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 it with permission.
Overview

The issue of liquefied natural gas (LNG) exports is a complicated, but crucial, 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. Low natural gas prices have recently slowed the rate of exploration and drilling for new wells; 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, 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.

Several projects are proceeding for LNG exports in North America. These include the Sabine Pass facility in Cameron Parish, LA, owned by Cheniere Energy. 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. 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.

These projects are not without their controversies. Prices are low in the United States, but the introduction of demand from export terminals to the North American market has a potential to increase domestic prices. These price changes may 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). 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.” Political concerns on the economic impact of LNG exports make this issue into a public policy discussion on its broader implications.

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, Deloitte, and the United States Energy Information Administration. 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.

<table>
<thead>
<tr>
<th>Study</th>
<th>Average price without exports ($/MMBtu)</th>
<th>Average price with exports ($/MMBtu)</th>
<th>Average price increase (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIA</td>
<td>$5.28</td>
<td>$5.78</td>
<td>9%</td>
</tr>
<tr>
<td>Deloitte</td>
<td>$7.09</td>
<td>$7.21</td>
<td>2%</td>
</tr>
<tr>
<td>ICF</td>
<td>$5.81</td>
<td>$6.45</td>
<td>11%</td>
</tr>
<tr>
<td>Navigant</td>
<td>$5.67</td>
<td>$6.01</td>
<td>6%</td>
</tr>
</tbody>
</table>

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

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16 Ebinger et al, p. 33
loss of jobs.”\textsuperscript{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.”\textsuperscript{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.”\textsuperscript{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.\textsuperscript{20}

Here, we present an integration to do just that. With complementary models, PI\textsuperscript{+} 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 and macroeconomy—to model the issues discussed, but never examined in full, by the previous literature. Additionally, our study will include “macroeconomic feedback” iteration between the two models, because price/cost changes will change regional development.

\textbf{Figure 1.2} – This shows the iterations between PI\textsuperscript{+} 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. 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

\begin{itemize}
\item 17 Deloitte, p. 13
\item 18 Ibid.
\item 19 Ebinger et al, p. 36
\item 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).
\end{itemize}
the United States (plus the District of Columbia), NAICS industries,\textsuperscript{21} SOC occupations,\textsuperscript{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. 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\textsuperscript{+}

REMI PI\textsuperscript{+}, 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.\textsuperscript{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),\textsuperscript{24} Bureau of Labor Statistics (BLS),\textsuperscript{25} U.S. Census Bureau,\textsuperscript{26} the Energy Information Administration (EIA),\textsuperscript{27} and the Research Seminar in Quantitative Economics (RSQE)\textsuperscript{28} at the University of Michigan.\textsuperscript{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


\textsuperscript{23} This corresponds, roughly, to the four-digit NAICS classification. There are some aggregations, particularly in the retail sector. Please see “Industries for PI\textsuperscript{+} 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


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, and the time “lags” for an economy to return to stability after an exogenous shock. The CGE component of the model addresses the long-term, 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. 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 markets, housing and costs of living, and production costs for businesses. These merge 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.

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.

Network Model

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.**

**GPCM Constraints**

**Rules for Market Clearing**

1) At each node

\[
\text{Flow in} = \text{Flow out}
\]

2) \( \text{Origin Flow} \)

\[ \text{Fuel Loss} = \text{Origin Flow} - \text{Dest Flow} \]

(occurs only on arc)

3) \( \text{Flow} \)

\[ \text{LB, UB, Cost} \]

3a) If \( LB < \text{Flow} < UB \) then \( P_i = \text{Flow} + \text{Cost} \)

3b) If \( P_j > \text{Flow} + \text{Cost} \) then \( \text{Flow} = UB \)

3c) If \( P_j < \text{Flow} + \text{Cost} \) then \( \text{Flow} = LB \)

where \( P_i = \text{price at node i, P}_j = \text{price at node j} \)

3d) \( R = P_j - (\text{Flow} + \text{Cost}) \)

3e) If \( R > 0 \), then \( R = \text{marginal value of increasing the UB.} \)

3f) If \( R < 0 \), then \( R = \text{marginal cost of increasing the LB}. \)

**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 relocate 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.*

<table>
<thead>
<tr>
<th>Data from PI’ into GPCM</th>
<th>Data from GPCM into PI’+</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Gross domestic product ($)</td>
<td>• Natural gas prices for commercial, industrial, residential, and utility sectors</td>
</tr>
<tr>
<td>• Gross manufacturing product ($)</td>
<td>• Demand for natural gas-fueled vehicles</td>
</tr>
<tr>
<td>• Population (persons)</td>
<td>• Production information for natural gas</td>
</tr>
<tr>
<td>• Real disposable personal income ($)</td>
<td>• Volume information for LNG exports</td>
</tr>
<tr>
<td>• Electrical power generation (GW-h)</td>
<td></td>
</tr>
</tbody>
</table>

Furthermore, we expanded the scope of this impact study to include 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 savings rates, capital costs, and self-financing of projects from profits), direct reinvestment of producers’ surpluses into oil and gas exploration and drilling, and increased shareholder income, household wealth, and therefore (at some point) 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 to create a wealth effect in the economy. 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 forecast.


