

The Macroeconomic Effects of 2017 Through 2025 Federal Fuel Economy and Greenhouse Gas Emissions Standards

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Abstract

In the absence of a national carbon price, the federal Corporate Average Fuel Economy standards and the related greenhouse gas emissions (GHG) standards are the primary mechanisms through which the U.S. reduces transportation GHG emissions. In 2012, these standards were set to rise for light-duty vehicles between 2017 and 2025, eventually achieving a target of 54.5 miles per gallon in 2025. Since 2012, conditions have changed: forecasts of future gasoline prices have dropped dramatically, consumers have demanded larger vehicles, and the cost of compliance appears to be larger than previously thought. In this article, we analyze the possible macroeconomic effects of the standards with both 2012 inputs and updated inputs to reflect these new market developments. The results reveal that the short-term effects of the federal standards will be negative, but the long-term effects will be positive, using both 2012 and updated inputs. The transition from annual negative employment impacts to positive impacts occurs between 2023 and 2026, depending on which set of assumptions are used. Possible revisions to the standards that freeze them at 2020 levels or decrease their stringency reduce short-term negative impacts but also reduce long-term positive impacts. We conclude with a discussion of policy implications as they relate to the current energy and climate policy conditions. © 2019 by the Association for Public Policy Analysis and Management.

INTRODUCTION

In 2017, the transportation sector surpassed the electric power sector as the largest contributor of greenhouse gas (GHG) emissions in the U.S. economy (U.S. EIA, 2018). The bulk of transport-related emissions result from driving gasoline and diesel-powered vehicles (Ngo, 2017). A series of scientific reports, including those from the National Research Council of the National Academy of Sciences (Leung & Vail, 2016) and the Intergovernmental Panel on Climate Change (IPCC, 2014), stress that GHG emissions must be controlled to slow the pace of global climate change.

The federal Corporate Average Fuel Economy (CAFE) standards, combined with the more recent Environmental Protection Agency (EPA) GHG standards, are—due to the absence of a national carbon price—the primary mechanisms through which the U.S. federal government reduces GHG emissions from the transportation sector. The National Highway Traffic Safety Administration (NHTSA) has set the CAFE standards for light-duty vehicles to achieve a target of 54.5 miles per gallon (MPG) by 2025. The EPA's transportation GHG program has set limits on grams of

carbon dioxide emissions per mile that are roughly equivalent in stringency to the CAFE standards.

This study examines how the two regulatory programs could affect the U.S. economy. The objective in this modeling exercise is to simulate the national and regional impacts of the federal standards on standard macroeconomic indicators. We do so with two sets of inputs: 1) the 2012 Perspective reflects inputs that were used when the regulations were finalized in 2012 and the agencies published their regulatory impact assessments in support of the 2017 to 2025 standards; and 2) the updated inputs in the 2016 Perspective reflect the fundamentally reshaped energy markets and rapid changes in the auto industry since the standards were finalized in 2012. Specifically, the 2016 Perspective inputs capture changes in global oil markets and future gasoline prices, the shift in new vehicle sales from cars to light trucks, and the projected higher costs of compliance with the standards. In addition, in light of the Trump administration's recent decision to reopen the midterm review of the standards and propose new limits, this study also models alternative Trump administration regulatory scenarios.

Our modeling accounts for macroeconomic impacts that occur through three separate mechanisms: 1) an increase in the production cost of a vehicle due to the standards, which we term the "vehicle price premium"; 2) investments in supply chain innovation by manufacturers to achieve the standards; and 3) a decline in petroleum consumption as consumers use more fuel-efficient vehicles. We consider the effects of the three mechanisms individually and collectively, for the nation as well as in various regions of the U.S.

Our basic findings are that: 1) the vehicle price effects, which intensify as the standards become more stringent, cause losses of employment and gross domestic product (GDP) through a decline in new vehicle sales and a reallocation of consumer spending to automobiles but away from non-automotive goods and services; 2) the investments in supply chain innovation that are induced by the regulations offset some of the adverse effects of higher prices, since additional investments in fuel-saving technology boost employment and output; and 3) the savings in gasoline expenditures have both positive and negative effects, the former through consumer expenditure savings and the latter through a reduction in demand for U.S. petroleum. The net nation-wide effect of gasoline savings is positive.

When the three mechanisms are combined, the overall annual impact of the regulatory programs on the national economy is negative in the near-term but positive in the long-term. The positive effects on the economy are ultimately much larger in magnitude than the negative impacts, primarily because the savings in expenditures on fuel are quite large relative to the vehicle price premium. Results vary across regions, where some regions have only brief negative consequences, while others such as the Midwestern auto industry corridor take longer to rebound. The southern oil producing and refining region of the country never recovers compared to the baseline without the standards. Modeling results for possible future Trump administration scenarios reveal the same pattern: short-term losses and long-term gains. Freezing the standards at 2020 levels or reducing the stringency of the standard reduces some of the short-term losses but also results in much lower levels of long-term gains.

This article contributes to the extant literature in several ways. First, while the majority of studies on fuel economy standards focus on microeconomic and welfare issues associated with the standards, this is one of only a few studies that considers the macroeconomic effects of the standards. It is important to consider the macroeconomic impacts because fuel economy standards have the potential to affect not only the original automotive equipment manufacturers, but also other sectors within the automobile and gasoline supply chains. Federal programs also affect consumer expenditures, and the changing allocation of expenditures in a wide

range of industries has macroeconomic ramifications. These trends ultimately can affect all sectors within the U.S. economy, but we also show that there will likely be uneven impacts by region. Like other simulation modeling analyses that provide a perspective in public policy research (for several recent studies see, e.g., Barrios et al., 2017; Frank et al., 2018; Reardon et al., 2018; Reznik et al., 2019), the insights we offer here are complementary to the microeconomics-based welfare analyses of the standards.

Second, the study incorporates all three mechanisms of macroeconomic impact (i.e., a vehicle price premium, supply chain innovation, and gasoline savings), whereas previous studies focus on only one or two of the mechanisms. The analytic treatment of the positive impacts of supply chain innovation is particularly notable; and our methodological approach, relative to previous studies, is uniquely able to capture and isolate the effect of such innovation on the economy. Third, the analysis draws upon updated information from a variety of sources on the automobile and petroleum sectors and thus provides new perspectives compared to when the regulations were finalized by the agencies in 2012. Fourth, our modeling effort is one of the few in the literature that reports regional as well as national results, responding to the demand from elected officials for information about how macroeconomic impacts will be distributed across different regions. Finally, the study has practical importance because the U.S. federal government, as noted above, has recently reopened the midterm evaluation of the 2017 to 2025 standards, with a specific focus on the 2021 to 2025 standards, and has proposed revisions to the standards. Thus, our study lends insights for a policy debate that is playing out in real time.

We begin this article with an overview of the federal programs, followed by a discussion of relevant literature and possible macroeconomic effects. We then present the modeling strategy, the input data, and how we construct the three mechanisms in our modeling approach. Subsequently, we present our results, followed by a discussion and conclusion.

U.S. FEDERAL MILEAGE AND CARBON DIOXIDE STANDARDS

Brief History of Mileage and CO₂ Standards

The Arab oil embargo of 1973 and 1974 led to a quadrupling of world oil prices, which caused a rapid increase in gasoline prices and fuel shortages across the country. Congress and President Gerald Ford responded with new legislation aimed at reducing America's dependence on petroleum. Enacted in 1975, the Energy Policy and Conservation Act authorized the U.S. Department of Transportation (DOT), through NHTSA, to set minimum MPG performance standards for all new cars and light trucks sold in the U.S. The legislation, followed by NHTSA rulemakings, contributed to a doubling of average new car mileage from 13 MPG in model year 1974 to 27.5 MPG in model year 1985 (for an extensive review of this history, see Klier & Linn, 2011).

From 1985 to 2004, the standards were changed only slightly but, in response to rising fuel prices and pressure from California, the George W. Bush administration rejuvenated the CAFE program (Graham, 2010). The light-truck standards were made more stringent from 2005 to 2011, while the standards were reformed for safety reasons to account for the size distribution of a manufacturer's fleet of vehicles. The Bush administration also worked with the Democratic Congress to enact the bipartisan Energy Independence and Security Act, which extended the size-based reforms to passenger cars and authorized increasingly stringent standards for both cars and light trucks. Using this new authority, President Barack

Obama's administration first tightened CAFE standards for model years 2011 to 2016 and then, in 2012, promulgated a schedule of gradually stricter standards through model year 2025.

NHTSA required an average of 41 MPG by model year 2021 and established a goal of 54.5 MPG by model year 2025. The final CAFE standards for model years 2022 to 2025 were scheduled to be set by a NHTSA rulemaking following a midterm evaluation. The midterm evaluation, scheduled for completion by April 2018, was intended to account for new information about market conditions, technologies, and regulatory impacts. The CAFE standards were not finalized for 2022 to 2025 in 2012 because the Department of Transportation only has the statutory authority to establish standards for a five-year timeline (Killeen & Levinson, 2017).

In 2007, the U.S. Supreme Court determined that the EPA possesses the authority under the Clean Air Act to regulate GHG emissions from motor vehicles. Drawing on this authority, the EPA made an "endangerment" finding in 2009, as GHG emissions from mobile sources were determined to be a contributor to climate change and therefore a threat to both public health and the environment. In response to a 2009 instruction from President Obama, the EPA, in consultation with NHTSA, created an entirely new performance standard governing GHGs emitted by new cars and light trucks. The new standards were finalized through model year 2025 and are roughly equivalent to NHTSA's CAFE standards. While the EPA's standards are slightly stricter, they allow automakers to earn extra compliance credits by modifying air conditioners to reduce GHGs and by producing certain types of advanced vehicles such as plug-in electric vehicles.

In late 2016, after the presidential election but before President Trump took office, the EPA determined, based on a midterm evaluation, that the GHG standards for model years 2022 to 2025 should proceed as planned. NHTSA, however, did not come to a similar conclusion, and continued to work on the midterm evaluation. In April, 2017, the Trump administration reopened the midterm review at the EPA and declared that the agency would reconsider the standards out of a concern that they are too stringent. NHTSA released a Notice of Proposed Rulemaking and Preliminary Regulatory Impact Analysis in July 2018 (NPRM, 2018), which outlined the Administration's preferred plan to freeze the standards at 2020 levels, as well as several other possible options, on which they invited public comment.

Previous Literature on the Economic Effects of Federal Standards

There is a wealth of studies on U.S. fuel economy standards (see Anderson et al., 2011, for a review), which we divide into three broad segments. The first segment evaluates the welfare implications of CAFE from a microeconomic perspective (Austin & Dinan, 2005; Jacobsen, 2013; Kleit, 2004; Klier & Linn, 2012; Leard et al., 2017; Liu et al., 2014). Related studies have examined the effects of CAFE on costs of production, new vehicle prices, vehicle sales, used vehicle prices, vehicle scrappage rates, fleet fuel economy, and vehicle safety (see, e.g., Anderson & Sallee, 2011; Austin & Dinan, 2005; Bento et al., 2017; Clerides & Zachariadis, 2008; Goldberg, 1998; Greene, 1998; Jacobsen, 2013; Jacobsen & van Benthem, 2015; Klier & Lin, 2012; McAlinden et al., 2016). In addition, several authors have compared the welfare effects of CAFE with those of an alternative price instrument (i.e., a higher gasoline tax or carbon tax), and found that the latter is more cost effective (e.g., see Austin & Dinan, 2005; Davis & Knittel, 2016; Goldberg, 1998; Karplus et al., 2013; Kleit, 2004). Similarly, studies have evaluated complementary policies to CAFE such as feebates (Fischer et al., 2007; Liu et al., 2014) or economy-wide cap and trade systems (Karplus et al., 2013), or alternative designs such as the

incorporation flexible compliance mechanisms (Fischer et al., 2007; Leard & McConnell, 2017).

A second strand of literature, also from a microeconomics perspective, looks into the tradeoffs that manufacturers and consumers face among different vehicle attributes such as weight, power, and fuel efficiency (Klier & Linn, 2012; Knittel, 2011; Leard et al., 2017; Ullman, 2016; Xie et al., 2017). Findings from this literature suggest that compliance with CAFE standards may require substantial investments in technology as well as foregone improvements in vehicle power and weight. Ullman (2016) estimates that manufacturers might respond to federal standards by increasing vehicle footprint, and thus compromise some of the fuel-consumption savings of CAFE. Leard et al. (2017) find a substantial difference in consumer willingness-to-pay for fuel efficiency and performance. Their findings suggest that tightening the CAFE standards has led to little private welfare gain precisely because consumers value foregone performance gains more than fuel economy improvements.

A final strand of literature, which is more closely aligned with the focus of this paper, considers the macroeconomic impacts of CAFE. Early studies, conducted before the development of the 2017 to 2025 standards, found primarily net positive economy-wide effects of federal fuel economy standards on output, income, and employment (Dacy et al., 1980; Teotia et al., 1999). Bezdek and Wendling (2005) provide an extensive review of the early literature as well as their own modeling contribution. Using a Management Information Services, Inc. model, a modified input-output model, to calculate the effects of a modest or stringent CAFE standard, Bezdek and Wendling (2005) found that both policy options resulted in net positive effects on output and employment. Although the price effect of the vehicle standards negatively affected the economy, the positive effects of gasoline savings more than compensated. Morrow et al. (2010) used the National Energy Modeling System to compare the car sales impacts, employment, and GDP effects, among other outputs, of a variety of GHG emissions policies. Their results revealed that neither CAFE nor any other GHG policy scenario resulted in significant changes to GDP.

More recently, McAlinden et al. (2016) apply a labor productivity factor to derive estimates of employment impacts due to changes in new vehicle expenditures resulting from the 2025 federal standards. They found that the standards will result in a loss of between 15,700 and 137,900 jobs within the automobile industry in 2025, depending on assumptions about the price of gasoline and the price premium associated with achieving the 2025 standards. There are also two recent publications that sit at the intersection between the first and third strands of literature. Karplus et al. (2015) used the combined computable general equilibrium-based Integrated Global System Model and the MIT Emissions Predictions and Policy Analysis model to analyze the differences in outcomes between 2017 to 2025 fuel economy standards and an equivalent carbon price. They found that fuel economy standards have the potential to reduce global consumption of goods and commodities by between 6 and 10 percent by 2050. Sarica and Tyner (2013), using a hybrid top-down and bottom-up model, analyzed a wide variety of policy options to enhance energy security and reduce GHG emissions: CAFE standards, renewable fuel standards, clean-energy standards, and an economy-wide carbon tax. They found that 2017 to 2025 CAFE standards have a small negative effect on GDP compared to a GHG-equivalent carbon tax.

