bcf/day one. Certain categories stand out over others, but all of them can expect at least some impact from the policy change as we have modeled it in this study.



Macroeconomic Impacts

From a macro perspective, LNG exports generate a similar pattern and scale as the jobs impacts in the previous section. Gross domestic product initially rises under the 3bcf/day and 6bcf/day scenarios, though it declines when the price hikes from the LNG exports have their effects in the network model on the economy. This demand shift is temporary, however, and the economy begins to recover towards its baseline in the 2020s to have a much less strenuous effect than the one from the original shock around 2018. From a policymaking perspective, the question becomes a point of the distribution of the impacts (between industries, occupations, and states) and the years. The macroeconomic benefit of initial investments and construction from 2012 to 2018 are considerable in their own light, especially in an economy that still has an 8.3% unemployment rate into 2012.[41] This benefit would provide the most amelioration to the strained labor market of the 2010s than a labor market of the 2020s with a full recovery that approaches full employment. In any case, the proportional impact of this decision in the relative sense of the United States' economy is not large, and other major conditions will determine the overall trajectory of the American economy to 2025.

[41] "Labor Force Statistics from the Current Population Survey," *United States Department of Labor: Bureau of Labor Statistics* (BLS), accessed on September 7, 2012, http://data.bls.gov/timeseries/LNS14000000

Figure 3.8 – This is the annual gross domestic product impact for the United States, graphed in the same manner as Figure 3.5 on total employment and 3.6 on private, non-farm employment. Gross domestic product rises, initially, under the export scenarios, but it falls (due to higher prices).

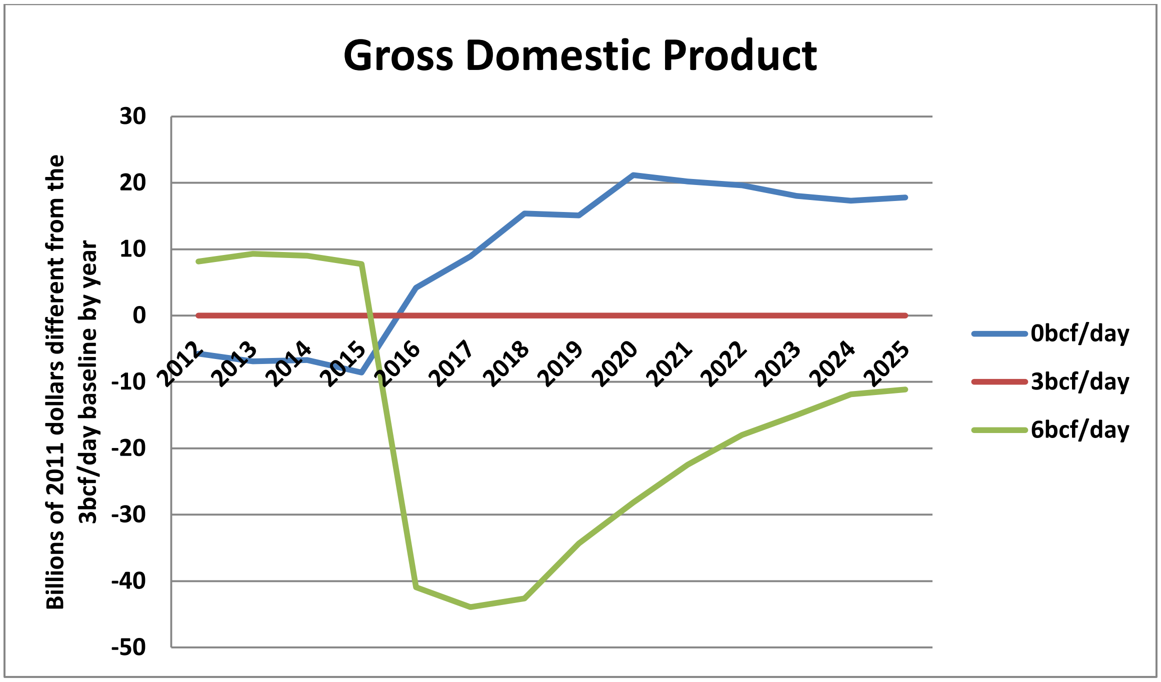


Figure 3.9 – This is the same graph, only showing the percentage change of the two alternative scenarios, relative to the 3bcf/day baseline. Historical growth rates suggest the United States' economy will rise from approximately $15 trillion at current date to around $22 trillion by 2025. Out of that growth, LNG exports of these scales and price changes have the potential to influence total growth between 0.1% and 0.2%. Hence, this is a considerable impact given the size of the whole economy, but other factors will influence major growth numbers over the next fifteen years.

