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The economic viability of gas-to-liquids technology and the crude oil–natural gas price relationship

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ABSTRACT

This paper explores the viability of a gas-to-liquids (GTL) technology and examines how GTL penetration could shape the evolution of the crude oil–natural gas price ratio. Much research has established the cointegrated relationship between crude oil and natural gas prices in the U.S. The persistently low U.S. natural gas prices in recent years seem to mark a shift in this relationship, and have led some in industry to begin considering investments in GTL capacity in the US. In order to look forward over decades when the underlying economic drivers may be outside of historical experience, we use a computable general equilibrium model of the global economy to evaluate the economic viability of GTL and its impact on the evolution of the crude oil–natural gas price ratio. Our results are negative for the potential role of GTL. In order to produce any meaningful penetration of GTL, we find it necessary to evaluate scenarios that seem extreme. With any carbon cap GTL is not viable. Moreover, even without a carbon cap of any kind, extremely optimistic assumptions about (i) the cost and efficiency of GTL technology and about (ii) the available resource base of natural gas and the cost of extraction, before the technology penetrates and it impacts the evolution of the crude oil–natural gas price ratio.

1. Introduction

Gas-to-liquids (GTL) is an old technology dating back to the start of the 20th century. It is an alternative to the production of liquids from crude, and therefore its economic viability has depended on the relative cost of crude oil and natural gas. The wide availability of inexpensive crude oil throughout the 20th century undercut commercial interest in GTL outside of a few special situations. In the 1990s, the discovery of numerous stranded gas fields sparked a push to commercialize GTL plants: stranded gas is, by definition, relatively cheap because it does not have the means to move to the places of the high-price demand. Two of the most important plants currently in operation, the Oryx and Pearl plants in Ras Laffan, Qatar were built to utilize gas from Qatar's massive North field. A number of other plants proposed for stranded gas fields were ultimately either shelved or delayed, but Shell now operates a plant in Bintulu, Malaysia, a partnership led by SASOL operates one in Uzbekistan, and Chevron operates one in Escravos, Nigeria. Interest in the U.S. has arisen recently in the wake of the expanded availability of very inexpensive natural gas. A number of proposed plants have been announced in press releases, although none are yet actually under construction.

Looking past the enormous short-term volatility in crude oil and natural gas prices, industry professionals and econometricians have identified a long-term tie between the two prices: see for example, the cointegration analysis of Serletis and Herbert (1999), Bachmeier and Griffin (2006), Asche et al. (2006), Villar and Joutz (2006), Brown and Yucel (2008), Hartley et al. (2008), Ramberg and Parsons (2012), Loungani and Matsumoto (2012), and Brigida (2014). Industry professionals express this tie with a number of different rules-of-thumb or benchmarks. The simplest among them is the 10-to-1 rule: the crude oil price in the U.S. (expressed in dollars per barrel) should roughly equal 10 times the natural gas price in the U.S. (expressed in dollars per MMBtu). Since 2005, the actual ratio has been above this benchmark more often than not, and since late 2008 it has persistently been well above it. This represents a real shift in the tie as documented in Ramberg and Parsons (2012), Loungani and Matsumoto (2012) and Brigida (2014), and it is this shift in the long-term price relationship that lies behind the increased interest in GTL in the U.S.

All of these statistical analyses are backward looking by their nature. New capital investments in GTL need to demonstrate their profitability on a forward looking basis. Can an investor expect that the ratio of crude oil and natural gas price will continue to be as high as it has been recently? Or, should she expect it to revert to its old level? Many factors help to

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determine the relationship between the two price series, and these factors change over time. Indeed, some of the statistical work on the cointegration relationship have documented the role of technology change in moving the benchmark—for example, Hartley et al. (2008) document that the introduction of combined cycle natural gas power plants increased the demand for natural gas and therefore shifted the benchmark ratio down. See also Serletis and Rangel-Ruiz (2004). How will the evolving equilibrium in supply and demand for each fuel change as the global economy develops, and how will this move the equilibrium price ratio and the profitability of GTL? How will constraints on carbon emissions shape this equilibrium price ratio and the profitability of GTL?

To address these questions, we use a computable general equilibrium (CGE) model of the global economy to analyze the penetration of the GTL technology under different scenarios for several underlying economic drivers. We also use the model to analyze the impact of the GTL technology on the price ratio by contrasting how the ratio evolves differently depending upon the efficiency of GTL and therefore its ability to penetrate as prices shift. Of course, the CGE model is not a crystal ball telling us what the future will bring. But it is a useful tool for analyzing in a rigorous fashion different constellations of assumptions about key drivers—scenarios—and how each shapes and constrains the total economic picture in equilibrium. The exercise can help us to think through the scenarios that might be consistent with economically rational expansion of GTL and the scenarios that are not consistent with it. And the exercise can help us understand how the crude oil and natural gas price ratio evolves in each scenario, shaped in part by the availability of GTL, but also by other drivers.

The structure of the remainder of this paper is as follows: Section 2 presents our parameterization of a GTL technology and the CGE model in which we embed it. Section 3 discusses our choice of scenarios and analyzes the penetration of GTL under each scenario. Section 4 concludes.

2. A CGE model with a GTL technology

2.1. The GTL technology

There are a number of GTL technology formats under development. Most make diesel or other distillate fuels, but some make gasoline (Greene, 1999; Robertson, 1999; Knott, 2002; Cohn and Bromberg, 2011). Only the diesel/petrochemical feedstock versions have been proven economic —at least on a large scale (Simbeck and Wilhelm, 2007; Hydrocarbons Technology, 2010b; Shell Global, 2011); the gasoline-producing version of the technology has not left the laboratory (Cohn and Bromberg, 2011). Accordingly, we model the less costly diesel-producing version.