Compared to McAlinden et al. (2016), our focus is more broadly on the U.S. economy, not just the automotive sector, and entails a more extensive modeling effort to derive macroeconomic estimates. Compared to Karplus et al. (2015) and Sarica and Tyner (2013), our analysis is deeper in its treatment of macroeconomic effects but narrower in the range of policy options that are investigated. We also

add to this literature with a focus on supply chain innovation, as well as an analysis of regional impacts.¹

Macroeconomic Impacts: Theoretical Expectations

The macroeconomic impact of the regulatory programs will primarily depend on the magnitude and timing of the vehicle price increases (referred to as a “price premium” hereafter) and the gasoline savings from the standards. The effect of a vehicle price premium for each model year will be more immediate, since the premium is paid or financed at the time of purchase of a vehicle, while the gasoline savings accumulate over the long lifetime of the vehicle as the consumer owns and drives it. Unless one suspects that a dollar of vehicle price premium has a different macroeconomic impact than a dollar of fuel savings, an assumption that we will return to below, the long-run effect on the U.S. economy is determined by the relative magnitude of the price premium compared to the accumulated gasoline savings. If the vehicle price premium is larger than the accumulated fuel savings, the long-run macroeconomic effect should be negative; if the accumulated fuel savings exceed the vehicle price premium, the long-run macroeconomic effect should be positive. In this respect, the macroeconomic expectation is similar to a microeconomic prediction based on neoclassical assumptions.

Insofar as the vehicle price increase is estimated to be larger than the fuel savings in the first year but not over the entire life of the vehicle, as the 2012 NHTSA and EPA regulatory impact assessments suggest is the case, then the interesting question is how long will it take for the positive effects of the fuel savings to overtake the adverse effects of the price premium? We focus on this trade-off between short-term losses and long-term gains from a macroeconomic perspective.²

As we model the macroeconomic impact of the vehicle price increase, we are careful to consider that the impact of the price premium on the U.S. economy will not be entirely negative. Higher prices for new vehicles fund economic activity in the automotive supply chain. Fuel-saving technologies such as turbochargers, stop/start systems, and lithium ion batteries are added to vehicles, and those investments in innovation have positive employment, output, and income effects. We expect that

¹ The federal agencies responsible for oversight of the vehicle standards also considered macroeconomic impacts, although to a limited extent. In 2012, NHTSA (2012) and the EPA (2012) provided the official regulatory impact analyses (RIA) in support of the federal CAFE and GHG standards, respectively, for model years 2017 to 2025. Both reports included a detailed engineering-economic analysis of compliance technologies, including their costs and fuel-consumption benefits, but differed in their analytic treatment of employment effects. The NHTSA analysis estimated changes in car sales based on different consumer valuation scenarios, with results ranging from a decline in sales by 2.4 million vehicles to an increase in sales of 3.8 million vehicles. Applying an average productivity rate and a ratio of domestic labor to the production of cars sold in the U.S., NHTSA estimated a range from 143,000 fewer jobs to an increase of 225,000 jobs in the automobile sector. In contrast, the EPA (2012) included a qualitative discussion of possible impacts on new vehicle sales but no quantitative modeling of employment or other macroeconomic effects. Yet, such an analytic exercise is worthwhile, since it provides policymakers insight into how the standards will affect many industries, how much the economy as a whole will be impacted, and how the macroeconomic impacts will vary by geographic location and time. Thus, the macroeconomic information is complementary to the standard cost and benefit information supplied in regulatory impact analyses.

² A mystery we do not seek to resolve is why producers do not supply mandated levels of fuel economy voluntarily if, in fact, the accumulated fuel savings exceed the additional costs of the technologies. The 2012 NHTSA and EPA regulatory impact assessments discuss a variety of demand- and supply-side hypotheses that might explain the imperfect market performance. Yet, we regard the mystery as essentially unresolved. For a good recent point/counterpoint discussion of the demand-side issues, see Alcott and Sunstein (2015), Dudley and Mannix (2015), and Mannix and Dudley (2015).

those stimuli arising from a vehicle price increase will offset, at least to some degree, the adverse effects of increased vehicle price premiums on consumers.

Our theoretical expectations, however, are of course complicated by the fact that changes in vehicle expenditures, supply chain investments, and gasoline savings will have different effects on the economy, both in magnitude and geography. Assume, for example, that a consumer pays \$100 to the auto industry for new fuel-saving technology and then also saves \$100 that would otherwise have gone toward the purchase of gasoline in a less efficient vehicle. The \$100 of automobile expenditures is expected to boost innovation in the auto sector, thus adding to output and employment, and the \$100 savings on gasoline will also allow the consumer to purchase other goods and services, whereas the loss of \$100 to the petroleum industry will reduce output and employment throughout the petroleum supply chain. Concurrently, the higher price paid by the consumer to the auto industry will require a reallocation of consumer spending, which will have negative effects on the industries from which the reallocations occur, such as construction and retail.

Thus, theoretical expectations are for multiple impacts that vary by region of the country insofar as areas that have a disproportionate share of automobile, oil, and gasoline industries are expected to experience disproportionate effects. Tracking the dynamic impacts described above requires a macroeconomic model that has industry specificity through input-output tables, is dynamic, and allows for geographic granularity.

Comparison to Societal Cost-Benefit Analysis

It is essential to appreciate that the present analysis is macroeconomic in character. It is not an exercise in estimating changes in consumer and producer surplus, nor does it estimate the social welfare effects that are the focus of cost-benefit analysis. In order to highlight some of the aspects, and limitations, of our analysis, we compare it to some of the common features of benefit-cost analysis.

Our macroeconomic model assumes that consumers take the vehicle price premium as given, pay it in full, and subsequently accumulate gasoline savings over time. A benefit-cost model would allow for financing of the vehicle through a loan paid with interest, which has the effect of spreading out the burden of the price premium over the duration of a loan agreement. Our somewhat unrealistic assumption—only about 20 percent of vehicles are in fact purchased with cash—is related to a common limitation of macroeconomic modeling packages: they assume that debt/savings levels in the economy are fixed.

Our modeling approach also assumes that consumers, at the point of purchase, react to the gross price of the vehicle and do not account for the operating savings that result from a vehicle equipped with fuel-saving technology. Gasoline savings have an important influence in our modeling, but they are operationalized in a different way. Instead of acting, in the eyes of the consumer, as a deduction from the gross price of the vehicle, as might be predicted in a rational-choice model of the consumer, they operate as a stimulus to consumption of other goods and services as predicted by the input-output tables.

The gasoline savings in our modeling have a more powerful beneficial effect than they would in a benefit-cost model. Since the gasoline savings accrue only gradually over the average 16-year life of a vehicle, they are heavily discounted in benefit-cost analysis by the discount factor that is used to represent the consumer's time preference. In contrast, there are no time preferences in the sort of macroeconomic modeling used here. A dollar of fuel savings has the same impact on the economy regardless of which year it is experienced. We regard this as a limitation of our

modeling, since an ideal macroeconomic model would allow for consumers with temporal sensitivity to the operating costs of a vehicle.

Our modeling also does not account for a variety of behavioral changes by consumers and producers that might be induced by regulations. Producers might respond to regulation by offering more large vehicles and fewer small vehicles, since the federal standards are relatively more stringent for small vehicles. Consumers might respond to regulation by holding on to older cars for a longer period of time, which could nullify some of the projected fuel savings. Although federal agencies do not typically account for such behavioral effects, the microeconomic literature on CAFE is beginning to build the foundations for inclusion of such effects into societal cost-benefit analysis. Also, as is typical of macroeconomic models, our study does not address the external effects of the regulations such as reduced pollution or any other externalities associated with petroleum consumption. Analysis of externalities is typically a central focus of societal benefit-cost analysis.

In light of all of these considerations, we emphasize that macroeconomic modeling of federal CAFE and GHG standards is not a substitute for societal benefit-cost analysis. It is a complementary form of analysis that answers different questions of concern to policymakers. In particular, our analysis focuses on simulating the macroeconomic effects of the policy on employment and GDP whereas a benefit-cost-analysis would focus on estimating the societal costs and benefits of the policy.

METHODOLOGICAL APPROACH

Modeling Platform

The modeling platform used to simulate the macroeconomic effects of the regulations is the 160-industry sector and 9-region REMI PI+ 2.0.2, as constructed by the Regional Economic Models, Inc. REMI PI+ is a dynamic structural economic forecasting and policy analysis model that is based on some standard neoclassical economic assumptions. Indeed, it is similar to a model used to generate long-term macroeconomic forecasts by the Congressional Budget Office (CBO) and the Federal Reserve Board's "FRB/US Model." The integrated structural model of REMI combines input-output, computable general equilibrium, econometric, and economic geography modeling components. All four of these components are essential to our objectives, and their combination can vastly improve regional economic development analysis (Partridge & Rickman, 2010).

The input-output aspect of the model provides industrial detail through a typical input-output accounting matrix, thereby allowing the analyst to track relationships among economic sectors, or business-to-business, as well as final sales to households and wages paid to and spent by households.³ REMI's input-output tables are populated with Bureau of Labor Statistics data. It is especially useful for this study to have detailed descriptions of the automobile and oil/gas supply chains. The version of the model that we use includes 160 sectors, with a four-digit level of granularity in North American Industry Classification System code.

³ A typical input-output model accounts for production, spending, and employment, in a static setting, whereas REMI is able to additionally account for the labor force, fiscal operations, and population dynamics, all over time (Bonn & Harrington, 2008; also see pages 11–13 of REMI, 2018, for a more detailed description of such differences). The REMI model is also able to capture responses of producers and consumers to price changes. If the price of a consumer commodity rises, for example, REMI is able to account for substitution across commodities, whereas a standard input-output model would not (Rose & Wei, 2011).

Table 1. Nine region classification and the states within each region.

Region Classification	States
East North Central	Illinois, Indiana, Ohio, Michigan, Wisconsin
East South Central	Alabama, Kentucky, Mississippi, Tennessee
Mid Atlantic	New Jersey, New York, Pennsylvania
Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Pacific	Alaska, California, Hawaii, Oregon, Washington
South Atlantic	Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, Washington D.C., West Virginia
West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
West South Central	Arkansas, Louisiana, Oklahoma, Texas

The computable general equilibrium aspect provides dynamic equilibrium properties in the economy, such as price responses due to shifts in supply or demand. As part of this component of the model, markets are assumed to return to equilibrium after a shock. REMI is one of just a few models that includes both the computable general equilibrium and input-output modeling logic (Kelic et al., 2013).

The econometric component provides the speed of adjustments for economic impacts based on historical, real-world dynamics. The model contains thousands of simultaneous equations pertaining to output, demand, labor and capital demand, population, labor supply, prices and costs, and trade ratios.

Finally, the economic geography provides labor and industry agglomeration characteristics of each regional economy. The model is structured as multiregional, in which each individual regional economy incorporates demographic, industry, output, wage, and price composition specific to that region, and the regional economies interact through trade and commuter flows, inter-regional migration, and business location decisions. When a specific region experiences an expansion in the local labor market through an increase in labor demand, labor supply expands through an increase in migration of individuals from other regions. The economic geography component of the model can also adjust labor productivity and supply, and access to certain commodities due to changes in land use or industrial mix (Rose & Wei, 2011).

One of the primary benefits of the REMI model is its geographic granularity and its corresponding regional data disaggregation. The model contains region-specific information, including industrial composition of each region but also forecasts that are specific to each region and how their industrial growth and competition will change over time. The nine regions used in the model correspond to the Census Bureau's nine major divisions of the U.S. and are presented in Table 1. The model structure is presented in Appendix A.⁴

The REMI model was first introduced and verified over 35 years ago (Stevens et al., 1983). Since then, it has undergone modifications to refine and expand the model to include the migration equations and economic geography aspects (Fan, Treyz, &

⁴ All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.

Treyz, 2000; Greenwood et al., 1991; Rickman et al., 1993; Treyz, 1993; Treyz et al., 1993; Treyz & Petraglia, 2001). In fact, the REMI model is one of the most widely used models of its kind (Mills, 1993; Rose & Wei, 2011). Refer to Appendix B for a review of REMI literature, including studies that test the validity and performance of the model.

It is important to note, however, that the REMI model, like all modeling platforms, has its limitations (see, e.g., a review by Mills, 1993). The main drawback is also the model's greatest strength: its complexity. The model is based on decades of development and refinement, combines four different modeling approaches into one platform, and contains thousands of simultaneous equations. These aspects lend a "black box" image to the model, which is concerning enough to some analysts that they eschew the model in favor of more simplistic user-generated modeling approaches. Yet, the model documentation that REMI provides is highly detailed. Furthermore, there is valid argument to be made for using a more complex model when the analytic objectives are to consider multiple regulatory mechanisms at once, track impacts through specific supply chains, and derive both national and regional estimates.

There are, however, several other limitations to the model as well: 1) although the data are publicly available, the model itself is proprietary, which restricts replicability without access;⁵ 2) it is costly to access; and 3) the model is not guaranteed to be adjustable to the unique circumstances of each policy scenario. Similarly, not all parameters can be adjusted in the model. The input-output tables and corresponding multipliers, for example, cannot be user-adjusted.

In the process of conducting our analysis, we encountered some limitations of the model that are specific to the focus of our study. Assumptions about savings on gasoline expenditures, the oil and gas export-import ratio, domestic oil and gas supply chain activities, and revenue recycling back into the U.S. economy after consumers buy imports, are arguably unrealistic and could benefit from modernization. We discuss these specific limitations in more depth in the Appendix.

Input Data: 2012 vs. 2016 Perspectives

Our modeling compares the combined impacts of the federal standards for model years 2017 through 2025 to a baseline scenario where the federal standards are frozen at their 2016 levels. We then consider possible changes to the standards in light of the Trump administration's proposed rule to freeze the standards at their 2020 levels. Since several key modeling parameters changed between 2012, when the federal agencies finalized the standards, and 2016, when the agencies conducted their midterm review, we include both a 2012 and a 2016 perspective in this modeling exercise. This section describes the data inputs used in the modeling. We describe the assumptions of the Trump adjustments in the next section.

The 2012 Perspective is based on information that was available to the agencies during 2009 through 2012, when the 2017 to 2025 federal standards were developed, proposed, and finalized. To construct the 2012 Perspective, we collected several key parameters—the gross price premium, required fuel economy standards, gasoline savings, vehicle miles traveled (VMT), vehicle survival rates, and number of vehicles sold—from NHTSA (2012). We define these parameters in Table 2. Data on fuel economy, fuel prices, VMT, and survival rates are combined to estimate fuel savings for each calendar year.

⁵ All input files created for this analysis are available from the authors upon request. Thus, if one seeks to replicate this study, the only limiting factor is the need to pay for access to the model.

