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Leveling the playing field of transportation fuels: Accounting for indirect emissions of natural gas

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HIGHLIGHTS

- Natural gas used in transport causes indirect emissions in the electricity sector.
- These emissions result from increased coal use in electricity generation.
- They rival in magnitude indirect land use change (ILUC) emissions of biofuels.
- Natural gas fuels are estimated to be as carbon intensive as the petroleum fuels.
- Policy ignores indirect emissions from natural gas.

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ABSTRACT

Natural gas transportation fuels are credited in prior studies with greenhouse gas emissions savings relative to petroleum-based fuels and relative to the total emissions of biofuels. These analyses, however, overlook a source of potentially large indirect emissions from natural gas transportation fuels, namely the emissions from incremental coal-fired generation caused by price-induced substitutions away from natural-gas-fired electricity generation. Because coal-fired generation emits substantially more greenhouse gases and criteria air pollutants than natural-gas-fired generation, this indirect coal-use change effect diminishes potential emissions savings from natural gas transportation fuels. Estimates from a parameterized multi-market model suggest the indirect coal-use change effect rivals in magnitude the indirect land-use change effect of biofuels and renders natural gas fuels as carbon intensive as petroleum fuels.

1. Introduction

Recent advances in shale gas production and growing demand for greenhouse gas emissions reductions have spurred interest in natural gas as a competitor to petroleum-based transportation fuels. Though natural gas presently powers a mere 394,000 light-duty vehicles and 40,000 heavy-duty vehicles in the U.S., its share of transportation fuel rivals electricity and its fleet far exceeds the electric vehicle fleet (EIA, 2015a).

Short-run substitutions to natural gas are constrained by limited refueling infrastructure and incompatible engine technology, yet natural gas vehicle fuel consumption is increasing, and, by one estimate, will globally displace 1.5 million barrels of oil per day by 2030 (IHS, 2015). Natural gas vehicle fuel consumption is expected to grow faster than any other transportation fuel to 2040 (EIA, 2015d, 2015e). Motivated largely by concern about climate impacts of gasoline and diesel combustion, policy in the U.S. and elsewhere endeavors to overcome obstacles to expanded natural gas use in transportation, a sector responsible for nearly one-third of anthropogenic greenhouse gas emissions in the U.S. (EPAct, 2005; Knittel, 2012; EPA, 2013b; Obama, 2014; EPA, 2012). Federal tax expenditures in the U.S., for instance, promote natural gas vehicle sales and refueling infrastructure investments. In his 2014 State of the Union address, U.S. President Barack Obama touted natural gas as a “bridge fuel that can power our economy with less of the carbon pollution that causes climate change”, and he advocated policy to “shift more cars and trucks from foreign oil to American natural gas”. Federal Corporate Average Fuel Economy standards also favor natural gas vehicles by allowing manufacturers to count each natural gas vehicle sale as more than one vehicle sale in its compliance calculations, effectively subsidizing natural gas vehicle

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production. States also grant natural gas vehicles access to high-occupancy-vehicle lanes and provide other incentives to encourage adoption of a technology that is generally considered to be less carbon-intensive than petroleum-based fuels combustion. These and other policies are catalogued in CRS (2014). Still, some analyses suggest policy is necessary to “level the playing field” of transportation fuels that disadvantages natural gas, e.g., Knittel (2012).

Compressed natural gas (CNG) and liquefied natural gas (LNG) fuels are typically ascribed lower life-cycle carbon emissions than gasoline and diesel, for which they respectively substitute (Burnham et al., 2011; Larive et al., 2011; Kyle and Kim, 2011; Stephenson et al., 2012; Chan et al., 2013; Nigro and Jiang, 2013; Ou and Zhang, 2013), though Tong et al. (2015a, 2015b) estimate greater emissions from natural gas than conventional fuels for all heavy-duty truck technologies and for some medium and light-duty truck technologies depending upon modeling assumptions. Natural gas emissions are also generally thought to be lower than the sum of direct and indirect emissions of biofuels from corn and soy (Fargione et al., 2008; Searchinger et al., 2008; ARB, 2009; Hertel et al., 2009; Laborde, 2011; European Commission, 2012; Khanna and Crago, 2012).

The conventional wisdom that natural gas is a clean, alternative transportation fuel implicitly assumes, however, the absence of considerable indirect emissions, like the indirect land-use change (ILUC) emissions of biofuels that have attracted considerable attention in scholarly research and policy making since 2008, e.g., Fargione et al. (2008), Searchinger et al. (2008), ARB (2009), Hertel et al. (2009), Lapola et al. (2010), Laborde (2011), European Commission (2012) and Khanna and Crago (2012). Despite the interest in indirect biofuel emissions, the indirect emissions from other fuels like natural gas have been virtually ignored. In fact, in implementing a first-of-its-kind low carbon fuel standard that relies upon accurate measures of carbon intensities across fuels, California regulators identified only land use change as a significant source of indirect emissions. This paper, however, presents a parameterized analytical model that estimates significant indirect emissions from CNG and LNG that are ignored in previous life cycle assessments and in existing policy. These indirect emissions are estimated to rival and even exceed the ILUC emissions of biofuels and to render natural gas fuels no less carbon intensive than the petroleum fuels they are intended to displace.