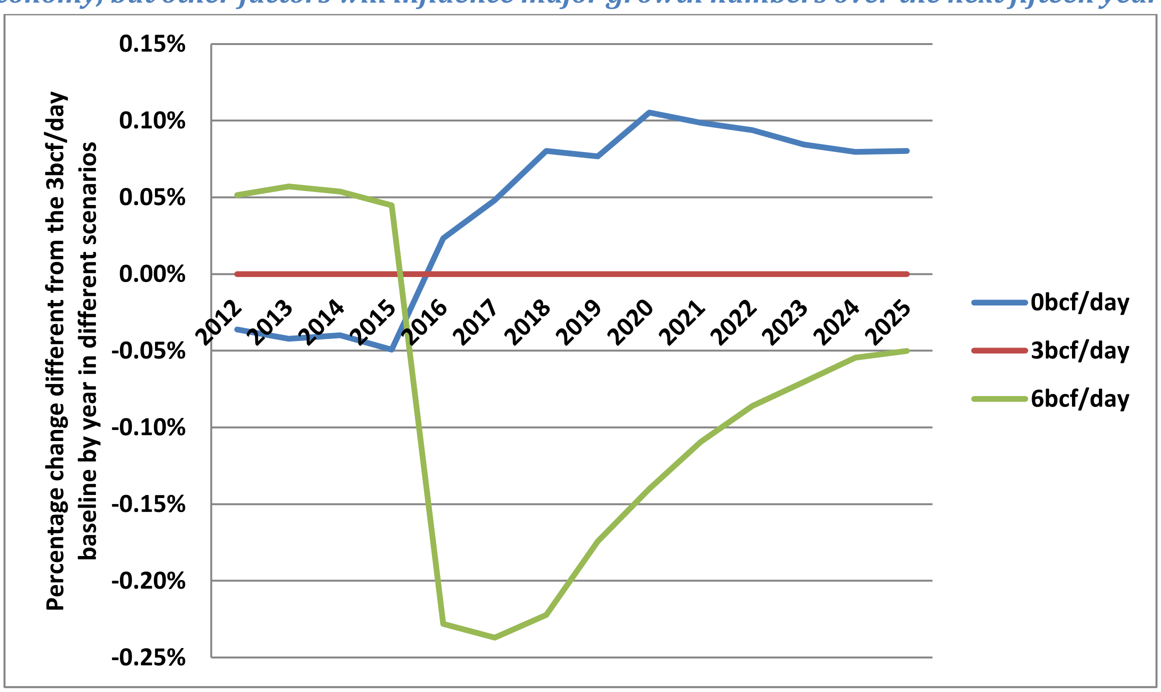


Figure 3.10 – These are—out of the gross domestic product component—the impacts of the LNG cases on real disposable personal income (RDPI). Taking the national population forecast, we divided the total change in real disposable income to find the per capita impact. The price index in the model takes account of our exogenous changes to natural gas prices from our own modeling. Interestingly, RDPI per capita does not change much per capita between the 3bcf/day and 6bcf/day scenarios, though the 0bcf/day scenario has low enough prices to increase price-adjusted income.