Table 2. Modeling parameter definitions and data sources.

Variable	Definition	Data Source	
		The 2012 Perspective	The 2016 Perspective
Fuel Prices	Annual forecasts of gasoline prices estimated by the EIA.	EIA (2012)	EIA (2016)
Vehicle Price premium	The increase in the production cost of a vehicle due to the standards	NHTSA (2012)	NHTSA (2012) + NRC (2015) adjustments
Car/truck ratio	The share of estimated new cars and trucks that enter the fleet in each model year	NHTSA (2012)	EIA (2016)
Required fuel economy standards	The miles-per-gallon standards established by the federal government	NHTSA (2012)	NHTSA (2012)
Vehicle miles traveled (VMT)	The total miles that an average vehicle is driven each year	TAR (2016)	TAR (2016)
Vehicle survival rate	The probability that the average car remains usable in each year of its life	TAR (2016)	TAR (2016)
Number of vehicles sold	The assumed number of vehicles that will be purchased in each year	EIA (2016)	EIA (2016)
Gasoline Savings	The dollar savings that a consumer acquires due to having a more efficient vehicle that requires less gasoline.	Authors' calculations based on fuel price, fuel standards, VMT, survival rate	Authors' calculations based on fuel price, fuel standards, VMT, survival rate

Notes: The 2012 Perspective is based on economic data and assumptions used in the 2012 Regulatory Impact Analyses of the National Highway Traffic and Safety Administration (NHTSA). The 2016 Perspective updates the 2012 data and assumptions to reflect the information available to policymakers in 2017. The values for each variable vary by vehicle model year. Table 3 presents parameter values for selected years.

We also generate 2016 Perspectives, since the oil and automobile industries have changed so fundamentally since 2012, when the regulations were last adopted. Compared to the 2012 inputs, the 2016 inputs reflect: 1) the higher technology costs estimated by the National Research Council (NRC); 2) a large reduction in the Energy Information Administration's (EIA) forecast for average gasoline prices in 2025; and 3) a major shift in the mix of vehicle sales from passenger cars toward light trucks (TAR, 2016, ES-1). It is important to note that these changes do not reflect simple year-to-year changes that one would naturally expect in time series data. Instead, the goal is to capture fundamental changes that occurred since the 2017 to 2025 rule was adopted. Below, we expand on each of these changes in order to demonstrate that they are large enough to merit special attention.

The NRC, following a request by NHTSA, established a committee to assess the fuel-saving effectiveness and direct manufacturing costs of a series of technologies used in NHTSA (2012) (NRC, 2015). After a thorough examination, the committee confirmed the validity of most of the estimates of technology cost and fuel-saving

effectiveness (2012). For a limited number of technologies, the NRC found that both costs and fuel savings were underestimated or overestimated. We use NRC findings to devise a low-cost and high-cost price premium (referred to as “2016 Low Perspective” and “2016 High Perspective,” respectively) to serve as 2016 inputs. Recent studies have also used the same NRC findings to update the vehicle price premium in their modeling efforts (Xie et al., 2017; Xie & Lin, 2017). The manner in which we devised these estimates is outlined in Appendix C.⁶

When the 2012 RIA was drafted, the projected future 2025 price of gasoline, according to the EIA, was \$3.84 per gallon. The *Annual Energy Outlook* (AEO) (U.S. EIA, 2016) reflects significant changes that have occurred within oil markets since 2012, such as the shale gas revolution and changes in global oil demand. As a result of these and other changes, the new projected price of gasoline is significantly lower than previously expected, around \$2.74 per gallon by 2025. Our 2016 Perspective inputs use the EIA (2016) gasoline price forecasts. Of course, the price of gasoline in the future is highly uncertain so we also run sensitivity analyses around the estimates using the EIA’s low and high projections.

In rulemaking analyses, NHTSA and the EPA generally rely on forecasts of new vehicle sales prepared by the EIA. Separate forecasts are made for passenger cars and light trucks, using the regulatory definitions of the two vehicle types. Industry definitions are somewhat different, in part because they classify fewer “crossover” vehicles (i.e., those that share some attributes of both standard passenger cars and sport utility vehicles) as cars and instead classify those vehicles as trucks. When the 2012 rulemakings were prepared, the model year 2025 forecast was for 67 percent of cars and 33 percent of light trucks. EIA has changed that forecast substantially, as AEO 2016 reported a model year 2025 forecast of 52 percent of cars and 48 percent of light trucks. The modification reflects rapid changes in consumer purchasing decisions, in part due to the fact the fuel prices have fallen and are projected to remain below \$3.00 per gallon through 2025.

The change in the vehicle fleet mix does not change the vehicle price premium significantly, as neither the agencies nor the NRC reported significantly different costs of compliance for light trucks versus cars. The temporal pattern of gasoline consumption, however, changes significantly, as the savings in gasoline consumption are pushed further into the future due to the unexpected influx of light trucks. The delay in gasoline savings occurs because the scheduled increases in fuel economy standards occur more rapidly for passenger cars than for light trucks. Much of the increase in required fuel economy for trucks does not occur until model years 2022 to 2025. The gasoline savings due to the projected sales of those trucks occur gradually over a 37-year period. In the long-run, the fuel savings from the average truck are larger than the savings from the average car, in part because trucks are much less fuel efficient at baseline and in part because trucks are typically driven more than cars.

Using these assumptions, we summarize the key input data in Table 3 for the 2012 NHTSA Perspective, the 2016 Low Perspective, and the 2016 High Perspective. This table provides estimates of the price premium per vehicle, the number of vehicles sold, and the price of gasoline for all perspectives. The vehicle price premiums and sales volumes are specific to cars and trucks and are combined to produce an estimate of total expenditure premium on vehicles in each calendar year. We use these input data to construct the three mechanisms through a series of steps defined in the next section.

⁶ All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher’s website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.

Table 3. Input data for the three perspectives.

Perspective/Year	2017	2020	2025	2030	2035
NHTSA 2012 Perspective					
Price Premium per Car (\$)	364	858	1,578	1,566	1,566
Price Premium per Truck (\$)	147	629	1,226	1,218	1,218
Total Light-Duty Car Sales (Thousands)	7,980	8,098	8,597	9,126	9,669
Total Light-Duty Truck Sales (Thousands)	9,362	8,112	7,834	7,660	7,571
Price of Gasoline (\$/gallon)	3.64	3.75	3.84	3.96	4.04
2016 Low Perspective					
Price Premium per Car (\$)	395	940	1,758	1,746	1,746
Price Premium per Truck (\$)	159	689	1,366	1,358	1,358
Total Light-Duty Car Sales (Thousands)	7,980	8,098	8,597	9,126	9,669
Total Light-Duty Truck Sales (Thousands)	9,362	8,112	7,834	7,660	7,571
Price of Gasoline (\$/gallon)	2.03	2.52	2.73	2.94	3.20
2016 High Perspective					
Price Premium per Car (\$)	549	1309	2,468	2,449	2,449
Price Premium per Truck (\$)	222	959	1,918	1,906	1,906
Total Light-Duty Car Sales (Thousands)	7,980	8,098	8,597	9,126	9,669
Total Light-Duty Truck Sales (Thousands)	9,362	8,112	7,834	7,660	7,571
Price of Gasoline (\$/gallon)	2.03	2.52	2.73	2.94	3.20

Notes: All monetary values are in constant 2010 dollars. The 2012 Perspective is based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. The 2016 Perspectives update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council. A detailed analysis of the data source and calculations behind the car and truck price premium for the 2016 Low and 2016 High Perspectives is in the Appendix. A Figure illustrating the differences in trajectories between the 2012 and 2016 gasoline prices can be found in Appendix H. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.

Proposed Trump Administration Changes

In order to supply analytic results relevant to current policy decisions about vehicle regulations, we additionally model two alternative regulatory pathways. The first freezes the standards after 2021, so that they indefinitely stay at the 2021 MPG limit. In this case, both the standard and the compliance costs are fixed at the 2020 levels. This scenario matches the proposed rule presented in NPRM (2018). The second reduces the annual increase in the standards by one-third; for example, instead of increasing by two miles per gallon per year, we allow for an increase of 1.33 miles per gallon per year between 2021 and 2025. The slower growth in the standards implies a reduction in the compliance costs. Because we are not able to estimate the compliance costs, we make the simplifying assumption that the costs grow more slowly and proportional to the change in the standards. For example, suppose compliance costs were expected to increase by \$100 per year under the standards. We assume that they now increase by \$67 per year. This scenario represents a possible alternative standard that the Trump administration may consider as it revises the final fuel economy rule. To examine how such changes in the standards would affect the economy, we model these two scenarios using 2016 Perspective inputs.⁷

Constructing Mechanisms in REMI

Vehicle Price Premium

In order to capture the effects of the vehicle price premiums due to the standards, we began by dividing vehicle consumers into two categories: those who purchase vehicles for personal use and those who purchase vehicles for use in private (i.e., industry or commercial) or government fleets. We assume that 80 percent of vehicle purchases are by individual consumers, 19 percent are private industry fleet purchases (e.g., rental car agencies and corporate fleets), and the remaining 1 percent are government fleet purchases. This distribution is based on historic vehicle sales data, as gathered by Polk (2016), and on the registration category breakout outlined by Polk (2002). The regional distribution of sales is allocated to the nine Census regions in proportion to total light-duty vehicle sales, as specified by the EIA (2012).

For consumers, the total additional expenditures on light-duty vehicles due to the regulations are treated as an automobile price increase. For government, the expenditures are treated as additional government spending on automobiles. For private industry, the expenditures are operationalized as additional production costs, and spread across 160 sectors according to the amount of total light-duty vehicle transportation-related GDP output for which each sector accounts.

There are several limitations to the way we model the price premium. First, the nature of the REMI modeling platform only allows us to model the price change in the average vehicle, rather than different price changes across different vehicle types. As a result, we cannot incorporate some of the findings in the literature, which suggests that some manufacturers use short-term pricing strategies (e.g., cut prices on fuel-efficient models) in order to comply with the CAFE standards (see, e.g., Liu et al., 2014), nor can we evaluate whether there are differential impacts of the

⁷ Since the NPRM (2018) is only a proposed rule, with a set of regulatory options, and not-yet-peer-reviewed assumptions and input parameters, we do not use the data and assumptions in the NPRM to model the impacts of freezing the standards. Furthermore, it is possible that parameters will change in the finalized rule, given the thousands of public comments submitted about the proposed rule (see, e.g., Linn et al., 2018, and IPI, 2018, and an article by Bento et al., 2018, for commentary on Trump administration assumptions).

standards across the country due to variation in consumer preferences for different vehicles. Second, the price premium does not incorporate the flexible mechanisms of trading and banking credits that manufacturers have at their disposal, though the utility of those mechanisms has been constrained by inconsistencies between the NHTSA and EPA programs (Leard & McConnell, 2017). Third, we implicitly assume that consumers pay for their vehicles upfront and do not take out a loan to finance the purchase, since savings and debt are held constant in REMI. These last two limitations affect the modeling results by concentrating the negative impacts in earlier time periods rather than spreading them out over time. REMI's inability to capture consumer loans should also result in smaller total impacts, since we do not incorporate the additional costs of financing automotive debt. Fourth, our model does not account for long-run changes to the prices of used cars as a result of the national standards, a phenomenon that Jacobsen (2013) has shown would reduce the extent of gasoline savings, since consumers will make greater use of older, fuel-inefficient vehicles. Finally, like the analyses prepared by federal agencies, we assume that the standards do not lead to any compromises in valued vehicle attributes such as performance. As noted above, there is a growing body of literature that finds that future performance gains are compromised by CAFE standards (Klier & Linn, 2012; Knittel, 2011; Leard et al., 2017; Ullman, 2016). If correct, this line of literature suggests that we have overestimated technology costs, since compliance is accomplished partly by foregone performance, but adverse impacts on new vehicle demand are also misgauged, since consumers will react negatively to the foregone gains in performance.

Automobile Supply Chain Reinvestment and Technological Innovation

Increased expenditures on vehicles pay for economic activity, which occurs originally in the supply chain of the automotive sector. We frame this activity as investment in technological innovation and deployment, since that is the functional purpose of the regulations. Like any form of economic activity, the supply-chain investments due to regulation stimulate employment and output.

We assume that 100 percent of the vehicle price premium is translated into spending in the automobile industry sector, but a certain percentage of that stimulus will occur entirely outside of the U.S. economy. All of the global automakers, including the Big Three (General Motors, Ford, and Fiat Chrysler), are allocating a significant share of new investments to China and other emerging markets. The forecasted rate of growth in new vehicle demand is higher in these regions than it is in North America and Europe (Greimel, 2016). Within North America, about 65 percent of new original equipment manufacturers (OEM) facility investments are being allocated to the U.S., with Mexico's share rising, the U.S. share declining, and the Canadian share stable (CAR, 2015).

An exact prediction of potential new automotive investment activities within the U.S. is difficult. Since the leakage of spending outside the U.S. reflects strategic decisions of specific manufacturers, descriptor variables of manufacturers may have explanatory power, at least as surrogates. The most common variables that have been suggested for consideration are the location of the company's global headquarters, whether the company has R&D centers in the U.S., whether the company assembles its vehicles in the U.S., whether a company assembles its engines or transmissions in the U.S., and the domestic content of the parts used in a company's vehicles.

To simplify a complex issue, we assume that 30 percent of all investments by OEMs—excluding investments by parts-makers—will occur outside of the U.S. This figure may seem low, since the U.S. market share of the Big Three in 2015 and 2016

was only 45.3 percent. Insofar as Toyota is treated more like the Big Three than like the other global automakers, with respect to investment interest in the U.S. market, the U.S.-related market share rises from 45.3 percent to 59.5 percent. Adding in Honda (9.2 percent) increases the total from 59.5 percent to 68.7 percent (WSJ, 2017). We maintain the 30 percent assumption in the 2012 and 2016 Perspectives, but we also run sensitivity analyses using different percentages both above and below this value.

REMI assumes regional purchase coefficients in auto industry supply chains of approximately 70 percent. In other words, for each dollar invested in the U.S. auto supply chain, approximately 70 cents stays in the U.S. economy. This estimate matches the U.S. Department of Commerce's Economics and Statistics Administration's finding that, of all domestically-produced motor vehicles and parts, the average domestic content is 71 percent (Nicholson & Noonan, 2014). The 70 percent of the OEM reinvestment that stimulates the U.S. economy is allocated in several categories of economic activity to the automobile industry: 4 percent goes toward research and development (R&D), 7.8 percent toward increased production in labor, 32.1 percent toward increased production of motor vehicle parts manufacturing (i.e., materials), 39.1 percent toward overhead and management, 7.1 percent toward shareholder income, and 9.6 percent toward auto dealership income. These percentages are derived in Appendix D.⁸

In the REMI model, regulation is modeled as increasing investment in R&D by increasing industry sales for scientific research and development services. The increase in labor is modeled as an increase in industry sales for motor vehicle manufacturing. Materials are modeled through motor vehicle parts manufacturing. The increase in overhead is entered into the model through industry employment for management of companies and enterprises. Shareholder income is operationalized as proprietor income in the auto industry, and dealership income is operationalized as automobile dealership income.

