Response

"The Renewable Fuel Standard in Competitive Equilibrium: Market and Welfare Effects"–Authors' Response to Comment

We thank David Just for his concise discussion of the main results of our article and his generous assessment of our work. We agree with much of what he articulated and thus we will focus this response on the last portion of his remarks. As George Box (1979) put it, "All models are wrong, but some are useful," and we hold this aphorism to be especially apt for the economic analysis of policy-relevant problems. Mindful of this, our own efforts to understand U.S. biofuel policies, starting with Lapan and Moschini (2009), have focused on parsimonious competitive equilibrium models that embed the relevant market failures, a structural representation of Renewable Fuel Standard (RFS) mandates, and an open-economy view of the agricultural and energy sectors. Still, the inevitable tradeoff between realism and tractability requires modeling choices. One of these relates to the substitutability between ethanol and fossil gasoline, and the relevance this has with the so-called blend wall. Our model treats all blends of ethanol and gasoline as perfect substitutes in consumption (in energy-equivalent terms), a choice that we discuss at length in the text (with reference to other studies that also adopt this perspective). Still, as noted by Just, the question arises as to whether it would be more desirable to model consumer demand in terms of two differentiated products: E10 (which can be used by all gasoline-powered vehicles) and E85 (only usable by flex-fuel vehicles).

It should be made clear to the reader that implementing a model with such differentiated demands for E10 and E85 presents additional difficulties of specification, calibration, and interpretation of welfare results. Whereas there is one way in which ethanol and fossil gasoline are perfect substitutes (once expressed in the same energy units), there are many ways for them to be imperfect substitutes, and these are not all equivalent. Consider, for example, the approach, used in some studies, of modeling ethanol and fossil gasoline as imperfect substitutes with a constant elasticity of substitution (CES) demand structure. The maintained CES property that consumers value product diversity per se, and that they will always demand a positive quantity of both fuels regardless of prices, is rather unappealing and difficult to reconcile with the basic presumption that, in fact, consumers ultimately care about miles driven (and the cost they incur to do that). A more plausible setting, explored by other studies, recognizes that the main source of differentiation between E10 and E85 is that the latter entails non-monetary costs for consumers, over and above the fuel price (due to the scarcity of E85 refueling stations, and the need for more frequent refueling stops because of the lower energy content of E85). This framework can also accommodate the conjecture that some consumers might have "green" preferences (i.e., might be willing, *ceteris paribus*, to pay a premium for renewable fuel). Demands for fuel blends, therefore, are inherently heterogeneous across consumers, although ethanol and fossil gasoline may well be perfect substitutes in the direct utility function of each consumer. To make this approach operational in the representation of a competitive equilibrium at the market level, such as the one undertaken in our article, requires aggregation across consumers who differ in terms of multiple attributes about which little is known (e.g., location of flex-fuel vehicle drivers *vis-à-vis* E85 refueling stations, opportunity cost of time, willingness to pay for green attributes, etc.). Such obvious informational challenges may ultimately limit the practical implementation of this approach for welfare evaluation.

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If E10 and E85 were perfect substitutes in the direct utility function of each consumer, but the extra cost of obtaining E85 varied across consumers, then aggregating over heterogeneous consumers would lead to market demands of the form $D_{10}(p_{10}, p_{85})$ and $D_{85}(p_{10}, p_{85})$, where the price subscripts have the obvious interpretation. In this setting a decrease in p_{10} would increase demand for E10 both because those already consuming E10 would buy more and because consumers at the margin would shift from E85 to E10. Similar logic for E85 implies that, when both fuels are consumed in the aggregate, $\partial D_i/\partial p_i < 0$ and $\partial D_i/\partial p_j > 0$. When the required blend ratio from the RFS mandates exceeds 10%, some ethanol must be sold in E85 blends. Analysis of such a model with differentiated demands suggests that, compared with our baseline where the two fuel blends are perfect substitutes everywhere, a given increase in the volume of ethanol sold would require a higher increase in the price of RINs, and this would increase the discount of E85 fuel price relative to E10. From the observation that the blend rate of ethanol in total gasoline fuel was actually below 10% in the 2015 data used to calibrate the model, and that the pricing of E85 at a premium relative to E10 remains common (Liao, Pouliot, and Babcock 2016), we conclude that the presumption of perfect substitution is appropriate for the 2015 baseline solution.

Analysis of the counterfactual 2022 and "optimal mandate" scenarios presented in the article, however, must be qualified by blend wall consideration. As noted in the article's text, strictly speaking the results presented presume no constraints on marketing larger volumes of ethanol via E85 blends. How would the product differentiation considerations outlined above affect such results? With a binding blend wall, not only would E85 need to be priced at a discount relative to E10, but it can be shown that the price of E10 would also increase (again, as compared with the baseline assumption of perfect substitutability), and lead to a decline in fossil gasoline consumption. Abstracting from the impact on terms of trade, the welfare costs associated with ethanol consumption beyond 10% would be higher (equivalently, the net benefits lower) because of the extra costs borne by the E85 buyers. Accounting for differentiated demands and the blend wall, domestic pollution would likely fall as fuel consumption falls—but our model suggests that such benefits are largely lost through leakage. Overall, then, as discussed in the article, we can view our results for the counterfactual 2022 and optimal mandate scenarios as providing an upper bound on the benefits of RFS mandates.

More broadly, the results of the model in our article may help to frame the policy question of what to do about the blend wall. Marketing ethanol beyond the 10% blend rate would require a larger fleet of flex-fuel vehicles and significant infrastructure investments to expand the number of E85 refueling stations. Such an undertaking might perhaps be worthwhile if cellulosic ethanol were commercially viable, and the 36 billion-gallon target of the original RFS were feasible. On the other hand, if ethanol use expansion is to rely primarily on corn-based ethanol, the analysis of this article suggests that the welfare payoff from optimally breaching the 10% blend wall is rather limited (and indeed such welfare estimates may need to be further scaled down by the product differentiation considerations discussed above).

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