Intuitively, an exogenous increase in natural gas consumption in transportation due to policy, for instance, must be met by an increase in the quantity of natural gas supplied, a decrease in natural gas consumption elsewhere in the economy, or by some combination of supply-side and demand-side responses. If the increased demand for natural gas in transportation were fully met by an equivalent increase in natural gas production, i.e., if natural gas supply were perfectly elastic, then indirect emissions from natural gas would likely be nominal. If, however, the marginal cost of natural gas production increases in the quantity of production (so that natural gas supply is upward sloping in price-quantity space), as ample empirical evidence suggests, then increased demand for natural gas raises the price of natural gas (Brown and Krupnick, 2010; Arora, 2014; Ponce and Neumann, 2014; Hausman and Kellogg, 2015). Higher natural gas prices, in turn, induce substitutions to other, potentially dirtier energy feedstocks elsewhere in the economy, including in electricity generation.

Electricity generation is responsible for more than forty percent of natural gas consumption in the U.S. (EIA, 2013). As natural gas prices rise in response to increased demand for its use in transportation, power generators are expected to substitute away from natural-gas-fired electricity generation and toward generation from other feedstocks like coal. A number of life-cycle analyses have concluded that a typical coal plant emits considerably more greenhouse gases than a typical natural gas plant (Spath and Mann, 2000; Burnham et al., 2011; Fulton et al., 2011). A consequence of natural gas use in transportation, therefore, may be increased carbon emissions in power generation. While life-cycle emissions of electricity generation are estimated with uncertainty, much like the life-cycle emissions of transportation fuels, a 2011 Intergovernmental Panel on Climate Change (IPCC) review of more than 90 credible life-cycle assessments concluded that natural gas plants generate 53% fewer carbon dioxide-equivalent emissions than coal plants – 469 g per kilowatt-hour (kWh) versus 1001 g per kWh (von Stechow et al., 2011; Caulton et al., 2014). Coal plants also emit far greater quantities of criteria pollutants than natural gas plants. These include nitrous oxides, sulfur dioxide, and particulate matter that are deleterious to human health (Jaramillo et al., 2007).

Thus, an indirect effect of greater natural gas use in transportation is greater carbon and criteria pollutant emissions in the power sector. This effect is analogous to the well-studied and controversial ILUC effect of biofuels: greater demand for agricultural output raises the rental rate of cropland, which induces conversion of undeveloped land to farmland, releasing the carbon stored in the ground and biomass. To our knowledge, however, the magnitude of indirect coal-use change (ICUC) emissions from natural gas has not been previously estimated.

Were a global and economy-wide carbon price imposed to internalize the climate change externality posed by carbon emissions, e.g., via an optimal carbon tax or optimal tradable permit standard, then an accounting of indirect effects of natural gas use in transportation would be of little value to policy makers, as would be the analogous accounting for biofuels. Interest in the ILUC, however, derives from the implementation of second and third-best policies to promote low-carbon technologies, including low carbon fuel standards.

So long as carbon emissions are not priced appropriately across sectors and jurisdictions, and so long as planners pursue alternative carbon emissions abatement strategies, the ICUC is presumably as relevant to policy as is the ILUC. This is true even though some jurisdictions regulate carbon emissions in the electricity sector. Because natural gas flows relatively uninhibited within the U.S., and at greater cost, around the world, sub-national carbon policy is ineffective in avoiding indirect emissions from natural gas transportation use. The emissions leak from the regulated jurisdiction to unregulated jurisdictions. While direct emissions leakage in the electricity sector may be constrained by restrictions on electricity imports to the regulated jurisdiction, a sector-specific policy such as those in place today, cannot contain leakage in other sectors. Intuitively, if a unit of natural gas is used to power cars in a jurisdiction that prices carbon emissions in the electricity sector, e.g. California, it raises the price of natural gas to electricity generators in the regulated and unregulated jurisdictions. Substitutions toward coal will come from the unregulated jurisdictions where such substitutions are unencumbered by carbon policy imposed in the regulated jurisdictions.

This paper proceeds in turn to develop an analytical model of ICUC emissions, to calibrate and simulate the model, to consider key uncertainties in estimating indirect emissions, to discuss implications of the analysis, and to address limitations of the model before concluding.

2. A model of indirect emissions from natural gas

In order to estimate the magnitude of ICUC emissions, we develop and parameterize a multi-market model in which natural gas is produced according to an upward sloping supply function. It is demanded in the residential, commercial, industrial,