The Gasoline Savings Mechanism

Savings in gasoline expenditures operate through the same three categories of consumers as before. Consumers are modeled as saving money on gasoline expenditures but are then subject to a macroeconomic balancing mechanism in which they spend an equivalent amount of money on all other goods and services; savings and debt are held constant in REMI.

For consumers, expenditures on gasoline are operationalized through a decrease in consumer spending on vehicle fuels, lubricants, and fluids. Since consumers retain the extra money that would have been spent on gasoline, they spend this money on other goods and services, which is entered into the model as a consumption reallocation. For industry, we enter gasoline savings as a production cost decrease, and those savings are spread across all industry sectors, according to their shares of transportation-related GDP. Similar to individual consumers, the government spends less on fuels, lubricants, and fluids, but has more money available for other types of expenditures. Taxation and deficit spending are held constant.

The decreased consumption of gasoline reduces U.S. demand for oil through both oil imports and U.S. oil production. REMI is structured to generate a 50-50 split in the relative impact on importation versus U.S. production of oil, and we assume that there is no change in that distribution throughout the time horizon of the study, but we discuss the sensitivity of this assumption in Appendix E. As U.S. oil

⁸ All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.

production changes, there are ripple effects throughout the energy supply chain such as changes in refining activity, oil and gasoline transport, purchases of equipment for exploration and development, and sales at wholesale and retail gasoline outlets.

Fuel savings are estimated using the following formula:

$$\text{Fuel savings} = \left(\Delta \frac{1}{\text{MPG}} \right) * \text{VMT} * \text{Survival} * \text{Fuel Price},$$

where MPG denotes the on-road fuel economy, VMT varies over the entire lifetime of each vehicle, survival rate varies by vehicle age and is different for cars and light trucks, and the fuel price uses the reference scenario of the Annual Energy Outlook (U.S. EIA, 2016). The VMT calculations incorporate the 10 percent rebound effect assumed by NHTSA (2012). As noted above, the fuel savings calculations do not make any assumptions about how consumers value fuel economy when purchasing vehicles.

Other Mechanisms Not Modeled

As noted above, we include the two mechanisms that have been used previously in similar studies (i.e., a vehicle price premium and gasoline savings), and then add a third mechanism to make the analysis more realistic (i.e., supply chain innovation). Although these three mechanisms represent the most important aspects of vehicle emissions regulations, there are several other possible mechanisms that one could additionally model in future work, and that previous energy research has highlighted as important for public policy (e.g., Tang & Popp, 2016; Weber et al., 2016): 1) changes in government spending due to a decline in fuel tax revenue and an increase in sales tax revenue from automobile sales; 2) changes in the composition of the manufacturing and raw materials sectors if the regulations encourage significantly more electric or fuel cell vehicle production; 3) infrastructure investments in charging stations and other such technologies; and 4) changes in the price of electricity if new power plants are built to charge electric vehicles or if vehicle-to-grid technologies make a break-through due to these regulations.⁹

MODELING RESULTS

We present results for two different economic indicators: employment and GDP.¹⁰ As also used by the U.S. Bureau of Economic Analysis, the employment output captures full-time, part-time, and sole proprietors in a job-year unit. Employment is a stock

⁹ It is important to note that the U.S. automobile industry is currently in flux. Not only are there many emerging technologies that are potentially poised to compete with the conventional vehicle in coming years—such as electric vehicles, fuel cell vehicles, biofuel-powered vehicles, among others—there is also the possibility that significant advancement of a radical technology, such as autonomous vehicles, or other market developments such as the rise of ride sharing (e.g., Uber and Lyft) could fundamentally reshape the future of the industry. In this analysis, however, we are exclusively interested in the possible effects of CAFE and GHG regulations and, thus, all modeling scenarios that we construct are limited to the mechanisms associated with the standards. In the case of electric vehicles and fuel cell vehicles, furthermore, the EPA determined in their 2012 RIA and the 2016 midterm assessment that widespread electrification would not be necessary in order to comply with the 2017 to 2025 standards. In any event, the penetration of electrification, autonomous vehicles, and ride sharing is likely to be limited in the timeframe of our analysis, especially prior to 2025.

¹⁰ For every modeling scenario, we produced results for 25 different macroeconomic indicators at the national and regional level. These include (among others) real disposable personal income, government spending, consumer price index, output in motor vehicle manufacturing, and oil and gas exports. The authors will make any of these results available upon request.

concept, meaning that it should not be aggregated over time but instead interpreted in a single year relative to a base year. GDP accounts for all business transactions minus demand for intermediate goods and services. Thus, this output only reflects net new economic activity. All graphs presented in this section reflect the difference between the baseline scenario, in which federal standards do not rise above 2016 values, and the policy scenario. We report results for the period 2017 to 2035, since the underlying assumptions, inputs, and forecasts are more plausible for the shorter time horizon, and because intervening policy, technological, and economic variables can change in unexpected ways as the time horizon is lengthened by decades.

The Vehicle Price Effects

Within REMI, when vehicle production costs increase, prices rise for new vehicles. An increase in consumer price causes a decrease in the real compensation rate of households, since overall prices in the economy are higher for the same level of compensation. Real disposable income decreases due to higher consumer prices, consumption decreases, and this causes output to decrease. Both the income and substitution effects work together to result in a decreased demand for new motor vehicles. The increase in consumer price of new motor vehicles affects output of the automotive industry the most.

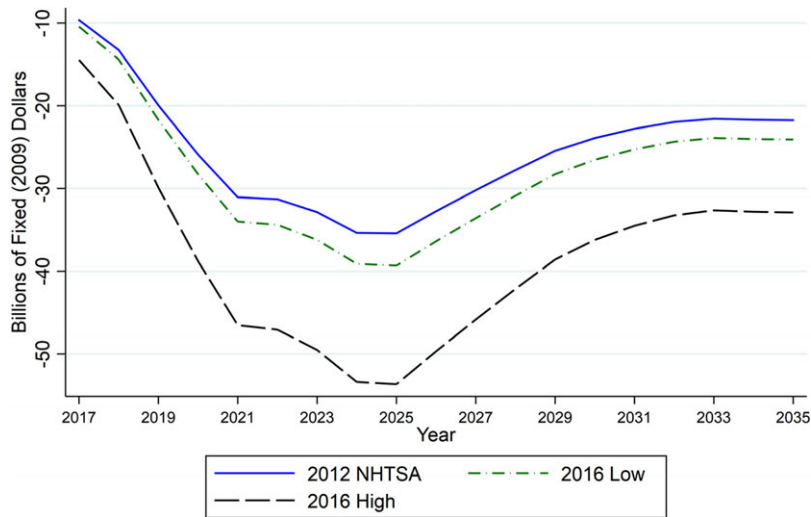
The increase in government expenditures on vehicles in REMI causes the amount of money available to spend elsewhere to decrease, which causes output to decrease and negatively affects employment. The decrease in employment causes real disposable income and consumption to decrease. The other effect of decreasing employment is a decrease in the optimal level of capital, and thus a decline in investment, and further decline in output.

For private industry, higher vehicle costs translate into greater production costs. Increases in private industry expenditures on vehicles cause an increase in the cost of creating output. This production cost increase is weighted by the amount of intermediate inputs associated with transportation, which has a larger effect on industries that rely more heavily on transportation. An increase in production costs causes composite prices to increase, which subsequently causes consumer prices to increase. It also causes domestic market share, as well as output, to decrease.

The effect of higher vehicle prices on GDP is presented in Figure 1. Total employment effects for this mechanism, as well as the other two mechanisms (below), are presented in Appendix F.¹¹ The 2012 Perspective—labeled as 2012 NHTSA—shows a loss of \$35 billion in GDP (or a 0.17 percent decline) around 2025, an effect that is enlarged to a peak of about −\$58 billion (or a 0.26 percent decline) in the 2016 High Perspective. The adverse effects of regulation through higher vehicle prices dissipate from 2026 to 2035. As noted above, REMI is built to represent an economy that responds and recovers to external shocks such as an exogenous increase in vehicle prices due to regulation.

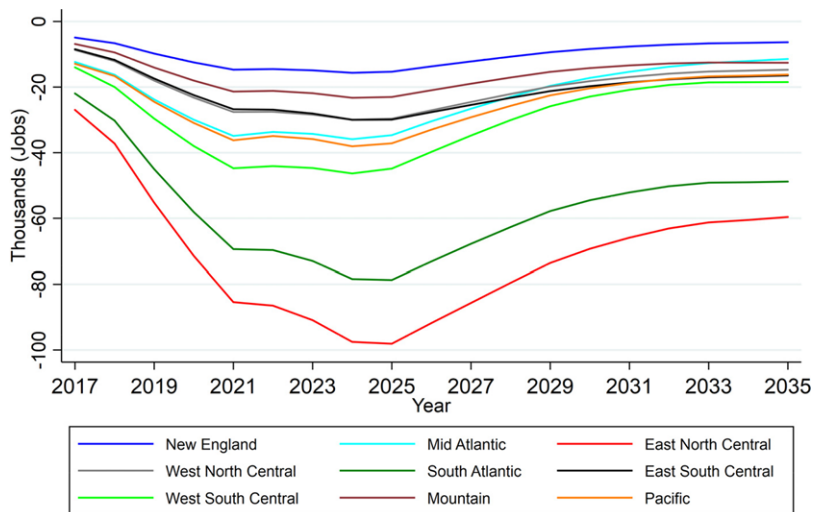
Figure 2 presents the employment impacts across all regions using the 2016 Low Perspective input data. This graph demonstrates that the price premium mechanism hits the East North Central region the worst, with a loss of approximately 100,000 jobs in this region around 2025. The South Atlantic region is also negatively affected disproportionately. This finding is consistent with the geographic portrait of the U.S. automotive industry, in which the majority of activity occurs within these two regions. Results for GDP demonstrate similar trends across the regions, thus we do

¹¹ All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.



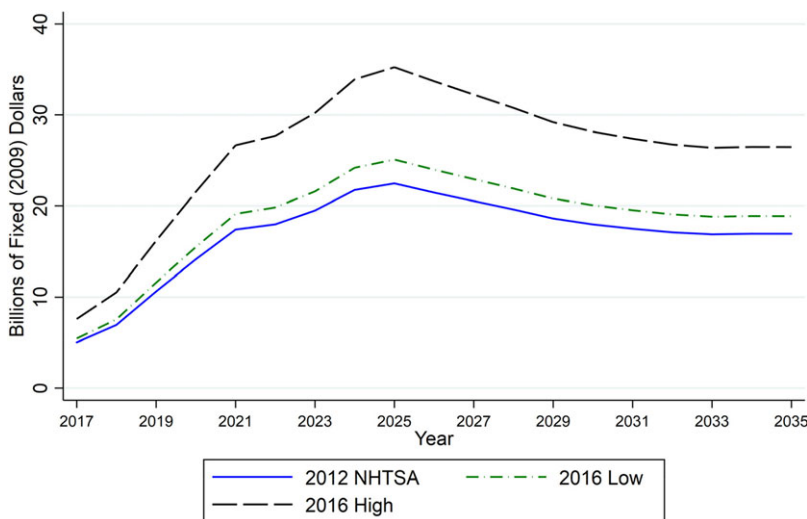
Notes: Reported is the difference in GDP between the baseline scenario and each price premium scenario. GDP is in billions of 2009 dollars. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council.

Figure 1. Impact of CAFE Price Premium on GDP.
[Color figure can be viewed at wileyonlinelibrary.com]



Notes: Reported is the difference in employment between the baseline scenario and the price premium in the 2016 Low Perspective scenario, by region. Employment is measured in job-years.

Figure 2. Impact of CAFE Price Premium on Employment, by Region.
[Color figure can be viewed at wileyonlinelibrary.com]



Notes: Reported is the difference in GDP between the baseline scenario and the supply chain innovation scenario. GDP is in billions of 2009 dollars. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council.

Figure 3. Impact of Automobile Supply Chain Innovation Expenditures on GDP.
[Color figure can be viewed at wileyonlinelibrary.com]

not present them here. Results vary in magnitude for the other perspectives but not in general trends.

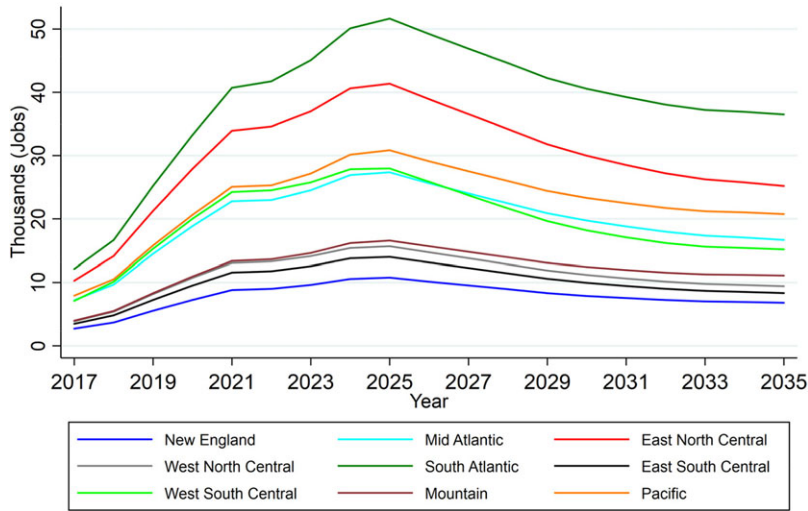
The Automobile Supply Chain Reinvestment and Technological Innovation Effects

The stimulus to the supply chain from the vehicle price increase is expected to boost the economy. Specifically, the increase in sales for R&D, labor, and parts is equivalent to an increase in output, which causes the optimal level of capital to increase, and thus investment, and results in a feedback effect that increases output further. An increase in employment has a similar effect in REMI. More employment causes the optimal capital stock to increase, which raises investment. Higher investment causes output to increase, which again feeds back to employment.

