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Spatiotemporal analysis of ethanol market penetration

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ABSTRACT

Consumption of ethanol in the United States has increased rapidly over the last few years, fueled by both higher crude oil prices and generous public support measures for renewable fuels. The contribution of ethanol to the transport energy mix varies markedly by state. Heterogeneity in ethanol adoption and market development is investigated using a hierarchical, spatiotemporal model. A Bayesian Markov chain Monte Carlo method is employed for estimation of the proposed flexible model structure. Besides spatial dependence among neighboring states, differential inclusion rates of ethanol are found to be largely determined by national- and state-level biofuel incentive policies, relative gasoline prices, feedstock availability, household median income, MTBE bans, and density of fuel retail infrastructure. Our findings imply that increasing renewable fuel support as well as investing in extending the transportation and fuel retail infrastructure can result in higher ethanol consumption.

1. Introduction

Corn-based ethanol has become an increasingly important component of the U.S. transportation fuel supply in the form of E10 and, to a lesser extent, E85. E10 (E85) is a fuel mixture of 10% (85%) ethanol and 90% (15%) gasoline by volume that can be used in the internal combustion engines of automobiles and light-duty vehicles without need for any modification. Flex fuel vehicles are needed to utilize E85. U.S. ethanol production increased from 3.9 billion gallons in 2005 to 13.2 billion gallons in 2010 (RFA, 2011). Over 90% of the nation's finished motor gasoline contains ethanol (RFA, 2011). But the level of ethanol blending varies widely across regional markets. Fig. 1 presents the shares of ethanol blended into gasoline in the 48 contiguous states in 2010. It shows that ethanol blending shares ranged from 5.3% to 14% across the states in that year. While gasoline sold in the Midwestern states contains over 9% ethanol on average, the size of the ethanol market in some other regions is more modest. In October 2011, the U.S. Environmental Protection Agency (EPA) approved E15 gasoline blends for model years 2001 and newer cars and light trucks. Furthermore, the U.S. Department of Agriculture announced that it will assist in the installation of 10,000 blender pumps across the country in the next five years. Therefore, understanding the factors that have encouraged or constrained the market penetration of ethanol is critical for assessing the potential demand growth coming from higher allowable blending rates and expanded retail infrastructure.

Despite this heterogeneous market and policy environment, the determinants of regional ethanol adoption have not been systematically explored and remain poorly understood. This paper seeks to address this gap in the literature and to offer insight into the influence that a variety of economic and technological factors have on the penetration of ethanol into the transportation fuels market. In doing so, this study provides a rigorous empirical understanding of regional ethanol adoption process.

Analysis of ethanol demand and market development is sparse in the literature. The model developed in Anderson (2012) links consumers' fuel preference to market demand. Corresponding empirical analysis finds that ethanol demand is sensitive to relative gasoline-to-ethanol prices. Using a partial equilibrium optimization model, Szulczyk (2007) investigates the influences of fossil fuel price, biofuel production technology, greenhouse gas offset prices, and also biofuel feedstock and by-products on the development of biofuel markets. Cotti and Skidmore (2010) find that federal- and state-level incentives including subsidies and tax credits have significant effects on states' ethanol production capacities.

A related line of research investigates adoption and impacts of various renewable energy technologies and policies. Corts (2010) studies the impact of government fleet adoption of flex-fuel vehicles (FFVs) on alternative fuel retail infrastructure. He finds a positive spillover effect of FFV adoption on the expansion of retail E85