GTL efficiency and cost data were compiled in Ramberg (2015) from an array of studies and reports. We assume GTL produces a perfect substitute for petroleum-based diesel fuels and petrochemical feedstocks. Indeed, the higher cetane rating of GTL diesel puts it on par with gasoline in terms of performance (Sasol, 2011; Eudy et al., 2005; Greene, 1999). In addition, GTL diesel produces significantly less particulate matter, carbon monoxide, NOx and volatile organic compounds than ultra-low sulfur diesel (Delucchi, 1997; Greene, 1999; Schaberg et al., 1997, 2006; Martin et al., 1997; Wang and Huang, 1999; Five Winds International, 2004; Perego et al., 2009). However, GTL produces significantly greater CO_2 emissions than crude oil refining. In part, this is due to the relatively low thermal efficiency of GTL. Under current technology, nearly 10 MMBtu of natural gas is required to produce an average barrel that is 70% diesel and 30% naphtha. This representative barrel contains about 5.5 MMBtu of energy, meaning that GTL is only 56% efficient. In contrast, crude oil refining can reach a thermal efficiency near 90%.

Table 1 shows the lowest and highest values encountered in the source literature for key parameters such as capital cost, fixed and variable operations and maintenance (O&M) costs, labor costs, and natural gas inputs per barrel of output reflecting a plant of the scale of the Shell Pearl GTL plant in Qatar: 120,000 barrels per day of output, of which 70% are diesel fuels and 30% are petrochemical feedstocks—see Pintz (1997), Choi (1998), Greene (1999), Robertson (1999), Wang and Huang (1999), Wallace et al. (2001), Halstead (2006), Gary et al. (2007), Simbeck and Wilhelm (2007), Slaughter et al. (2007), Taylor et al. (2008), Hydrocarbons Technology (2010a, 2010b), IEA (2010b), Rapier (2010), Bala-Gbogbo (2011), Lefebvre (2011), Liu et al. (2011), Shell Global (2011), Shaw (2012), Salehi et al. (2013), and Atuanya (2014).

Table 1
Key parameters of base case GTL plant.

Parameter	Value	Low	High
Capital cost per b/d capacity	$68,000	$13,000	$303,000
Fixed O&M cost per year	4% CAPEX	4% CAPEX	4% CAPEX
Variable O&M per barrel produced	$5.00	$3.13	$23.00
Gas input rate, MMBtu per barrel produced	9.85	8.8	14.13
Plant capacity, b/d	120,000	1000	300,000
Capacity utilization	93%	87%	96%
Project lifespan	25 years	20 years	30 years
Construction lead time	3 years	2 years	5 years
Tax rate (assumed)	35%	NA	NA
Debt financing (assumed)	0%	NA	NA
Discount rate (assumed)	10%	NA	NA

There is a wide range between the high and low estimates, which reflect various assumptions and technological specifications. Table 1 also shows the central figures chosen as the base case assumptions for our modeling which reflect the cost of GTL as currently deployed in the handful of commercial scale plants in operation.

It is useful to translate these assumptions into some simple cost benchmarks using a discounted cash flow calculation. Construction and operation of the base case GTL plant incurs a levelized cost of $42.39/bbl of output before natural gas feedstock costs are taken into consideration. The feedstock cost obviously varies with the price of natural gas. With a feedstock requirement of 9.85 MMBtu per barrel of output, and applying a natural gas price varying from $2.00/MMBtu to $5.00/MMBtu to $8.00/MMBtu, the levelized feedstock cost ranges, respectively, from $19.70/bbl of output to $49.25/bbl to $78.80/bbl. The total levelized cost therefore ranges from $62.09/bbl of output to $91.64/bbl to $121.19/bbl.

These figures show how challenging it is for GTL to be a profitable choice. Consider, for example, the situation in 2007, when the price of natural gas in the U.S. averaged $6.75/MMBtu, the price of diesel averaged $49.89/bbl, and the price of petrochemical feedstock averaged $102.60/bbl, yielding a weighted price of a barrel of diesel/petrochemical feedstock of $65.66 (EIA, 2014). The corresponding levelized cost of the GTL output would have been $101.51/bbl, so that the process would have made a loss of $35.85/bbl or $9.96 billion if these prices were to hold over the 25-year lifetime of the plant. Or consider, for example, the more favorable situation in 2015 when the price of natural gas in the U.S. averaged a much lower $2.62/MMBtu (EIA, 2016a), the price of diesel averaged $68.46/bbl (EIA, 2016b), and the price of petrochemical feedstock averaged $80.78/bbl (EIA, 2014, 2016b), yielding a weighted price of a barrel of diesel/petrochemical feedstock of $72.16. The corresponding levelized cost of the GTL output would have been $77.06/bbl, so that the process would have made a smaller loss of $4.90/bbl or $1.36 billion if these prices were to hold over the 25-year lifetime of the plant. Therefore, for our base case cost numbers, in order for an investor to confidently invest in GTL, she would need to anticipate either a reliably lower price of feedstock or a reliably greater product price than in the recent period. Alternatively, she would need to anticipate GTL costs that are lower than our base case.

2.2. Embedding GTL in a CGE model

We embed this technology into the computable general equilibrium (CGE) model EPPA6-ROIL, developed at the MIT Joint Program on the