The isolated effects from this innovation investment, in the absence of the negative price premium effect on consumers, is presented in Figure 3. By 2025, GDP is \$22 billion (0.11 percent increase) above baseline in the 2012 Perspective and \$25 to \$35 (0.12 to 0.17 percent increase) billion above baseline in the 2016 Perspectives. Comparing the aggregated innovation effects to the vehicle price effects, as presented in the previous section, reveals that the positive effects from innovation are at least half the size of the losses from the vehicle price effect. The majority of projected increases in both GDP and employment occur in the South Atlantic and East North Central regions, the latter of which is presented in Figure 4.

The Fuel Savings Stimulus

Consumption reallocation from gasoline savings increases consumption of other goods, which positively affects output, employment, optimal capital stock, and



Notes: Reported is the difference in employment between the baseline scenario and the supply chain innovation 2016 Low Perspective scenario, by region. Employment is measured in job-years.

Figure 4. Impact of Automobile Supply Chain Innovation Expenditures on Employment, by Region.

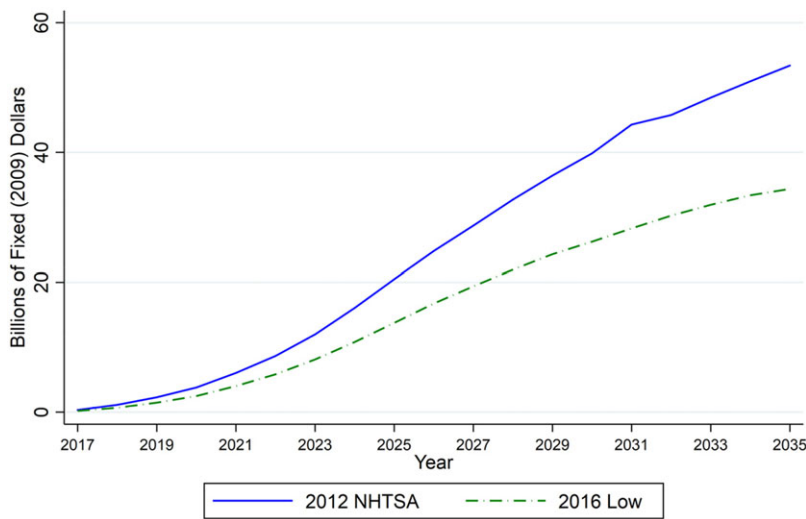
[Color figure can be viewed at wileyonlinelibrary.com]

investment in those sectors. Industry production cost reductions make U.S. industry more competitive, which has favorable trade ramifications such as more exports and less vulnerability to import competition. A losing sector in this process, however, is the petroleum sector since the decline in demand for gasoline reduces the U.S. demand for oil, which in turn reduces oil imports and reduces the demand for U.S. oil extraction. These conditions affect not only oil extraction but also the supply chain for oil production (e.g., oil refining, transport and refueling stations, equipment for exploration and drilling, and materials used in oil and gas development).

The impacts of the fuel savings are large but, as expected, it takes time for them to accumulate due to the long lifetime of vehicles and the gradual addition of new fuel-efficient vehicles in the U.S. fleet. The effects on GDP are presented in Figure 5. Since the two 2016 Perspectives have the same assumptions for gasoline savings—they only vary in their assumption about the size of the price premium—we only show the results here for the Low 2016 Perspective. Under the 2012 Perspective, the gains in GDP reach about \$20 billion (0.1 percent) in 2025 and continue to climb to over \$53 billion (0.22 percent) in 2035. These gains are attenuated in the 2016 Perspectives. As Figure 6 reveals, the South Atlantic region benefits the most from the gasoline savings while the oil-producing West South Central region is negatively affected across the entire study period.

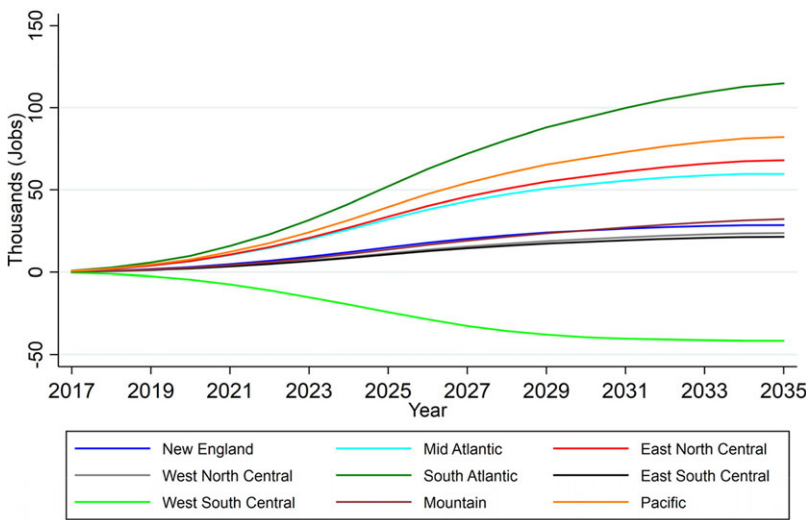
Combining All Fuel Economy Mechanisms

The combined effect of the three mechanisms is presented in Figure 7. For GDP, under the 2012 Perspective, it takes about six years, around 2023, for the annual change to switch from negative to positive. Under the 2016 Low and High Perspectives, the annual net positive effects on GDP are delayed until 2025 and 2026, respectively. Once GDP turns positive, it grows steadily and substantially thereafter, with diminishing returns beginning around 2030.



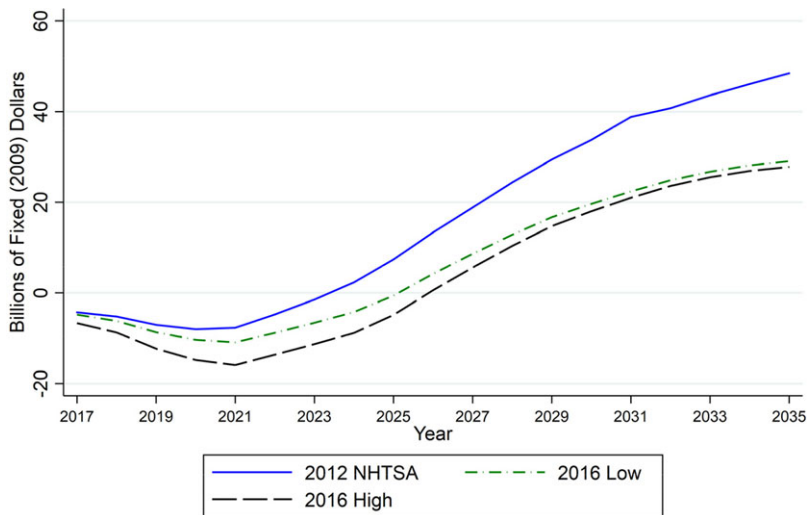
Notes: Reported is the difference in GDP between the baseline scenario and the gasoline savings scenario. GDP is in billions of 2009 dollars. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 Low Perspective” updates the 2012 data and assumptions to reflect the information available to policymakers in 2017 including the National Research Council’s 11 percent adjustment in the price-premium.

Figure 5. Impact of CAFE Gasoline Savings Scenarios on GDP.
[Color figure can be viewed at wileyonlinelibrary.com]



Notes: Reported is the difference in employment between the baseline scenario and the gasoline savings 2016 Low Perspective scenario, by region. Employment is measured in job-years.

Figure 6. Impact of CAFE Gasoline Savings Scenarios on Employment, by Region.
[Color figure can be viewed at wileyonlinelibrary.com]

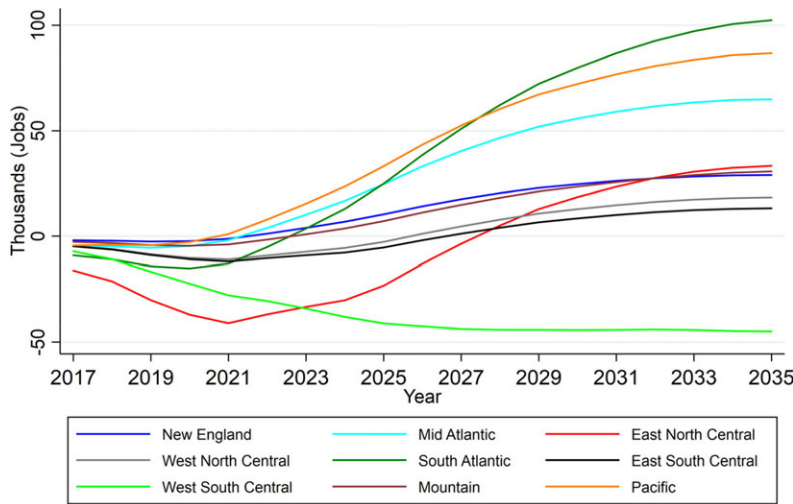


Notes: Reported is the difference in GDP between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios. GDP is in billions of 2009 dollars. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council.

Figure 7. Impact of CAFE Combined Scenarios on GDP.
[Color figure can be viewed at wileyonlinelibrary.com]

Figure 8 shows that the annual impacts are not the same across all geographic regions. We present results only for the 2016 Low Perspective for employment, since the trends are similar but with different magnitudes for the 2016 High Perspective and for GDP results. Three regions benefit the most from the regulations: South Atlantic, Mid Atlantic, and Pacific. The East North Central region starts with the lowest values for both of these indicators but then recovers faster than other regions. Unlike all other regions, the West South Central Region never fully recovers from adverse price effects and continues to measure losses through 2035. This region is a large oil producing region, and much of the U.S. supply chain for oil production is also located in this region. Consequently, a decrease in demand for oil hits this region harder than others, even though consumers of gasoline in this region still experience benefits.

Since negative impacts occur for several consecutive years, it takes more than one positive year to outweigh the accumulated negative effects. Thus, it is instructive to model how long it will take for the 2017 to 2025 federal standards to have a net positive impact on the U.S. economy compared to retention of the 2016 standards. To obtain these cumulative results, the annual changes in GDP are summed over a specified time period. Table 4 presents cumulative GDP results for all three datasets. The first column presents results between 2017 and 2025, the second between 2017 and 2035. The third column gives the year in which annual results turn from negative to positive, as is also reflected in Figures 3, 5, and 7. The fourth column presents the year in which the cumulative results turn from negative to positive. These results suggest that under no set of assumptions used in this analysis do the regulations have a net positive macroeconomic benefit between the years 2017 and 2025. If one extends the period of analysis up through 2035, however, the datasets produce net positive impacts on GDP. This table reveals that, depending on the dataset, annual



Notes: Reported is the difference in employment between the baseline scenario and the combined 2016 Low Perspective price premium, supply chain innovation, and gasoline savings scenarios, by region. Employment is measured in job-years.

Figure 8. Impact of CAFE Combined Scenarios on Employment, by Region.
[Color figure can be viewed at wileyonlinelibrary.com]

Table 4. Macroeconomic modeling results, cumulative 2017 to 2025 and 2017 to 2035.

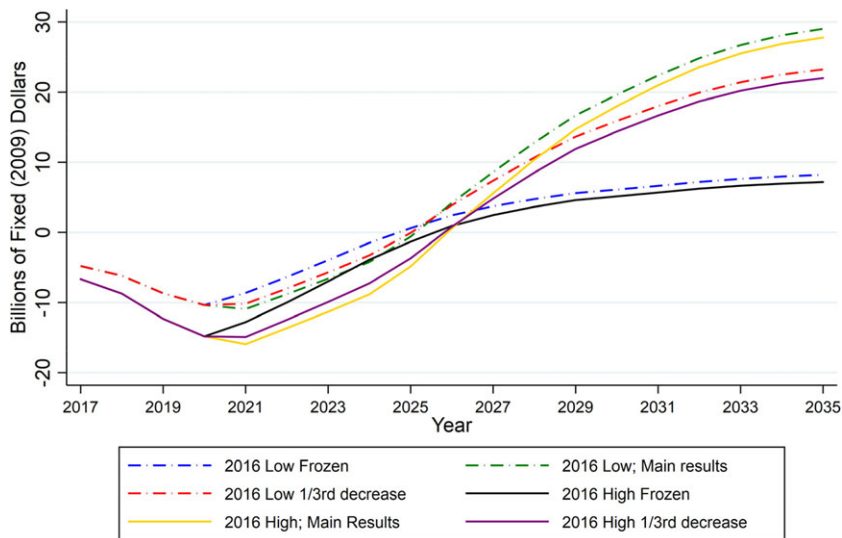
Dataset	2017–2025	2017–2035	Annual Effects Break-Even Year	Cumulative Effects Break-Even Year
NHTSA 2012 Perspective GDP (Billions 2009\$)	–28.7	308.7	2023	2027
2016 Low Perspective GDP (Billions 2009\$)	–61.1	132.0	2025	2030
2016 High Perspective GDP (Billions 2009\$)	–97.1	77.0	2026	2033

Notes: Reported is the cumulative difference in GDP between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios. GDP is measured in billions of 2009 dollars. “2012 NHTSA” is the 2012 Perspective, which is based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council.

levels of GDP will switch from negative to positive between 2023 and 2026; and cumulative levels will switch between 2027 and 2033.

Given the degree of uncertainty about future gasoline prices and the location of OEM operations, we run sensitivity analyses on these two parameters. The price premium is also uncertain, although our use of different modeling perspectives illustrates explicitly how this uncertainty affects our results. Results of the sensitivity analysis are presented in Appendix G.¹²

¹² All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher’s website and use the search engine to locate the article at <http://onlinelibrary.wiley.com>.



Notes: Reported is the cumulative difference in GDP between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios under the Trump administration regulatory pathways. GDP is in billions of 2009 dollars. “2016 Low Frozen” = 2016 Perspective dataset with a low price premium, with fuel economy standards frozen after 2020; “2016 Low 1/3rd decrease” = 2016 Perspective dataset with a low price premium, with fuel economy standards decreased by one-third after 2020; “2016 High; Main Results” = main modeling results for High 2016 Perspective; “2016 Low; Main Results” = main modeling results for Low 2016 Perspective; “2016 High Frozen” = 2016 Perspective dataset with a high price premium, with fuel economy standards frozen after 2020; “2016 High 1/3rd decrease” = 2016 Perspective dataset with a high price premium, with fuel economy standards decreased by one-third after 2020.

Figure 9. Impact of Trump Administration Regulatory Pathway Scenarios on GDP. [Color figure can be viewed at wileyonlinelibrary.com]

Trump Administration Changes

As discussed previously, the Trump administration recently proposed freezing the federal standards at the 2020 levels (NPRM, 2018). This section simulates the macroeconomic impacts of CAFE under this proposal. We present the results in Figure 9 and Table 5, where we also compare them to the main results presented above. We find that freezing the standards results in a smaller short-term loss as well as a smaller long-term gain, relative to the main results in which standards continue as designed. In the year 2035, freezing the standards will result in 236,000 fewer jobs than if the standards stay intact (333,600 jobs vs. 97,600 jobs). We also simulate the impacts of lowering the standards by one-third and find that this would result in 56,600 fewer jobs in the year 2035 than keeping the standards as is (333,600 vs. 268,000). These findings are consistent across alternative measures of the price premium.