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 exploitation 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.

Gas firms uninvolved in the direct business of LNG exports will still experience change to their profit margins and behaviors from the rate of exports. Adding 3bcf/day or 6bcf/day of additional demand to the North American natural gas grid will, from an aggregate perspective, shift the market’s demand curve to the right and drive prices upwards. Assuming no change in producers’ marginal cost of production, this will increase the profit margin for the competitive producers. We estimated this amount with the following equation:

$$\Delta \pi_T = (P_{S,T} - P_{IRR,B}) \times Q_{S,T}$$

$$\Delta \pi_T$$ = dollar change in aggregate profit margin for industry in response to price changes by year (“T”)

$$P_{S,T}$$ = forecasted gas price, by state (“S”) and year (“T”) from GPCM

$$P_{IRR,B}$$ = the “breakeven point” for gas prices with an expected 10% internal rate-of-return by basin38

$$Q_{S,T}$$ = forecasted gas production in physical units, by state (“S”) and year (“T”) from GPCM

Thereby, $$(P_S - P_{IRR,B})$$ is the average rate of return for an individual unit of gas

GPCM provides price and production data on the state-level in this simulation, which we then converted into average profit levels per unit of production. The breakeven point data was on a basin-level; hence, we sorted the various states into the Mid-Continent, Rockies, and Northeastern basins. This yields a difference in the expectations of industry profits. We reentered these back into the macroeconomic model with the same methodology as we did with the profit margins from the LNG exports themselves (after adjusting the anticipated export margins out of the total margins above). Low prices in the near future will lead to less direct investment and less of a wealth effect, while higher prices in the future would reverse this trend.

For most states, $$(P_S - P_{IRR,B})$$ is currently less than zero, and it looks to stay that way for the immediate future. This is consistent with the current state of the industry. Chesapeake Energy, for example, had to begin to sell assets like mineral leases and pipelines through the summer of 2012 to stay afloat, unable to garner a positive


35 Ibid., p. 30


37 Ibid.

return with prices being low. The CEO of ExxonMobil, Rex Tillerson, reported in regards to the company’s natural gas holdings and assets, “We are losing our shirts today... We’re making no money. It’s all in the red.” The giant ExxonMobil and smaller players in the market (including Chesapeake Energy and Cheniere Energy) are depending on increased LNG exports to boost prices in North America, and therefore restore their general operations back to profitability without causing large shutdowns or bankruptcies. This is an important effect from a macroeconomic perspective, and we have illustrated it in the aggregate using the equation for $\Delta \pi_T$. Ironically, there may be instances where higher natural gas prices are better for the economy, in light of the complex tradeoffs between operations, investments, the financial health of the industry, and the general benefit of lower prices for business and household customers in various regions.

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 models and user-generated assumptions, these results quantify the major economic factors involved in it. The model integration leads to a combined and consistent forecast with similar assumptions between the two.

### 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 a 3bcf/day case (the baseline) and two 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 between the different cases.

- **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 representation

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41 Ibid.
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. 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. 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.

*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.*

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**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 in the chart below.

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

The employment impact of LNG exports is a complicated interaction between several factors. Unsurprisingly, on its own, increasing natural gas prices in the United States by 5% to 10% (depending on the region, the year, and the exact scenario) increases business costs and the general cost of living to the point of causing a loss of total employment. However, the United States’ economy is a dynamic one, and impacts vary across the many states depending on their preexisting fuel preferences, industry combinations, household consumption patterns, and the rate they tend to prospect for natural gas. The patterns of redistribution and the wealth effect from an increase or decrease in shareholder or dividend income matters, as well. PI* and GPCM are dynamic models in the sense they display results and simulate over time, so chronology is another important factor in this study. Initial impacts may be more positive or more negative, but the movement of labor and capital (which affects the economy and the demand forecast for natural gas) will change the overall impact for time. Impacts tend to be stronger in the initial years, too, given that an economy tends to return to a more general equilibrium over time after a given shock in prices or investment.
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.\textsuperscript{44} 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.

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.

