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The price and income elasticities of natural gas demand: International evidence

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ABSTRACT

Natural gas contributes a growing share of the world's energy mix. In this paper we use national-level data for a sample of 44 countries to estimate the price and income elasticities of natural gas demand. We present both single-equation results and results instrumenting natural gas prices with proved natural gas reserves. Our instrument includes both domestic reserves and distance-weighted reserves in other countries. We obtain estimates of the average long-run price elasticity of natural gas demand of around −1.25 and of the average long-run income elasticity of natural gas demand of +1 and higher. We also present separate estimates for final natural gas demand by industry and households.

1. Introduction

Natural gas contributed 21% of the global energy mix in 2013, up from 16% in 1971 (International Energy Agency [IEA], 2015a). There is sizeable variation in the importance of natural gas in national energy mixes, with both high-income countries and countries rich in natural gas deposits tending to be more reliant on this energy source (Burke, 2013). Relatively strong growth in natural gas use is expected over coming decades, with the IEA (2011) referring to a "golden age" for natural gas and expecting the fuel's share of the global energy mix to increase to 23–24% by 2040 in its "new policies" and "current policies" scenarios (IEA, 2015b). Recent booms in shale gas and coal seam gas are helping to fuel this expansion.

There are large differences in end-user natural gas prices between countries (Holz et al., 2015; Makholm, 2015). These result from the costs involved in transporting natural gas by pipeline or in liquefied form, local tax/subsidy policies, and other factors. The IEA (2015b) estimates that price subsidies for consumers of natural gas equaled $107 billion globally in 2014, more than half of which was in only four countries (Iran, Russia, the United Arab Emirates, and Saudi Arabia). Consumer subsidies for natural gas are a product of policies such as price regulations and domestic natural gas reservations.

Natural gas is composed mostly of methane (CH_4) but can also have proportions of ethane, propane, butane, pentane, carbon dioxide, nitrogen, hydrogen sulfide, and/or water. Humans use the fuel for heating, transport, industrial operations, electricity generation, and other purposes. Natural gas-fired electricity generation plants offer flexibility to the electricity generation system through relatively fast start-up and ramping speeds (Neumann and von Hirschhausen, 2015). Relative to coal and oil, natural gas is also associated with fewer emissions of carbon dioxide (CO_2) or local pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulates (IEA, 2011). Methane leakage during the extraction, processing, and transport of natural gas reduces its greenhouse benefits, however (Howarth, 2014). Transport costs mean that international trade in natural gas occurs within several regional markets, each with different prices (IEA, 2015b).

In this study we use national-level data for 44 countries over the period 1978–2011 to obtain aggregate estimates of the price and income elasticities of natural gas demand. We also estimate separate elasticities for total natural gas consumption by industry and households. Understanding the sizes of these elasticities is useful for parameterizing energy-economy models. Knowing the price elasticity of natural gas demand is also useful for understanding the effects of adjustments to tax settings for natural gas, as well as the local consumption effects of opening natural gas markets to international trade. Countries maintaining artificially low domestic natural gas prices – a group that even includes net importers such as China (Razavi, 2009; IEA, 2011; Aolin and Qing,

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2015; Lin et al., 2015; Paltsev and Zhang, 2015) – could use our estimates to forecast the implications of natural gas price reform for domestic natural gas consumption.

Fig. 1 plots the average of the end-user natural gas prices for (a) industry and (b) households against natural gas consumption per capita for 31 countries in 2010, both logged. The fitted line has the appearance of a downward-sloping demand curve: lower natural gas prices are on average associated with higher per capita natural gas consumption. The figure also illustrates substantial cross-country variation in both natural gas prices and per capita natural gas consumption.We will examine the roles of additional variables that help to explain natural gas consumption.

This paper builds on a body of research estimating the price and income elasticities of demand for natural gas, often for a specific sector in a single country. There are advantages to our aggregate approach. First is that our study is able to span countries representing 50% of the world's population and 72% of global natural gas consumption as of 2011. Aggregate elasticities are also useful for modeling macro-level trends in natural gas use. It might be expected that the price elasticity of demand for natural gas is more elastic at the aggregate level than in some micro-level contexts, as there can be more substitution possibilities at higher levels of aggregation.

A key contribution of our paper is the use of a supply-side instrumental variable (IV) strategy to address the potential for endogeneity in natural gas prices. We instrument each country's natural gas price with the proved (and yet to be extracted) natural gas reserves of that country and of other countries, where other countries' natural gas reserves are weighted using a negative power function of distance. The instrument gives a higher weight to reserves in nearby countries and a lower weight to reserves in distant countries. Our instrument is measured in million cubic feet per capita. Natural gas reserves is a potentially suitable instrument because countries that are rich in natural gas, or that have neighbors rich in natural gas, tend to have lower natural gas prices on account of the smaller transport and other transactions costs from extraction point to market. Countries with natural gas endowments and/or access to nearby supplies are also more likely to supply below-cost or lowly taxed natural gas to domestic consumers. An example is Kazakhstan (Fig. 1). Our IV exclusion restriction is that natural gas reserves affect natural gas demand only via the natural gas price.