DISCUSSION AND CONCLUSION

In this analysis, we sought to determine how U.S. vehicle regulations may affect the U.S. economy, both nationally and by region. We created 2012 and 2016 Perspectives, divided the impacts of the federal standards into three separate mechanisms,

Table 5. Macroeconomic modeling results of main scenarios and alternative Trump administration regulatory pathway scenarios, by GDP and employment in years 2020, 2025, 2030, and 2035.

	2020	2025	2030	2035
Main Results with 2016 Perspective Low Price Premium				
GDP in Billions of 2009 Dollars (% change)	−10.36 (−0.06%)	−0.60 (0.00%)	19.64 (0.09%)	29.06 (0.12%)
Employment in Thousands of Jobs (% change)	−110.29 (−0.06%)	27.38 (0.01%)	251.27 (0.12%)	333.61 (0.16%)
Main Results with 2016 Perspective High Price Premium				
GDP in Billions of 2009 Dollars (% change)	−14.83 (−0.08%)	−4.85 (−0.02%)	18.00 (0.08%)	27.81 (0.11%)
Employment in Thousands of Jobs (% change)	−161.58 (−0.08%)	−20.84 (−0.01%)	231.15 (0.11%)	318.55 (0.15%)
Standards are Frozen after 2020, 2016 Low Price Premium				
GDP in Billions of 2009 Dollars (% change)	−10.36 (−0.06%)	0.61 (0.00%)	6.12 (0.03%)	8.24 (0.03%)
Employment in Thousands of Jobs (% change)	−110.29 (−0.06%)	22.19 (0.01%)	80.82 (0.04%)	97.60 (0.05%)
Standards Decrease by 1/3 after 2020, 2016 Low Price Premium				
GDP in Billions of 2009 Dollars (% change)	−10.36 (−0.06%)	−0.07 (0.00%)	15.91 (0.07%)	23.26 (0.09%)
Employment in Thousands of Jobs (% change)	−110.29 (−0.06%)	27.91 (0.01%)	204.24 (0.10%)	268.03 (0.13%)

Notes: Estimates are presented as both the total difference between the baseline scenario and the policy scenarios, as well as the percentage difference (in parentheses). “2016 Perspective High” and “2016 Perspective Low” update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 and 54.5 percent price premium adjustments of the National Research Council.

and worked within a dynamic macroeconomic modeling platform to produce estimates of economic impacts. We found that the vehicle price premium associated with tighter standards will cause losses of employment and GDP through a decline in new vehicle sales, as well as curtailment of spending on other goods and services. The price premium, however, pays for supply chain innovation and technological investment within the auto industry. This innovation stimulus offsets roughly half of the adverse effects of higher prices. In addition, the accumulated savings in gasoline expenditures is not trivial; over time, the positive effects of consumers spending their gas money instead on other goods and services is quite significant. The combination of supply chain innovation and gasoline spending reallocation has a positive net effect on the economy that outweighs the negative effects of the price premium. When the three mechanisms are modeled together, the overall annual impact of the regulatory programs on the national economy is negative in the near-term but positive in the long-term.

The economy would recover faster if we assume a 2012 Perspective, which captures a world in which gas prices are high, car sales dominate the fleet, and the assumed cost of compliance is low. When we adjust these parameters in the 2016 Perspectives, which provides a more realistic depiction of current circumstances, we find that it takes longer—by two or three years—for the economy to recover. However, in both cases, the positive effects on the economy are ultimately larger in magnitude than the negative effects, primarily because the fuel savings are quite large relative to technology costs. The economy recovers from the negative shock from an annual employment perspective by 2024 or 2025 under 2016 Perspective assumptions, and from a cumulative GDP perspective by 2027 to 2033. The combined effects in any given year using any set of input assumptions is never particularly large in magnitude, relative to annual GDP of about 19 trillion as of 2017. Yet, these estimates are much larger in magnitude than previous studies have produced, since most recent studies on 2017 to 2025 standards find net negative economic impacts. We attribute such differences in results to our use of a model that can account for the full U.S. economy, including its linkages to all other economies across the world, as well as our inclusion of supply chain innovation in the scenario modeling exercise.

Nonetheless, the near-term period of negative impacts on the economy gives some credence to proposals that would refine the 2017 to 2025 standards to make them more cost-effective. For example, harmonizing the banking and trading mechanisms at NHTSA and the EPA or offering compliance credits for a broader set of compliance technologies might reduce costs enough to offset some of the near-term negative effects. Of course, it is important to note that macroeconomic considerations are only one factor for policymakers to consider, and any refinements to the 2017 to 2025 standards should be subject to careful policy analyses that include but also extend beyond the scope of what we have addressed here.

One of the most important sets of results in this analysis is that not all regions fare as well as the others. Some, particularly, benefit, such as the coastal states, while others bear a disproportionate share of the burden, such as the Midwestern automobile manufacturing states (Illinois, Indiana, Ohio, Michigan, and Wisconsin) and Southern oil producing and refining states (Arkansas, Louisiana, Oklahoma, and Texas). Although the Midwestern state economies rebound in the late 2020s, the oil producing and refining regions continue to suffer economic declines through 2035 due to 2017 to 2025 vehicle regulations. These results have several political economy implications. First, the expectation of regional differences may lead to variation in political support or opposition by both geography and economic composition. Indeed, several have speculated, and some media investigations have confirmed, that large oil companies lobbied the Trump administration behind the scenes to roll back fuel economy standards (Tabuchi, 2018). Meanwhile, the coastal states, which appear to benefit the most from fuel economy standards, continue the push to maintain or even tighten the standards, and to couple them with other automobile regulations such as the zero emissions vehicle standard. Second, geographic disparity in degree and duration of costs from fuel economy regulations, such as those found in this study, may suggest the need for policy that moderates impacts in the hardest hit regions.

In his 2016 campaign for president, candidate Donald Trump proposed large-scale deregulation as a policy to boost the competitiveness of the U.S. economy and raise output, earnings, and employment. In his first two years in office, President Trump has followed through with a program of deregulation, including a possible freeze of CAFE standards after 2020. Our macroeconomic analysis suggests that a CAFE freeze may diminish the near-term hit to car sales, output, and employment. That near-term benefit, however, will be more than offset by foregone gains in technological innovation and fuel savings that would have boosted the economy to

a greater extent in the long run. In other words, the proposed freeze will not only miss the opportunity to limit GHG emissions, but it will also limit the macroeconomic benefits of the fuel economy standards.

Future research on macroeconomic modeling should target several issues that we identified in this study. In particular, future modeling exercises should seek to incorporate additional insights offered by microeconomic analyses of CAFE regulation, such as changes in consumer and producer behavior. In addition, rather than assume that levels of household debt are fixed, macroeconomic models need to allow for changes in the levels of household debt due to regulation and other factors. The analytic treatment of importation of goods and services (e.g., oil and auto parts) also needs additional enrichment to account for the partial recycling of revenues by foreign producers into the U.S. economy through purchases of U.S. goods or securities. Finally, the environmental impacts of federal standards may have impacts on the U.S. economy that are worthy of inclusion in macroeconomic modeling.

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APPENDIX A: REMI MODELING STRUCTURE

The model linkages and overall modeling structure are displayed visually in Figure A1, where the model is divided conceptually into five blocks. The first block is final demand and production. Production uses standard input factors, such as labor, capital, and intermediate inputs. Production coefficients are based on input-output tables. Consumption of different commodities within a region and at a certain point in time is based on the relative price of goods, personal income, income elasticity, and demographics. The second block covers business decisions about how to produce a certain amount of output given available factors of production; factor inputs for each sector are dictated by Cobb-Douglas production functions. In this block, changes in relative factor costs—such as the price of fuel, labor, and capital—affect relative factor intensities. The third block accounts for household and consumer decisions across regions, such as how consumers spend their money, participate in the labor market, and migrate from region to region. This block also includes detailed demographic information, such as age and gender, and corresponding birth and survival rates. A variety of other market concepts such as housing and cost of living, wage rates, costs of operation, consumption deflator (which converts industry prices to commodity prices), consumer prices, and others, are captured in the fourth block. Local wages are determined by equilibrium labor market conditions across all local occupations. Local labor force is determined by the local population, with cohorts in the third block. The final block tracks how well a region maintains competitiveness through, for example, limiting imports and responding to demand for exports. This block uses regional purchase coefficients to derive inter-regional trade flows, which are then fed back into the first block. All equations—such as those for output, consumption, real disposable income, investment, labor demand, and many others—are provided in REMI PI+ supporting documentation (REMI,

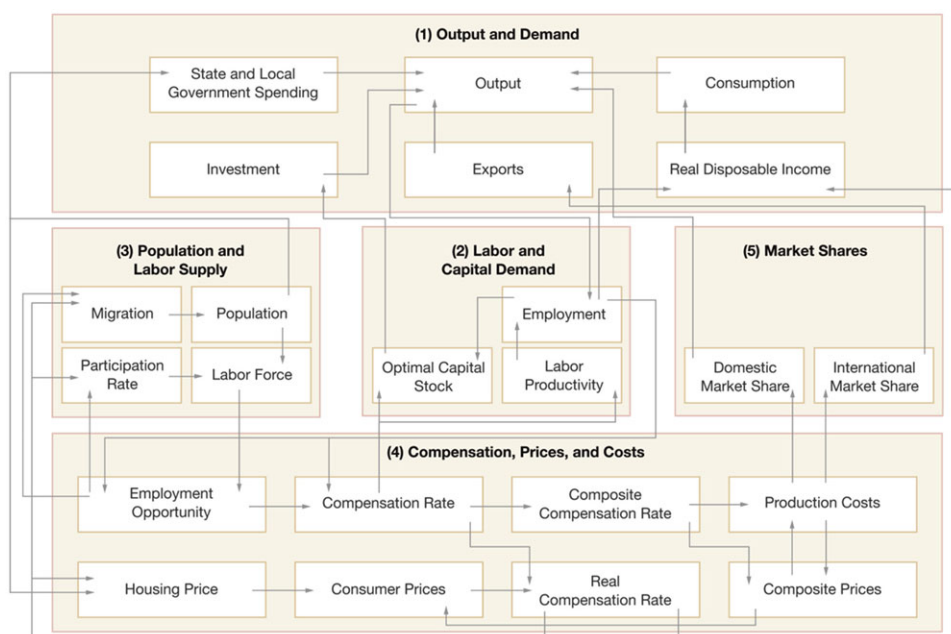


Figure A1. REMI Model Linkages.

2018).¹³ When one creates a policy scenario within REMI, he or she generates a “policy variable” (e.g., an increase in spending on a specific commodity) that essentially shocks one or several of the boxes within Figure A1. The model then needs to solve for a new equilibrium.

¹³ REMI PI+ 2.0.2 is associated with the 2.0 documentation. Additional documentation of the REMI model is available on the company’s website: <http://www.remi.com/model/pi/>.

APPENDIX B: REMI MODEL SUPPORTING LITERATURE

The peer-reviewed literature has tested and validated the REMI model in many ways through the years. Several scholars have compared the model operations and results to those obtained with models that include only one modeling aspect, such as just an input-output approach (see, e.g., Cribfield & Campbell, 1991; Rickman & Schwer, 1993, 1995a, 1995b for a comparison and analysis of multipliers; and Rey, 1997, 1998, for an estimation of error and discussion of the usefulness of econometric and input-output hybrid models). Others have evaluated the predictive accuracy (Cassing & Giarratani, 1992; Molotch & Woolley, 1994; Treyz et al., 1991) and explanatory power (Rose et al., 2011) of the model (see Rose & Wei, 2011, for a discussion of this literature). These studies all confirm that the REMI model is robust and highly accurate, especially over short- to medium-term timeframes. Predicting too far out into the future, however, leads to higher rates of inaccuracy. Analysts also favorably view and recommend the model over alternative modeling platforms, both generally (Rose & Wei, 2011), as well as for specific applications such as transportation studies (see Lawrence et al., 2017, for a review of this literature).

The peer-reviewed literature has employed the REMI model to analyze climate change policies (Lawrence et al., 2017; Rose et al., 2011; Rose & Wei, 2011; Wei & Rose, 2014), cyber attacks (Kelic et al., 2013), hospitality and tourism (Bonn & Harrington, 2008), the use of woody biomass for bioenergy (Perez-Verdin et al., 2008), changes in property taxes (Aydin & Harrington, 2008), business incubator outcomes (Sherman & Chappell, 1998), economic benefits of environmental management at U.S. nuclear weapons sites (Frisch et al., 1998), regional clean air incentives markets (Johnson & Pikelney, 1996), economic impact of retirement migration (Deller, 1995), and development benefits of highway decisionmaking (Weisbrod & Beckwith, 1992), among many other applications. The REMI model is also used extensively by city and state governments and other analysts to evaluate public and private program and policy impacts. A few recent examples include studies on Oregon's proposed cap-and-trade program, SB 1574 (Ditzel et al., 2017) and transportation and infrastructure planning (Cambridge Systematics, Inc., 2013; MDOT, 2013).

APPENDIX C: NRC PRICE CALCULATIONS

Within the framework of their multi-technology assessment, the National Research Council (NRC) (2015) provided a technology pathway example for a mid-size car with an I4 DOHC spark-ignition engine and estimated the direct manufacturing costs (DMC) for model years 2017, 2020, and 2025 that would be required to comply with the CAFE standards. The two sets of estimates provided (referred to as “low most likely” and “high most likely”), as well as the original 2012 estimates from NHTSA, are illustrated in Table C1. Table C1 provides the percent difference in the DMC between the low/high most likely estimates and the DMC estimates, respectively, based on the methodology that NHTSA adopted in the final rule. For model year 2025, the differences range from 11.4 percent to 56.4 percent. In constructing our projections for the 2016 Perspective price premium values, we refer to these adjustments as the NRC “high-cost estimate” and the NRC “low-cost estimate.”

Table C2 shows how we have applied the NRC adjustments to NHTSA’s (2012) analysis. Rows 8 and 9 in Table C2 capture the price premiums (i.e., DMC plus indirect cost) for the fleet that complies with the federal standards and is adjusted by the low (row 8) and high (row 9) most likely NRC estimates presented in Table C1. That is, the price premiums in rows 2, 3, 5, 6, 8, and 9 were calculated by applying the percentage differences from Table C1 to the NHTSA premiums in Table A2 (i.e., rows 1, 4, and 7). The percent differences for the low and high most likely estimates for model years 2018 and 2019 and 2021 to 2024 in Table C2 were calculated using a linear interpolation.