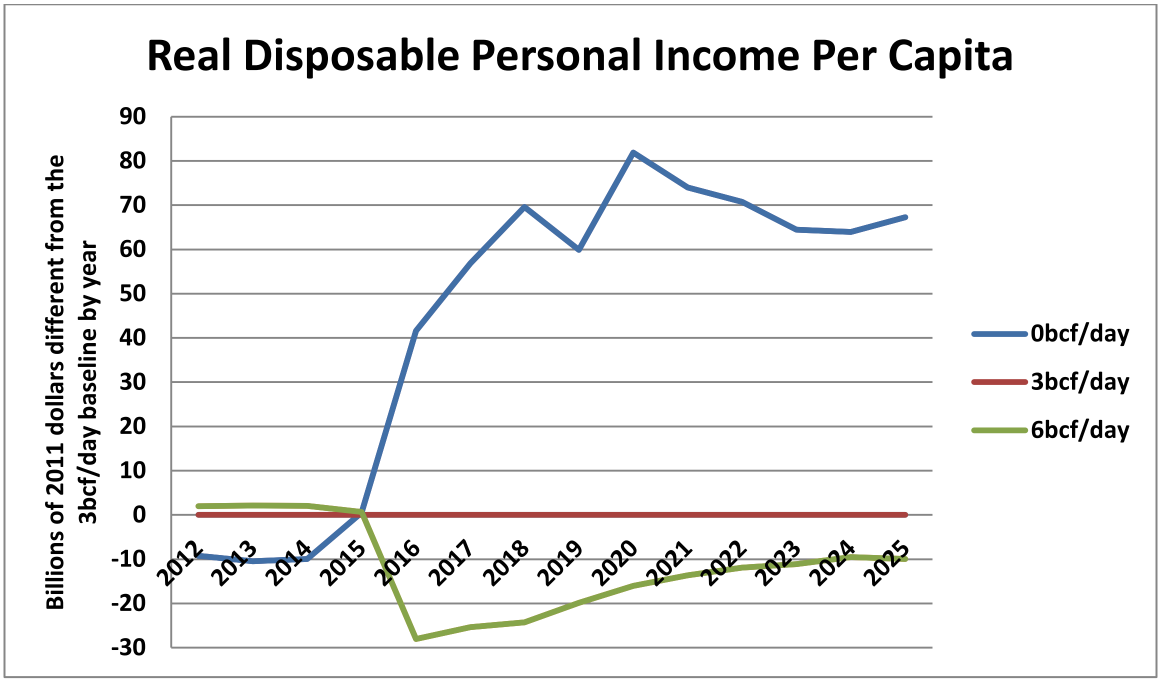
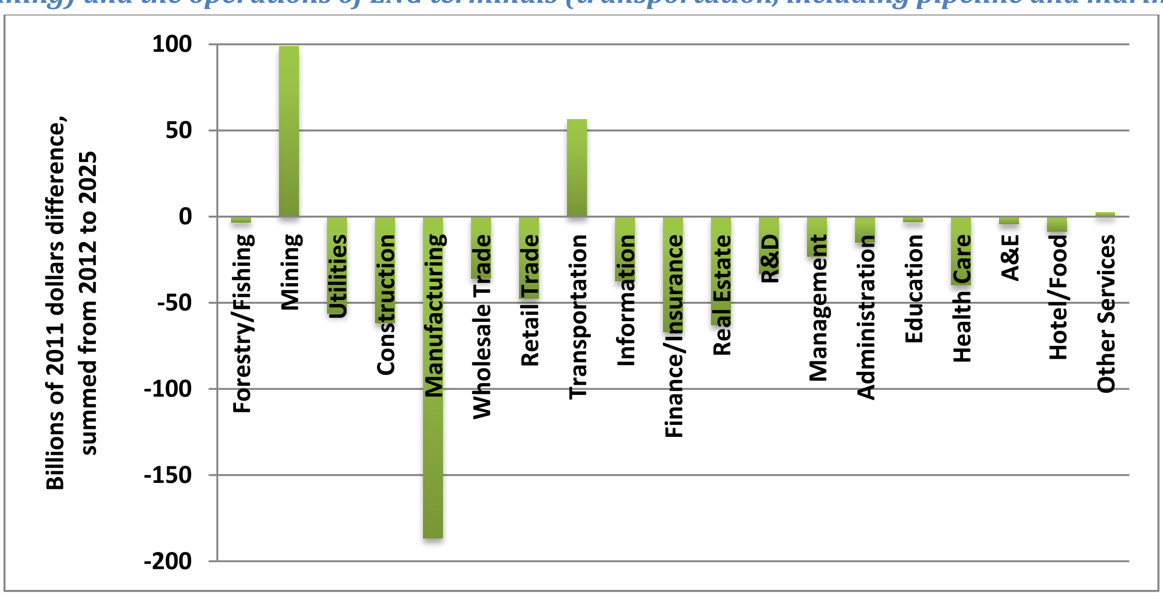


