RELATIONSHIP BETWEEN FUEL ECONOMY, VEHICLE ELECTRIFICATION, AND RURAL WELFARE IN THE UNITED STATES

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Overview

Road transportation and agriculture in the United States (U.S.) and globally are faced with many challenges and opportunities with respect to carbon policies and climate change that requires a transformation of both sectors. Road transportation is moving away from internal combustion engines (ICE) that use gasoline or diesel towards renewable resources. Major car manufacturers (e.g., Ford) and governments (e.g., California, United Kingdom) have announced efforts to phase-out fossil fueled cars. Battery electric vehicles (BEV) are expected to replace ICEs over the next decades. In the U.S., this development has important implications for agriculture in general and rural welfare in particular due to the large share of U.S. maize production being used for ethanol. The purpose of the paper is to shed light on the economic consequences at a fine spatial scale. The paper is expected to be of significance to participants of the 2022 IAEE Conference due to its assessment of interlinkage of future road transportation pathways as well as farm and rural welfare in the United States.

U.S. farming has been shaped over the last decade by the increasing biofuel demand, which now consumes about one-third of U.S. maize production. Maize ethanol is blended with gasoline at a rate of 10%-15% depending on the model year of the vehicle. Since 2017, the maximum amount (percentage-wise) of ethanol is blended with gasoline, which results in a direct link between gasoline and maize ethanol consumption (Dumortier et al., 2021). Given efforts to decarbonize the U.S. road transportation sector, the economic and environmental effects of a potentially decreasing maize ethanol demand in the long-term are evaluated. The research by Dumortier et al. (2021) assess the implications at the international level whereas this proposed paper assesses the effects within the United States. The proposed paper quantifies effects on commodity prices, land-use, and rural welfare of a decreasing U.S. maize ethanol demand and assesses alternative future pathways outside the road transportation sector. The paper couples a road transportation model with a fine-scale agricultural outlook model to identify areas that are most affected by changes in agricultural production. The model is set up in a way to include the effects of climate change on yields as well. The first step presented in this paper, focuses on the effects of a higher market penetration of BEVs to single out the effect of road transport decarbonization. A second step is expected to include climate change as well to assess the joint effects of both, a demand and supply shock to agriculture. The effects of yield decline (in addition to the decline in ethanol consumption) and the resulting spatial impacts of land allocation in the U.S. can inform stakeholders on the expected impacts on rural welfare and where policy measures can be applied.

Methods

A U.S. road transportation model is combined with a county-level agricultural model to determine the effects of vehicle electrification on U.S. agriculture until 2050. The scenarios are formulated around the projections from the U.S. Energy Information Administration (EIA) Annual Energy Outlook (AEO). The road transportation model allows the imposition of varying electric vehicle market penetration rates to subsequently calculate their impacts on agriculture. The analysis remains neutral on how the increase in BEV sales is achieved and rather serves to inform policy makers about the effects of accelerated BEV market development. The BEV scenarios go beyond the side cases currently presented in the AEO because very high market penetration rates of up to 100% of BEVs are simulated to determine the range of likely effects on agriculture.

The road transportation model follows standard methods of the travel demand literature in the sense that the total number of vehicles (stock) is modelled as opposed to vehicle sales. The total demand for the vehicle stock implicitly defines the sales through predetermined scrappage rates. Scrappage rates determine the probability of a vehicle being removed from the stock from one year to the next. An alternative approach to model travel demand is via vehicle kilometers travelled (VKT) but the data availability by vehicle type is low which is the reason that the vehicle stock is modelled. Two large categories of road transport are modelled: Passenger and freight. For passenger transport, passenger cars and light trucks are modelled. For freight transport, light-, medium-, and heavy-commercial are modelled. For each group (both passenger and freight), various powertrains are considered such as gasoline, diesel, E85, hybrid, plug-in hybrid, and battery electric. A total of 22 vehicle types are modelled. From travel surveys such as the National Household Travel Survey, VKT per vehicle type are calculated. The historical and projected fuel efficiencies from the VISION Model[1] and the EIA AEO are used to determine energy consumption by vehicle type. The BEV market penetration scenarios are imposed on the light-duty vehicle (LDV) fleet, i.e., passenger cars and light trucks. Specifically, the most aggressive scenario in terms of sales share reaches 100% of

[1] https://www.anl.gov/es/vision-model

LDV sales in 2050. There has also been a proposal to revise the Corporate Average Fuel Economy (CAFE) standards in 2021 to increase fuel efficiency for passenger cars and light-trucks for model year 2024 to 2029. Those proposed changes are included as well in our analysis.