Table C1. Incremental direct manufacturing costs of a mid-size car: Low Most Likely and High Most Likely estimates.

	Units	MY2017	MY2020	MY2025
NHTSA Mid-Size Car DMC Estimates	2010\$	1,274	1,184	1,060
NRC Mid-Size Car Low Most Likely Estimates	2010\$	1,381	1,297	1,181
Percent Difference (Low)	%	8.40	9.54	11.4
NRC Mid-Size Car High Most Likely Estimates	2010\$	1,923	1,806	1,658
Percent Difference (High)	%	50.9	52.5	56.4

Notes: MY stands for model year.

Source: NRC, 2015, pages 276–277, 422–423.

Table C2. Price premium adjustments using the NRC (2015) Low Most Likely and High Most Likely estimates.

Row	Source	Vehicle type	Model Year								
			2017	2018	2019	2020	2021	2022	2023	2024	2025
1	NHTSA	Car	\$364	\$484	\$659	\$858	\$994	\$1,091	\$1,221	\$1,482	\$1,578
2	NRC low		\$395	\$526	\$719	\$940	\$1,093	\$1,203	\$1,351	\$1,646	\$1,758
3	NRC high		\$549	\$733	\$1,002	\$1,309	\$1,524	\$1,681	\$1,891	\$2,307	\$2,468
4	NHTSA	Truck	\$147	\$196	\$397	\$629	\$908	\$948	\$1,056	\$1,148	\$1,226
5	NRC low		\$159	\$213	\$433	\$689	\$998	\$1,046	\$1,169	\$1,275	\$1,366
6	NRC high		\$222	\$297	\$603	\$959	\$1,392	\$1,461	\$1,635	\$1,787	\$1,918
7	NHTSA	Fleet	\$287	\$382	\$567	\$779	\$964	\$1,042	\$1,165	\$1,370	\$1,461
8	NRC low		\$311	\$416	\$619	\$853	\$1,060	\$1,149	\$1,289	\$1,521	\$1,628
9	NRC high		\$433	\$579	\$862	\$1,188	\$1,478	\$1,606	\$1,804	\$2,132	\$2,285

Notes: “NHTSA” refers to the data from the NHTSA 2012 Regulatory Impact Analysis. “NRC low” indicates that the NHTSA numbers have been adjusted to reflect the NRC’s low most likely estimate, and “NRC high” indicates that the NHTSA numbers have been adjusted to reflect the NRC’s high most likely estimate. The price premiums account for both the Direct Manufacturing Cost and the Indirect Cost.

APPENDIX D: OEM REINVESTMENT PERCENTAGE DERIVATION

NRC (2015) used the example of the mid-size car pathway in order to capture the cost components of achieving the 2025 CAFE standard. The Committee used three major categories of technologies: (1) a shift from a 2.4L naturally aspired (NA) Engine to a 1.6L TRBDS, (2) a shift from a 6-speed automatic transmissions (AT) to an 8-Speed AT, and (3) an overall shift to a lightweight vehicle body structure. Table D1 presents the direct manufacturing cost (DMC) information for each of those three technologies, broken down by DMC categories. In order to better align these categories with the REMI model input requirements, we reorganized Table D1 into D2.

The difference between Table D1 and Table D2 is that in the latter we have merged the following DMC categories.

- (a) Total packaging cost has been added to the Burden category in Table D2.
- (b) End item scrap has been added to the Materials category in Table D2.
- (c) Selling, General, and Administrative (SG&A) and Profit have been merged into a new category that we call Shareholder Income in Table D2.

The last two rows of Table D2 show the share of each DMC category as a percentage of: (a) DMC and (b) Total Cost (TC). The TC percentages incorporate the 1.46 retail price equivalent (RPE) multiplier used by the EPA. That is, in order to obtain total cost, the EPA applied the following adjustment to DMC: $TC = DMC \times 1.46$, where Indirect Cost (IC) is the 0.46 adjustment. Therefore, DMC represents 68.5 percent of TC (i.e., 68.5 percent = $100/146$) and IC represents the remaining 32.5 percent. Table D3 shows the various indirect cost categories of the RPE multiplier.

We made the following assumptions in order to merge the indirect cost categories of Table D3 with the DMC categories in Table D2.

- (a) Production overhead, with the exception of R&D, and corporate overhead in Table B3 are part of the burden DMC category of Table D2.
- (b) Selling and dealers categories in Table D3 form a new cost category labeled "Dealers."
- (c) Net income in Table D3 is part of the shareholders income category in Table D2.

Applying the adjustments discussed above results in the percentage shares illustrated in Table D4. Table D5 combines the information in Table D2 and Table D4 and shows the final percentage shares in each of the six cost categories.

Table D1. DMC categories for mid-size car compliance with 2025 CAFE standards.

	Materials	Labor	Burden	End Item Scrap	Selling, General and Administrative (SG&A)	Profit	Engineering, Design & Testing (ED&T)/ Research & Development (R&D)	Total Packaging Cost	Net Cost to OEM
1.6L TRBDS vs 2.4L NA Engine	\$218.82	\$72.58	\$154.24	\$11.72	\$33.96	\$33.12	\$12.36	\$0.90	\$537.70
8 Speed AT vs. 6 Speed AT	\$8.49	\$15.11	\$28.20	\$0.69	\$4.27	\$3.74	\$1.34		\$61.84
Lightweight Vehicle Body Structure	\$580.00	\$110.00	\$443.00						\$1,133.00
TOTAL	\$807.31	\$197.69	\$625.44	\$12.41	\$38.23	\$36.86	\$13.70	\$0.90	\$1732.54

Source: U.S. EPA, 2009; U.S. EPA, 2011; NHTSA, 2012.

The Macroeconomic Effects

Table D2. Reorganized DMC categories that align with REMI modeling inputs.

	Materials	Labor	Burden	Shareholder Income	ED&T R&D	Total
1.6L TRBDS vs. 2.4L NA Engine	\$230.54	\$72.58	\$155.14	\$67.08	\$12.36	\$537.70
8 Speed AT vs. 6 Speed AT	\$9.18	\$15.11	\$28.20	\$8.01	\$1.34	\$61.84
Lightweight Vehicle Body Structure	\$580.00	\$110.00	\$443.00			\$1133.00
TOTAL	\$819.72	\$197.69	\$626.34	\$75.09	\$13.70	\$1732.54
Percentage Share of DMC	47.3%	11.4%	36.2%	4.3%	0.8%	
Percentage Share of Total Cost	32.4%	7.8%	24.8%	3%	0.5%	

Table D3. Indirect cost categories of the RPE multiplier.

RPE Multiplier Contributor	Industry Average
<i>Vehicle Manufacturing</i>	
Cost of Sales	1
<i>Production Overhead</i>	
Warranty	0.03
R&D (product development)	0.05
Depreciation and Amortization	0.07
Maintenance, Repair Operations Cost	0.03
Total Production Overhead	0.18
<i>Corporate Overhead</i>	
General and Administrative	0.07
Retirement	<0.01
Health	0.01
Total Corporate Overhead	0.08
<i>Selling</i>	
Transportation	0.04
Marketing	0.04
<i>Dealers</i>	
Dealer New Vehicle Net Profit	<0.01
Dealer New Vehicle Selling Cost	0.06
Total Selling and Dealer Contributors	0.14
<i>Sum of Indirect Costs</i>	
Net Income	0.06
Other Costs (not included as contributors)	0.04
<i>RPE Multiplier</i>	1.46

Table D4. Cost categories and their shares of indirect cost and total cost.

	R&D	Production and Corporate Overhead	Dealers	Shareholder
Percentage Share of Indirect Cost	10.9%	45.7%	30.4%	13%
Percentage Share of Total Cost	3.4%	14.4%	9.6%	4.1%

Table D5. Cost categories as percentage shares of total cost.

	R&D	Overhead/ Burden	Materials	Labor	Shareholder Income	Dealers
Percentage Share of Total Cost	4%	39.1%	32.4%	7.8%	7.1%	9.6%

APPENDIX E: LIMITATIONS AND EXTENSIONS OF GASOLINE SAVINGS MODELING

Our results revealed that the net economic impacts of the gasoline savings are favorable, large in absolute magnitude, and dominate the long-run results of the REMI modeling. Therefore, besides the sensitivity analyses already presented, it is useful to consider how accurately the model can estimate the effects of fuel savings and how future research can refine our understanding of how gasoline savings affect the U.S. economy. Here, we consider whether the REMI results are consistent with the impacts of diminished U.S. fuel prices in 2014 to 2016, recent evidence concerning how U.S. consumers are reacting to the savings in fuel expenditures, and how the impacts of gasoline savings on oil imports and U.S. production can be refined in future research.

Insights from the Recent Collapse of Oil and Gasoline Prices

There is a significant literature in macroeconomics on how abrupt changes in the price of oil and gas have impacted the U.S. and global economies (e.g., see Edelstein & Kilian, 2009; Hamilton, 2011). One of the positive aspects of lower energy prices is a boost to consumer spending on other goods and services. Due to the decline in fuel prices from a peak of roughly \$4.00 per gallon (national average in May 2011) to \$2.20 per gallon (national average in 2016), the average American motorist has been saving roughly \$1,080 per year on gasoline expenses (assuming 15,000 miles per year at 25 miles per gallon) (Appelbaum, 2016; Arora, 2015; Blake, 2011; Cox, 2015; Skowronski, 2015; Soper, Olson, & Townsend, 2015). These savings are of the same order of magnitude as the present value of fuel savings for the model year 2025 federal standards, but they are much more immediate in their occurrence.

The U.S. economic recovery since the Great Recession of 2007 through 2009 has been quite slow by historical standards, indeed the slowest of any of the modern recessions studied by the National Bureau of Economic Research (Graham, 2016; Seefeldt et al., 2013). The question has been raised as to why the sharp decline in oil and fuel prices in 2014 through 2016 has not spurred a stronger U.S. recovery (Appelbaum, 2016). The primary explanation that has been offered is that consumers are not behaving in the ways that economic models such as REMI assume. First, when consumers save money on gasoline due to lower fuel prices, they may respond by paying off their credit card debts and boosting their savings and investments. Consumer debt payments as a share of disposable income rose from 2012 to 2015 (Arora, 2015). Since low-income consumers spend a higher fraction of their income on gasoline than high-income consumers, the behavior of low-income consumers needs to be studied carefully (Murphy, Plante, & Yücel, 2015).

On the other hand, the REMI model assumption that consumers spent 100 percent of the savings is not far off from the standard estimate that Americans save only about 5 percent of every dollar that they earn (Skowronski, 2015; Soper, Olson, & Townsend, 2015). Additionally, recent studies of credit and debit card holders find that consumers are spending between 80 percent and 100 percent of the gasoline savings induced by lower fuel prices (Farrell & Greig, 2015; Gelman et al., 2016). Some consumers may not yet be convinced that the savings are permanent and thus some of the transitory income is used to pay down debts. For application to the regulations we are studying, there is no particular reason for consumers to expect the savings to be temporary, though the magnitude may be seen as uncertain.

Some have found that motorists are plowing a substantial amount of the savings back into gasoline by purchasing premium gasoline (higher-octane, higher-priced blends) (Appelbaum, 2015; Hastings & Shapiro, 2013). The surge in sales of premium gasoline is considered ill-informed by many experts, as most vehicles designed to run on regular gasoline will not perform any better—or have lower maintenance

costs or burn more cleanly—when operated with premium gasoline (Stepp, 2016). About 70 percent of passenger vehicles on the road were designed to run on regular gasoline (Friedman, 2016). AAA has undertaken a public education program to discourage consumers from spending money on purchases of premium gasoline (Blumenthal, 2016). From a macroeconomic perspective, it seems unlikely that a shift from regular to premium gasoline will have much of a favorable economic effect. Once again, this consumer response may also be a short-term effect, but it needs to be studied further.

Unresolved Issues Related to Effects of Gasoline Savings on Oil Imports and U.S. Production of Oil

The structure of REMI and some of its key inputs were designed prior to the fundamental changes in energy markets that caused the sharp decline in oil and gasoline prices. For example, the default settings in REMI assume that the U.S. economy imports about 52 percent of its oil (in 2015, EIA put the U.S. oil-import share at 24 percent). Moreover, the geographic origin of U.S. oil imports has changed, as Canada and Mexico—both economies that are integrated with the U.S. economy—now account for a majority of U.S. oil imports (EIA, 2016; Fergusson, 2011; Wilson, 2011). In fact, some of the “oil imports” that remain are simply foreign users of U.S. oil refineries, since the product of the refiners (e.g., diesel fuel) is then exported to Europe or elsewhere in the world. Those “imports” to U.S. refiners would not be affected by the regulations under study. The U.S. is already a net exporter of natural gas and some forecasts suggest that the U.S. could become a net exporter of oil prior to 2025. In other words, the magnitude and nature of “oil imports” is changing in the U.S., and thus the structure of REMI needs to be modernized to reflect these changes.

Another key assumption of REMI is that a substantial share of the supply chain for U.S. oil and gas production is imported (e.g., some of the steel and chemicals used by U.S. oil producers are imported). However, REMI’s supply chain for oil and gas has not yet been updated to reflect the unconventional development practices that were pioneered in the U.S. and have become widespread in the U.S. industry in the last five years, such as horizontal drilling and multi-stage hydraulic fracturing with large quantities of water, sand, and chemicals.

We performed a bounding analysis to determine how sensitive the REMI results might be to changes in the analytic treatment of oil imports. When we compared two extremes—all of the gasoline savings lead to oil-import reductions versus all the gasoline savings lead to U.S. oil production cuts—our results did change significantly (results not reported here). Thus, we recommend future research to modernize the structure of REMI to reflect new energy production practices in the U.S., including forecasts of how they are expected to evolve in the years ahead.

The Need to Incorporate Revenue Recycling from Imports

A basic feature of most input-output models is that cash outlays for imported goods and services permanently leave the economy under study. Sectors with large import shares in their supply chains, other things being equal, have smaller multipliers than sectors whose supply chains draw entirely from producers in the domestic economy. This is certainly not a unique feature of REMI but it is likely to have influenced the results of our modeling significantly.

We confronted the issue twice, once in the case of oil imports and again in the case of the stimulus of the automotive supply chain. In the case of oil imports, it is well known that much of the money paid for foreign oil is recycled back into the U.S.

economy—directly or indirectly—when foreigners purchase U.S. goods and services or invest in U.S. financial assets such as Treasury securities, stocks, and mutual funds (Higgins, Klitgaard, & Lerman, 2006). Today, the largest sources of U.S. oil imports are Mexico and Canada, yet those two economies are highly integrated with the U.S. economy.

