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The effect of the price of gasoline on the urban economy: From route choice to general equilibrium

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ABSTRACT

RELU-TRAN2, a spatial computable general equilibrium (CGE) model of the Chicago MSA is used to understand how gasoline use, car-VMT, on-the-road fuel intensity, trips and location patterns, housing, labor and product markets respond to a gas price increase. We find a long-run elasticity of gasoline demand (with congestion endogenous) of −0.081, keeping constant car prices and the TFI (technological fuel intensity) of car types but allowing consumers to choose from car types. 43% of this long run elasticity is from switching to transit; 15% from trip, car-type and location choice; 38% from price, wage and rent equilibration, and 4% from building stock changes. 79% of the long run elasticity is from changes in car-VMT (the extensive margin) and 21% from savings in gasoline per mile (the intensive margin); with 83% of this intensive margin from changes in congestion and 17% from the substitution in favor of lower TFI. An exogenous trend-line improvement of the TFI of the car-types available for choice raises the long-run response to a percent increase in the gas price from −0.081 to −0.251. Thus, only 1/3 of the long-run response to the gas price stems from consumer choices and 2/3 from progress in fuel intensity. From 2000 to 2007, real gas prices rose 53.7%, the average car fuel intensity improved 2.7% and car prices fell 20%. The model predicts that from these changes alone, keeping constant population, income, etc. aggregate gasoline use in this period would have fallen by 5.2%.

1. Introduction

How does the urban economy respond to an increase in the price of gasoline? Since the mid 1970s econometric studies have measured the price elasticity of the demand for gasoline, using state, national and international cross-sectional or time series data. These studies tell us how a change in the gasoline price would affect total vehicle miles traveled (VMT), changes in the stock of vehicles owned and the average fuel economy of cars being operated. From these studies, we know the probable ranges of the price elasticity of the aggregate demand for gasoline, and the "rebound effect", the propensity to drive more as the fuel economy of cars improves in response to higher gasoline prices.

Small and Van Dender (2007) estimate that both the price elasticity of the demand for gasoline and the rebound effect declined over time (except, perhaps, in recent years not yet studied). Hughes et al. (2008) agree on the decline of the elasticity but not necessarily on the decline of the rebound effect, although differences between the two studies appear to be explainable by differences in specification. One reason for the declining elasticity is the fact that since the oil embargo of 1975, incomes have risen but gasoline prices have remained stable or declining (except for recent years). Another reason is that CAFE standards and the fuel economy of cars on the market have improved.

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In this paper, we will evaluate the effect of a higher gasoline price in a computable general equilibrium (CGE) model of a spatially disaggregated urban economy (the Chicago MSA) as it responds from the very short run of travel route adjustments to the long run of location and building stock changes. The structural model treats explicitly aspects that are suppressed in reduced form econometric modeling. This advantage of CGE models sheds more light onto our understanding of how the gasoline price affects urban form and structure.

1.1. Econometric studies and CGE modeling

We consider some limitations of reduced-form econometric specifications and explain how our CGE model, RELU-TRAN2, attempts to compensate for them:

(a) *Endogenous congestion*: Road congestion indirectly affects gasoline consumption but is hard to treat well in an econometric model. Efforts to capture the congestion effect are few and have relied on very rough aggregate proxies of congestion such as the level of urbanization in a state or the ratio of adults to lane miles of highways (Small and Van Dender, 2007); or the average metropolitan-wide congestion delay indices of the Texas Transportation Institute (Hymel et al., 2010). In our spatially disaggregated CGE model of the Chicago MSA, route choices on a spatial road network are modeled explicitly for different incomes and values of time, taking into account monetary cost (e.g. gasoline) as well as travel time, as these times and costs are endogenized by congestion.

(b) *Effects of adjustments in urban markets*: Labor, housing, and land markets are changed by travel behavior and in turn affect travel behavior. But the indirect changes in gasoline consumption from endogenous changes in wages, rents and goods prices, in location decisions and in building stocks are not explicitly treated in econometric studies. Our CGE model treats travel and car use decisions for commuting and for discretionary (non-work) trips and also treats labor supply, location of work and residence, location of firms, housing type and market adjustments in rents, wages and retail prices, the asset prices of buildings and the adjustment of building stocks. These adjustments are simulated in stages. Thus, we are able to trace the change in elasticity from the very short run to the long run, decomposing the effect of each stage on the long run elasticity.

(c) *Sorting out and decomposing various rebound effects*: In the econometric literature, the commonly held definition of the "rebound effect" seems to be the increase in the use of an appliance when its fuel intensity falls. In the case of cars most authors have measured use of the car by VMT (vehicle miles traveled), although TRIPS (number of trips made), HOURS (total hours of travel) or GAS (gasoline burned) would all also be equally valid measures of use in the extensive margin. A car's use in the intensive margin can be measured by MPG (miles per gallon), by MPH or speed (miles per hour), by GPM (gallons per mile) or by monetary cost (dollars per mile). Our CGE model predicts all of these indicators of car use and the trade-offs among them that consumers make when they allocate their time and income between travel and other activities and when they choose a bundle of trips to maximize utility. In the literature, GPM is normally used as a measure of fuel intensity. But we distinguish between the TFI (technological fuel intensity) of a car's engine and its on-the-road fuel intensity which is determined by the car's speed under congested conditions given its TFI. The TFI of cars actually driven improves by technological progress in the car industry or by consumer choice of more fuel efficient cars. Then, as the price of gasoline rises, TFI and/or speed improve indirectly and the monetary cost of driving a mile rebounds. From this, rebounds occur not only in VMT, but also in GAS, HOURS and TRIPS, taking back from the initial reductions in these variables induced by the higher gasoline price.

(d) *Changes in fuel intensity*: A reduction over time in average fuel intensity is a well-observed trend. Fig. 1 plots the national trends for 1980–2009.[2] Improvement comes in part from consumers choosing more fuel efficient vehicles in response to a higher gas price. This would raise the demand for such cars causing imperfectly competitive car-makers to produce more of them while marking-up prices. At the same time, in the used car market, fuel intensity is higher on average and the relative prices of used cars would fall, offsetting in part the adoption of the more fuel efficient vehicles. Changes in the supply of vehicles by fuel intensity could also be driven in some measure by CAFE standards. Bento et al. (2009) have attempted to model the effects of these standards in a national model with endogenous car production, but their model does not include urban structure and markets.

Our CGE model is focused on metropolitan structure. It treats as endogenous consumer choices among car-types but does not treat car-production as endogenous. In the model, five abstract car types shown in Fig. 2 are available to consumers, and differ by their TFI. Each higher curve in Fig. 2 represents a car type of higher TFI. Each curve also captures that for a given car type on-the-road fuel intensity falls with car speed, making a relatively flat bottom and rising at high speeds.[3] We assume that higher TFI cars are larger, more comfortable, safer but also more expensive to own. The choice of a car type trades off higher ownership and gasoline cost for car size, comfort and safety. Average on-the-road fuel intensity is determined by the distribution of the consumers among the car types and by the traffic congestion which determines speed. In the legend of Fig. 2, the

[2] The MPG data for Fig. 1 was not available post 2007.

[3] The empirics of the curves in Fig. 2 will be discussed in Section 3.