The agricultural outlook model includes barley, maize, oats, rice, sorghum, soybeans, and wheat. The spatial scale of the analysis are the counties (around 3,070) in the contiguous United States. For each commodity, demand functions for (1) food and other uses, (2) feed, (3) biofuels (is applicable), and (4) exports are modeled similar to Dumortier et al. (2017) and Dumortier et al. (2021). The model determines land allocation of the aforementioned eight crops for each U.S. county by solving for commodity price time series over the projection horizon that clears the market, i.e., crop demand equal to crop supply. The model also includes cost of production and thus, the net farm income (crop revenue minus cost of production) can be determined for each county. The resulting changes in land area, commodity prices, and costs allows for the determination of changes in rural welfare.

Results

Preliminary results show that a sales share of 100% in the light-duty vehicle market by 2050 results in a decline of commodity prices and net income by less than 10% for maize which is the most impacted commodity in our analysis. Although the decrease in maize ethanol consumption leads to a decrease in price, maize export increases dampen the effects for U.S. farmers. The regions most affected by the decarbonization of the road transportation sector are the Southeast and regions with low cropland profitability. Although area allocation to maize is decreasing, the area allocated to other crops is increasing which decreases the commodity prices for all crops. Areas with low crop yields are impacted more because cost of production remain relatively stable in our analysis and thus, the low profit margins are further reduced due to the price decline.

Conclusions

The use of gasoline in the U.S. light-duty vehicle sector will decline due to an increasing number of electric vehicles or the use of some other fuel such as hydrogen. Although the replacement of the vehicle fleet occurs slowly over time because only a small number of vehicles are sold every year (compared to the overall vehicle stock), the consequences of selling more BEVs and fuel-efficient vehicles are long-term due to the longevity of cars. At the same time, this major transition occurs in the road transportation sector, other sectors such as aviation or shipping may increase their use of biofuels in the future. Research suggests that the 1.5°C warming limit above pre-industrial levels may be unachievable without the use of so-called Bioenergy Carbon Capture and Storage (BECCS) technology. There is little doubt that bioenergy will play an important role in the future to meet climate change goals. The question is whether maize ethanol is part of the energy mix and if not, what the consequences for agricultural production and rural welfare in the U.S. are. There are other challenges and opportunities, which are affecting U.S. agriculture. Possibly declining yields due to climate change may result in stabilized commodity prices because a decline in demand is accompanied by a decline in supply. More recently, there is also interest in making U.S. farmers engage so-called carbon farming, i.e., adopting management practices including potential changes in land-use to avoid or sequester carbon in biomass and soils.

Although a crop price decline is expected due to the reduction in the maize ethanol demand, other opportunities related to carbon policies need to be considered in future research as well. For example, there is significant interest in carbon farming, which could be an additional source of revenue to farmers in areas of low crop productivity because those land owners could convert low productivity cropland to either grassland or forest to earn carbon credits. Maize ethanol blended with gasoline is one of many feedstock and pathway combinations to meet renewable energy demands. Other possible feedstocks are for example soybeans and rapeseed for biodiesel production. The heavy freight sector is expected to decarbonize at a latter point because the sector is very energy intensive and battery technology is not yet at the point to replace diesel in that sector. Thus, biodiesel could potentially be a transition fuel for the freight sector which in turn would increase the demand for soybeans. Ethanol being used in the aviation sector is an alternative to road transportation and future research needs to assess the pathways and how those affect the agricultural sector.

References

Dumortier, Jerome, Miguel Carriquiry, and Amani Elobeid. (2021). "Where does all the biofuel go? Fuel efficiency gains and its effects on global agricultural production." *Energy Policy* 148(A), 111909.

Dumortier, Jerome, Hamze Dokoohaki, Amani Elobeid, Dermot J. Hayes, David Laird, and Fernando E. Miguez. (2020). "Global land-use and carbon emission implications from biochar application to cropland in the United States." *Journal of Cleaner Production* 258, 120684.

Dumortier, Jerome, Nathan Kauffman, and Dermot J. Hayes. (2017). "Production and spatial distribution of switchgrass and miscanthus in the United States under uncertainty and sunk cost." *Energy Economics* 67: 300-314.