The paper proceeds as follows. Section 2 discusses our method and data. Section 3 presents our results. Section 4 compares the results to prior estimates. The final section concludes.

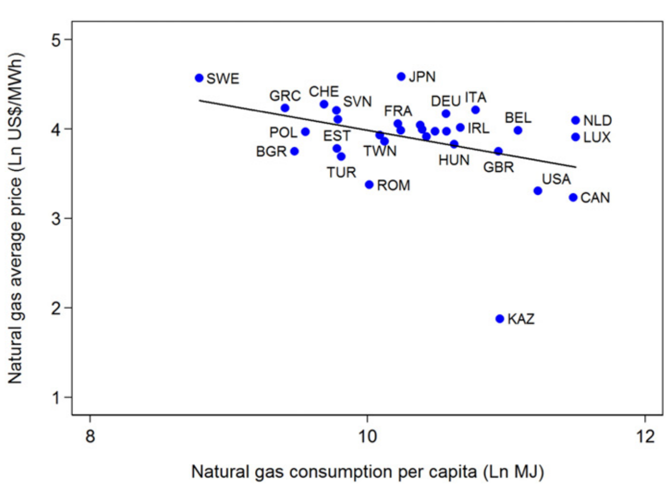

Fig. 1. Natural gas prices and per capita consumption, 2010. Covers 31 countries. The average price is the simple mean of the average prices paid by (a) industry and (b) households. Consumption covers all primary energy derived from natural gas. The year 2010 is used as more observations are available for this year than for 2011. World Bank country codes are used. Price is shown on the *y*-axis in line with the standard presentation of a demand curve. Sources: IEA (2015a, 2015c).

2. Methods and data

2.1. Specification

We begin by estimating a cross-country aggregate demand function for natural gas consumption (G) in country c during 2010:

$$\ln G_c = \alpha + \beta \ln P_c + \gamma \ln Y_c + \delta \ln S_c + \eta \ln L_c + \theta T_c + \kappa \ln D_c + \varepsilon_c \quad (1)$$

where P is the average end-user price of natural gas, calculated as the simple mean of the end-user prices for industry and households. Y is gross domestic product (GDP) per capita, S is the size of each country's population, L is land area, T is average temperature in °C, D is the price of road-sector gasoline (a proxy for the price of oil substitutes), and ε is an error term. Using cross-sectional variation means that coefficients will have a long-run interpretation on the assumption that variables are settled at long-run equilibria (Pesaran and Smith, 1995). We expect β (the long-run price elasticity of demand) to be negative and γ (the long-run income elasticity of demand) to be positive. δ is expected to be positive, as larger populations are likely to consume more natural gas. We expect θ to be negative, as natural gas is commonly used for heating purposes in cold climates. The year 2010 is used for our cross-sectional estimates as it allows for a larger sample of countries than is available for 2011. Our use of natural gas consumption (cf. production) data and the end-user (cf. extraction) price is as is suitable for estimating a demand (cf. supply) function.

We have access to data for more than one year (y), allowing us to form a country-level panel, albeit one that is unbalanced due to missing observations. We thus proceed to a panel specification:

$$\ln G_{c,y} = \alpha + \beta \ln P_{c,y} + \gamma \ln Y_{c,y} + \delta \ln S_{c,y} + \eta \ln L_{c,y} + \theta T_{c,y} + I_y + I_c + \varepsilon_{c,y} \quad (2)$$

where D has been removed due to data limitations.

We use three panel estimators:

a) *Between estimator*, which uses the mean of each series for each country, and so exploits only between variation; the between estimates exclude the year dummies (I_y) and country dummies (I_c)
b) *Pooled ordinary least squares* (OLS) with year dummies but no country dummies
c) *Fixed-effects estimator* with year dummies, i.e., the full Eq. (2)

The between estimator is thought to provide long-run estimates and, like the cross-sectional estimator, avoids time series issues such as the existence of unit roots and the precise specification of dynamics (Baltagi and Griffin, 1983, 1984; Pirotte, 1999, 2003; Baltagi, 2008; Stern, 2010). The static fixed-effects estimator controls for time-invariant country characteristics such as geography but, by focusing on within variation with no consideration of lags, is likely to pick up shorter-run effects. Shorter-run effects should be expected to be smaller than long-run effects, as it likely takes time for natural gas use to respond to price changes, especially given the importance of long-run contracts (Neumann and von Hirschhausen, 2015) and of infrastructure lock-in in energy markets. Estimates from static pooled OLS regressions might be expected to lie somewhere in-between the between estimates and the static fixed-effects estimates; although pooled OLS does not consider lagged responses, this estimator does utilize the information embodied in the mean levels of each variable in each country, which is likely to represent long-run content. An alternative approach to obtain long-run elasticities is to estimate a distributed lag model. We find that the long-run price elasticity from fixed-effects distributed lag models converges to the price elasticity obtained using the between estimator. The relatively short and unbalanced time series component of the data does not suit a country-by-country time series analysis.