The employment impacts from LNG exports vary based on the year and the scenario. There is a small bump in the initial years from 2013 to 2014 for the investments in export terminals on the Gulf Coast and the Atlantic Ocean, but the operations phase (and large price changes) throughout the economy engender the largest of the impacts. Unsurprisingly, on their own, higher gas prices of 5% to 10% depending on the time and the region will increase the cost of living and doing business in the United States and cause a net loss of employment. However, the United States’ economy is a dynamic one, and the impacts depend on preexisting fuel mixtures, household consumption, industry combinations, and the ability of agents to adjust over time. Here, higher prices for gas will lead to the 75% and 25% mixture of reinvestment and a wealth effect, which generates a positive overall employment impact from the exports. Over time, the concentration of wealth and resources into infrastructure and gas development projects causes the costs of capital and labor to rise throughout the economy, which causes the downward trend (in the 6bcf/day scenario) compared to the baseline.

LNG exports have a broad socioeconomic impact. They concentrate the most in fields related to construction, extraction, and even manufacturing over service-related trades. Fields that support that sort of “direct action,” which includes design and management, also have a relatively larger impact than in the service trades. On the whole, though, healthcare, legal, and other professional and businesses services do not have a large impact from this change, which insulates much of the non-energy economy from this policy’s impacts.

**Figure 3.7 – This table shows the difference in labor demand between the 3bcf/day baseline and the 6bcf/day alternative case in 2025. For instance, it illustrates that the total number of job-years for legal occupations is approximately 0.07% higher in 2025 for the higher export scenario than the base. The largest impact is in the construction and extraction field, though there are impacts throughout the distribution of possible careers and fields in the United States’ economy.**
Macroeconomic Impacts

From a macroeconomic perspective, LNG exports generate a similar pattern and scale as the jobs impact in the previous section. Gross domestic product initially rises under the 3bcf/day and 6bcf/day cases, and it rises further when the price changes take their net effect throughout the economy. The initial shock is temporary, though, and the economy readjusts itself in the face of higher labor, capital, and fuel costs into different industries and an overall smaller output given an increased scarcity of resources. From a policymaking or an industry perspective, the question becomes a point of the distribution of the impacts (between different market players, occupations, states, and households) and the timeline. The macroeconomic benefits of initial construction are small in a relative sense, though the overall benefits of expanding gas production and the expansion of that industry may be considerable in the 2010s and early 2020s. These are, of course, important in an economy that maintains an 8.3% unemployment rate into 2012.\textsuperscript{45} 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 is not large, and other major conditions will determine the trajectory of the United States’ economy to 2025.

\textit{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.}

The macroeconomic impact of exports is positive but not extremely large. For context, historical growth rates suggest the United States’ economy will expand from approximately $15 trillion today to around $22 trillion (real) by 2025. Out of that growth, these impacts from LNG exports at these scales and these price changes have the potential to influence total growth between 0.1% and 0.2%. With those numbers in mind, for example, $30 billion is 0.2% of $15 trillion. The “peak” impact of LNG exports that we forecast is for 6bcf/day over 3bcf/day in 2016, which is around a 0.15% difference in GDP. This positive impact from the exports to gross product is consistent with other researchers in the literature who found a benefit from these projects for the American economy.\textsuperscript{46} Notably, exports will draw money \textit{into} the United States, which then recycles in the economy to


\textsuperscript{46} Ebinger et al, pp. 36-37
generate its own activity and additional product. This is a considerable impact given the total size of the American economy, but it is not a huge determinant of future growth patterns.

**Figure 3.9**—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. The economy expands with greater exports, but mostly in the investment portion of gross domestic product. Higher prices reduce the real value of the remaining consumer spending faster than increased employment opportunities can make up the difference, as seen in this graphic here.

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**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. Texas stands to gain much of the future exploration from increase investment in the Eagle Ford and other large formations. 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 3.10 – This map shows the relative distribution of LNG exports by state. This is the intensity of the impact, measured by the percentage change in RDPI, of moving from the 3bcf/day scenario to the 6bcf/day scenario. This is in 2018, to show the “peak” of the impacts before the economy has time to reallocate resources or move population from area-to-area and “recover” from the price shocks of the 2010s. The bluer states see the fastest acceleration of their growth (Louisiana is the highest, with a +2.63% impact) while paler states see a slowdown or reduction (Ohio is the slowest at -0.43%). Colorado and Florida are the median states, being near a 0.0% impact from the increase in LNG. Alaska is generally positive and Hawaii is generally negative from lost tourism dollars.

The economic impact of LNG exports was slightly positive 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, and 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), and continued positive impacts over time as higher prices drive down competitiveness but up other factors in the economy like shareholder income and a wealth effect from households. Some states 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. Further regions have a negative impact from the LNG exports effect of higher gas prices, given their need for gas as a factor input. This manifests strongly in manufacturing industries and in states concentrated along the upper Mississippi River and the Ohio River. 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.