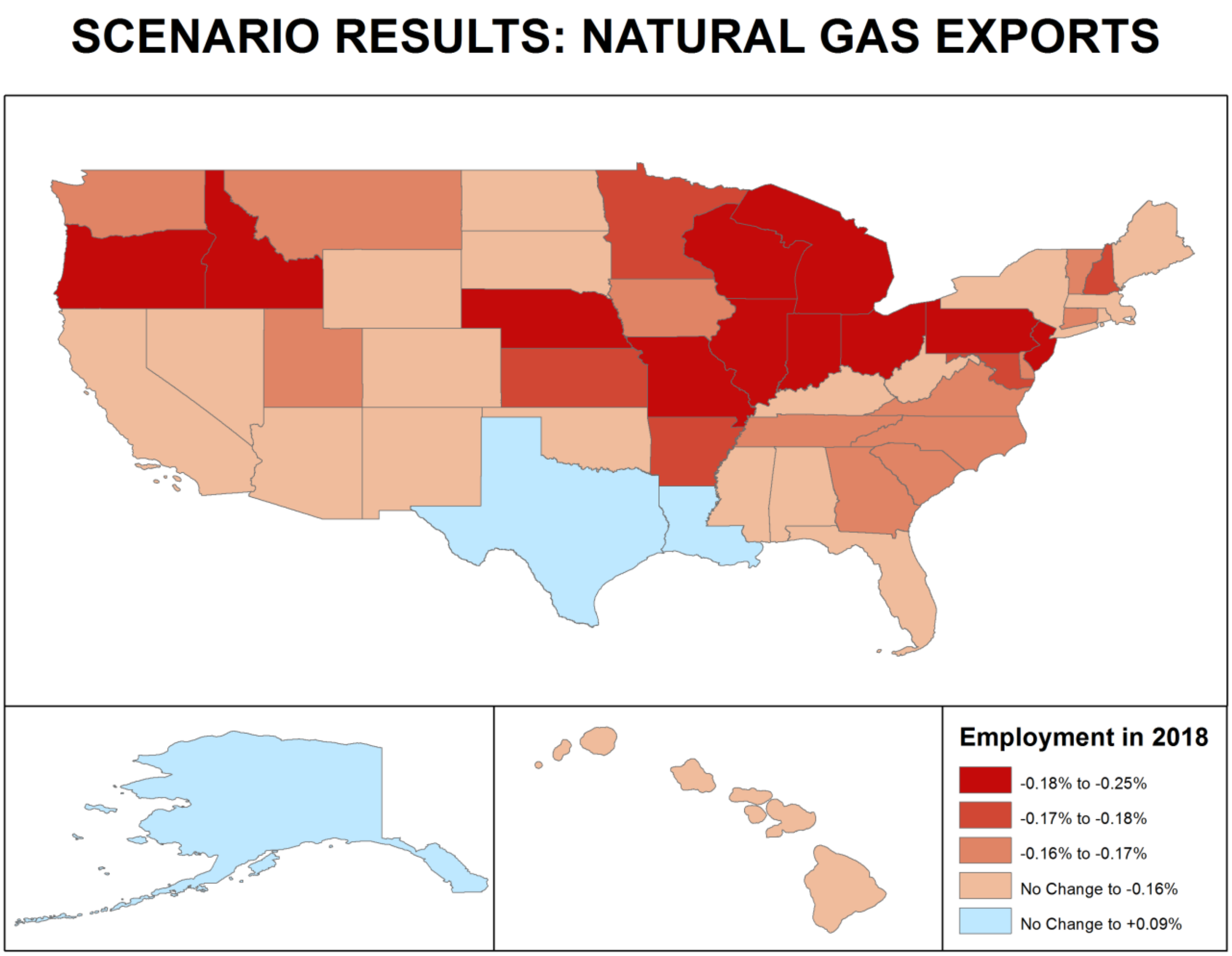
Figure 3.11 – This chart below shows the effect of the LNG exports on private, non-farm industry sales/output at the two-digit NAICS, summed from 2012 to 2025. The numbers show the output lost by moving from the 0bcf/day scenario to the 6bcf/day one. Most industries, particularly utilities, construction, and manufacturing lose this output from decreased competitiveness in the face of higher natural gas input prices. A few industries, however, benefit, owing to the increase in reinvestment (mining) and the operations of LNG terminals (transportation, including pipeline and marine).