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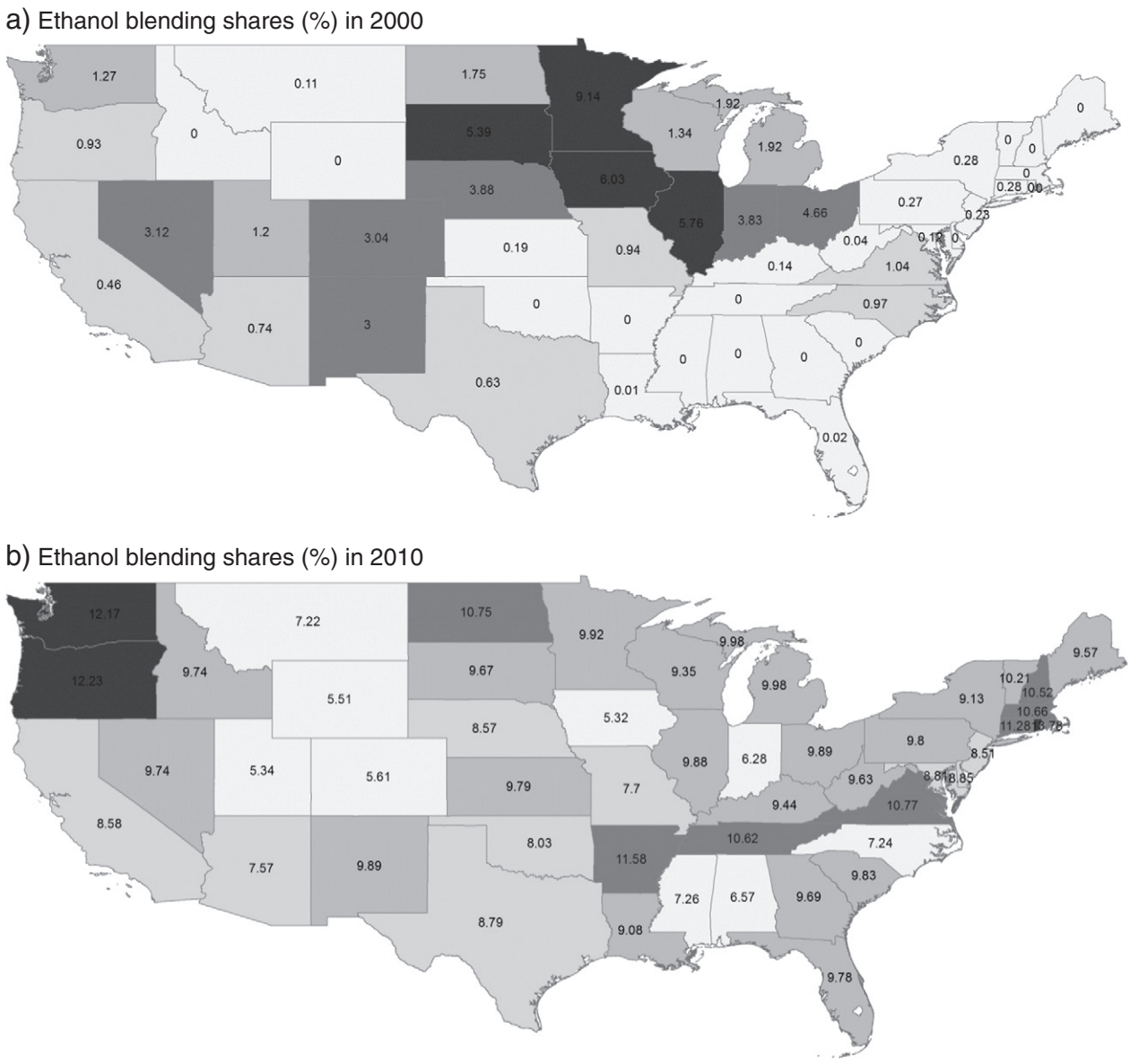

Fig. 1. Spatiotemporal evolution of ethanol blending shares (%) in 2000 and 2010.

stations. Gallagher and Muehlegger (2011) focus on the efficacy of state-level incentives on adoption of hybrid-electric vehicles (HEVs). They also empirically examine the effect of various factors such as gasoline prices, consumer preferences, and government incentives on HEV adoption. Attitudes toward adoption of anaerobic digestion technology are examined in Bishop et al. (2010). Variables constructed based on behavioral economics and conservation adoption literature are found to be significant in determining the adoption decision. Lyon and Yin (2010) empirically analyze the political and economic factors driving state governments to adopt a Renewable Portfolio Standard (RPS), requiring electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date. In terms of empirical methodology, our study is close to the spatiotemporal modeling framework in the literature (see, among others, Albuquerque et al., 2007; Goodwin and Piggott, 2009; Waller et al., 1997).

Our paper differs from the existing studies in several important ways. First, we explicitly take into account the spatial dependence pattern of ethanol adoption, i.e., the effect of ethanol market development in neighboring states. Quantified by geographic proximity, the neighboring effect is found to be one of the significant determining factors in ethanol market penetration. Second, heterogeneity in ethanol adoption and market development is investigated using a hierarchical, spatiotemporal model. Besides various time-varying regional explanatory variables, a set of regional fixed characteristics reveals interesting results. A Bayesian Markov chain Monte Carlo (MCMC) method is proven to be capable of handling estimation of the proposed flexible model structure.

In our case heterogeneity in individual states gives rise to observed biofuel adoption behavior and is one of the main focuses of this study. Econometric methods that have been traditionally employed, e.g., fixed- and random-effect models, are not sufficiently flexible. The fixed-effect model restricts the state level parameter to be constant and doesn't specify any probability distribution of heterogeneity. The random-effect model quantifies the state level variations by estimating a probability distribution, but does not capture any state specific effects (see Allenby et al., 2005; Rossi et al., 2005, Ch. 5 for similar discussions). The applied Bayesian hierarchical model has the advantage over traditional approaches in that it directly yields estimates of parameters of interest at not only the aggregate market level but also the individual state level after appropriately accounting for the uncertainty in these estimates.