Geographic Distribution

Given the differences in potential impacts across scenarios for gas prices, total employment, macroeconomic performance, and between different industries, it should not be a surprise that the impacts of LNG exports vary greatly by state and region. The primary beneficiaries of the policy are Texas and Louisiana. Both states, and especially Texas, have large sectors and clusters connected to the oil and gas industries. Louisiana is the location of the Sabine Pass facility, and Texas will provide much of the pipeline transportation, water transportation, professional services, and technical expertise to operate the new LNG export sub-industry in the United States. Alaska sees a similar benefit, given that historical patterns indicate that many of the extra dollars earned from the exports will make their way to Alaskan lands for future fossil fuel exploration. Other states, like California, New York, Illinois, and Texas have large financial sectors and concentrations of high-income workers and investors, and they will see a disproportionate share of the benefits. The benefits concentrate in these states, while the negative impacts appear in more inland, manufacturing states.

Figure 3.12 – This heat map shows the relative distribution of the impacts from LNG exports. This is the employment impact from the 3bcf/day case moving to 6bcf/day. We chose 2018 to show the height of the impacts before the economy begins to reallocate resources and "recover" from the initial price shocks in the late 2010s and early 2020s. The red states see a slowdown in their growth rates from LNG exports, while the blue states on the Gulf Coast see acceleration, relative to baseline.



The economic impact of LNG exports was slightly negative in the macroeconomic sense on the national scale. Hence, if a few states like Texas and Louisiana are gaining, then a balance of other states must have some loss to compensate. In these simulations, those states are concentrated in the Midwest around the Great Lakes. These states still have strong manufacturing bases, and they rely heavily on natural gas as an input to their production. Increasing natural gas prices in North America will impact these areas and their industries more strongly than other places. Conversely, over time, they will begin to shift to petroleum-based or bio-fuels inputs in response to higher gas prices, which explains the “bending of the curves” above and a recovery back to the baseline. Many states, however, are relatively indifferent to the prospect of LNG exports, including California, much of the Mountain West, the Great Plains, and many of the states of the Southeast. Hawaii is not a part of the North American natural gas grid, and it feels no direct price impact from these programs. It does receive a great deal of government and tourist spending from the mainland though. This means that developments in the continental United States will still make their way back to the Hawaiian economy.

Conclusion

This paper presents integration between the PI^+ and GPCM models using the test case of LNG exports. PI^+ is a macroeconomic model of the United States with regional breakdowns for counties or states. It is a combined model of input-output, econometric, computable general equilibrium, and New Economic geography concepts, and it is meant to generate realistic, year-to-year, economic impacts of policies and projects on an economy. GPCM is a network model of the North American gas grid, which represents the interactions between buyers, sellers, intermediaries, and transportation throughout the United States, Canada, and Mexico. Here, we used information from the two models to improve the impacts and forecasts of the two. The regional economic model provided information about macroeconomic, industrial, and demographic growth to drive the demand forecast of the gas network model, which provided information about relative prices and investment for the economic model. Iterating between the two, we closed the loop and ran simulations to illustrate the impacts of planned and potential LNG export facilities on the United States’ economy.

LNG exports will have a mixed impact on the economy depending on the perspectives for time, industry, and region. We ran three scenarios: 0bcf/day to assume and examine no exports, 3bcf/day of baseline, and 6bcf/day of higher exports. In regards to time, more exports generally lead to positive economic impacts in the short-run (from expanded infrastructure investments), but negative impacts over time as higher prices drive down competitiveness. This manifests strongly in manufacturing industries and in states concentrated along the upper Mississippi River and the Ohio River. Some states, however, see gains from the additional exports, producer surpluses, and reinvestment, especially on the Gulf Coast and in Alaska. Other regions in the United States and the service sector do not have a strong impact in either direction through the three cases. We do not wish or find grounds to advocate for LNG exports in either direction here. The policy decision for both private industry and policymakers should come down to multifaceted considerations, and they should consider environmental and other issues beyond the purely economic ones here. LNG exports hold some promise for the United States’ economy, and impacts may change over time beyond 2025 and as the economy and the gas industry continues to evolve past 2012 and into the next decade.