In the case of automotive supply chains, cash is paid to German, Korean, and Japanese suppliers of parts, but REMI assumes that none of it is recycled back into the U.S. economy. In reality, a share of the revenues paid to foreign parts suppliers is reinvested back into the U.S. economy, for the same reasons described in the case of oil imports. Of particular concern are the important roles that Mexico and Canada play in the U.S. automotive industry (Swiecki & Menk, 2016). REMI treats Mexico and Canada as foreign economies when, in fact, the U.S., Mexican, and Canadian economies are highly integrated, partly as a result of the North American Free Trade Agreement (Dziczek et al., 2017).

We performed some preliminary exploration to determine whether oil-revenue recycling into U.S. capital markets would significantly change our results. REMI has a capital-market sector with developed links to employment, GDP, and income. When we allowed petrodollars from U.S. imports to recycle back into U.S. capital markets, the results of our REMI model changed noticeably, and pushed the long-term macroeconomic benefits of the regulation many years out into the future (results not reported here). This result is due to the expectation that the federal regulations of fuel economy and GHG emissions will reduce the volume of recycled petrodollars entering the U.S. economy. For future research, we suggest a more in-depth analysis of global capital markets and the manner in which petrodollars circulate within these markets.

Recycling of the auto-import dollars raises some similar and distinct issues. The roles of Canada and Mexico as integrated economies are again important, similar to the case of oil imports. However, car exporters in Germany, Korea, and Japan are quite different from the main oil-exporting countries (e.g., Saudi Arabia, Venezuela, and Nigeria). Although the issues are analytically challenging, we encourage future research that would more realistically capture the U.S. economy by building in some recycling of dollars paid for imported goods and services.

APPENDIX F: EMPLOYMENT RESULTS FROM MAIN MODEL SPECIFICATIONS

In this appendix, we present the national employment results for each of the three mechanisms as well as the combined model.

Price Premium Mechanism

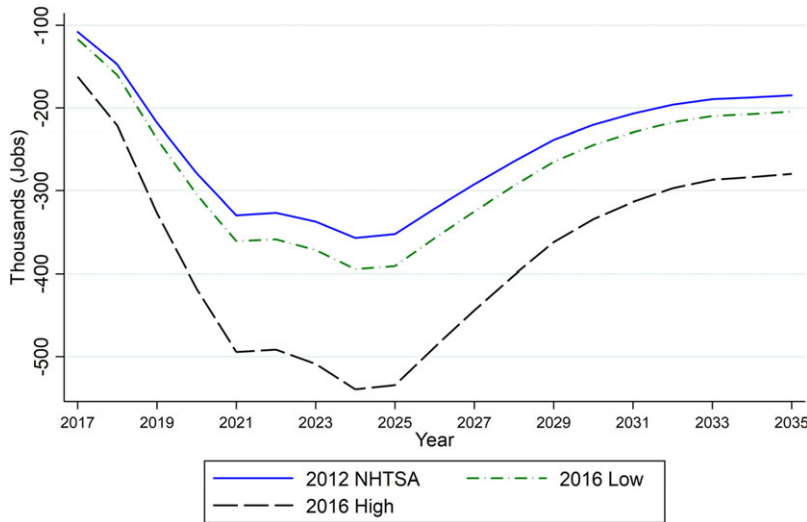
As displayed in Figure F1, the employment impacts of the price premium for vehicles are negative and increasingly so, until the employment losses reach their peak value around 2024 to 2025.

Supply Chain Innovation

As displayed in Figure F2, employment increases by approximately 210,000 jobs in 2025 using the 2012 Perspective and 225,000 to 325,000 using the 2016 Perspectives.

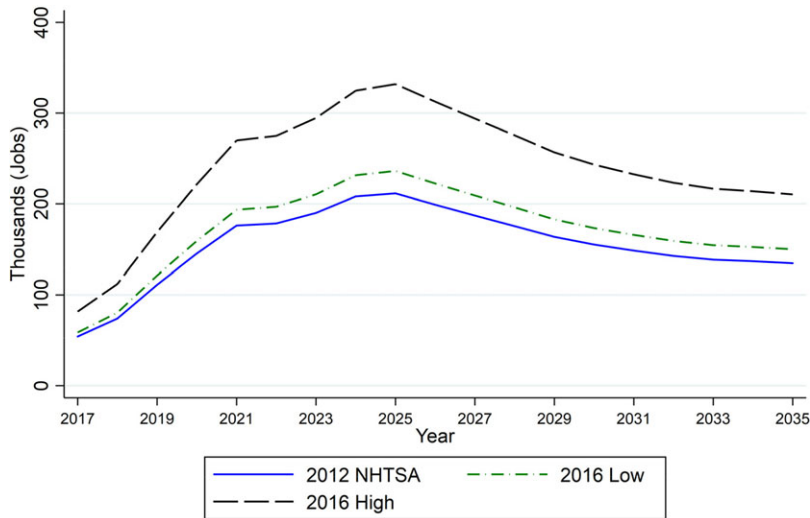
Gasoline Savings

Under the 2012 Perspective, the gains in employment reach about 280,000 in 2025 and continue to climb to 600,000 in 2035, as displayed in Figure F3. These gains are attenuated in the 2016 Perspectives, which trend together due to the fact that they contain the same assumptions about fuel price and fuel savings, thus we only include one of them. The 2016 Perspectives both rise to about 200,000 in 2025 and just over 400,000 in 2035.



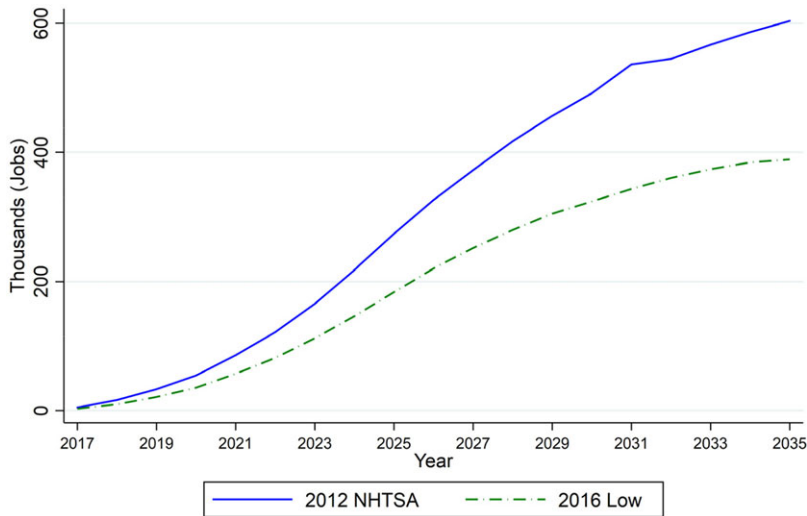
Notes: Reported is the difference in employment between the baseline scenario and each price premium scenario. Employment is measured in job-years. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 percent and 54.5 percent price premium adjustments of the National Research Council.

Figure F1. Impact of CAFE Price Premium on Employment.



Notes: Reported is the difference in employment between the baseline scenario and the supply chain innovation scenario. Employment is measured in job-years. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 percent and 54.5 percent price premium adjustments of the National Research Council.

Figure F2. Impact of Automobile Supply Chain Innovation Expenditures on Employment.

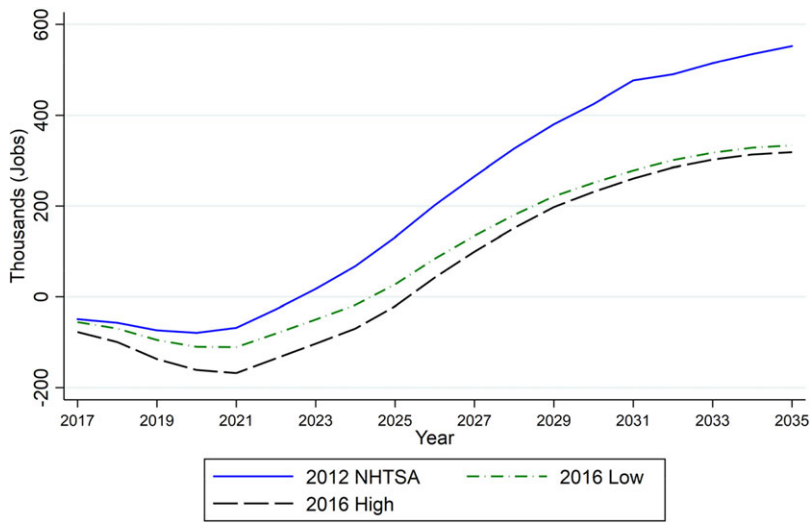


Notes: Reported is the difference in employment between the baseline scenario and the gasoline savings scenario. Employment is measured in job-years. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 Low Perspective” updates the 2012 data and assumptions to reflect the information available to policymakers in 2017 including the National Research Council’s 11 percent adjustment in the price-premium.

Figure F3. Impact of CAFE Gasoline Savings Scenarios on Employment.

Combined Mechanisms

Figure F4 displays the employment results for the combined scenario, which include all three of the individual mechanisms. For total employment, under the 2012 Perspective, it takes about six years, around 2023, for the annual change in the level of employment to switch from negative to positive. Under the 2016 Low and High Perspectives, the annual net positive effects on employment are delayed until mid-2024 and early-2025, respectively. Once employment figures turn positive, they grow steadily and substantially thereafter, with diminishing returns beginning around 2030.



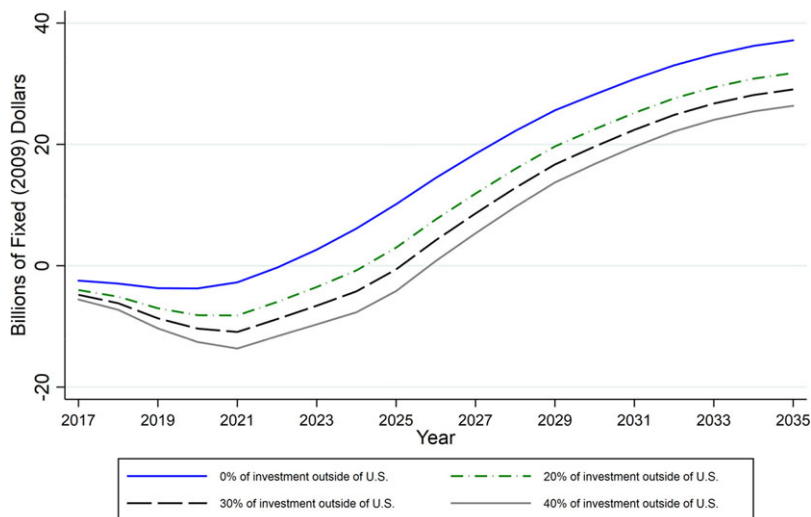
Notes: Reported is the difference in employment between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios. Employment is measured in job-years. “2012 NHTSA” is the 2012 Perspective, based on economic data and assumptions used in the 2012 NHTSA Regulatory Impact Analysis. “2016 High” and “2016 Low” are the 2016 Perspectives, which update the 2012 data and assumptions to reflect the information available to policymakers in 2017. The difference between high and low reflects the 11 percent and 54.5 percent price premium adjustments of the National Research Council.

Figure F4. Impact of CAFE Combined Scenarios on Employment.

APPENDIX G: SENSITIVITY ANALYSIS

We first run a sensitivity analysis on the assumption that 30 percent of all supply chain innovation investments are made outside of the U.S. In Figure G1, we vary this percentage from 0 percent to 40 percent.¹⁴ This figure presents only those results for the 2016 Low Perspective and the GDP indicator, since other datasets and indicators produce similar trends. We find that the model is sensitive to the assumption about the geographic allocation of auto industry reinvestments. If we assume that 0 percent of all the innovation investments within the industry triggered by U.S. regulations happens in other countries, then the U.S. could experience as much as \$10 billion in new GDP in 2025. Of course, this estimate is unrealistic but, nonetheless, the 0 percent analysis provides insight as a bounding calculation. If we instead assume that 40 percent of all innovation occurs on foreign soil, then the GDP benefit from these regulations would be closer to zero in 2025. When the results are compared at the extreme input assumptions of 0 percent and 40 percent of innovation spending occurring outside the U.S., the break-even point for net gain to the U.S. economy varies by about three years.

Second, we run a sensitivity analysis on gasoline price using both the 2016 Low and High Perspectives. In Figure G2, we introduce higher and lower gasoline price projections for the 2016 Low Perspective (\$2.74/gallon and \$1.82/gallon in 2010 dollars, respectively), as provided by EIA (2016). Results are less positive when the

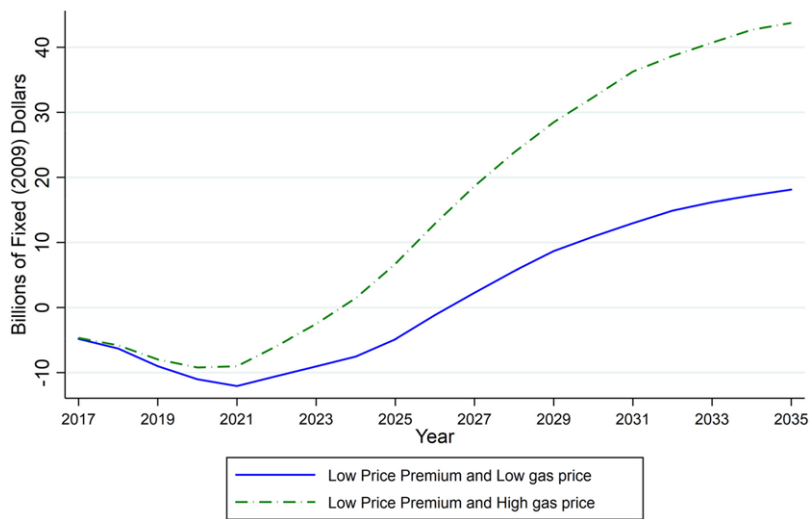


Notes: Reported is the difference in GDP between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios using the 2016 Low Perspective dataset. The sensitivity analysis varies the assumed percentage of OEM investment that occurs outside of the U.S., from 0 to 40 percent. The line that assumes 30 percent matches the main results for the 2016 Low Perspective, as presented in Figure 7.

Figure G1. Impact of CAFE Combined Scenarios on GDP with Sensitivity Analysis on the Percentage of Supply Chain Innovation.

¹⁴ All sensitivity analyses were also run on the individual mechanisms. These results can be made available upon request.

price of a gallon of gasoline is lower, and more positive when the price is higher. The sensitivity adjustments do not result in either scenario switching from negative to positive in more than a half-year time.

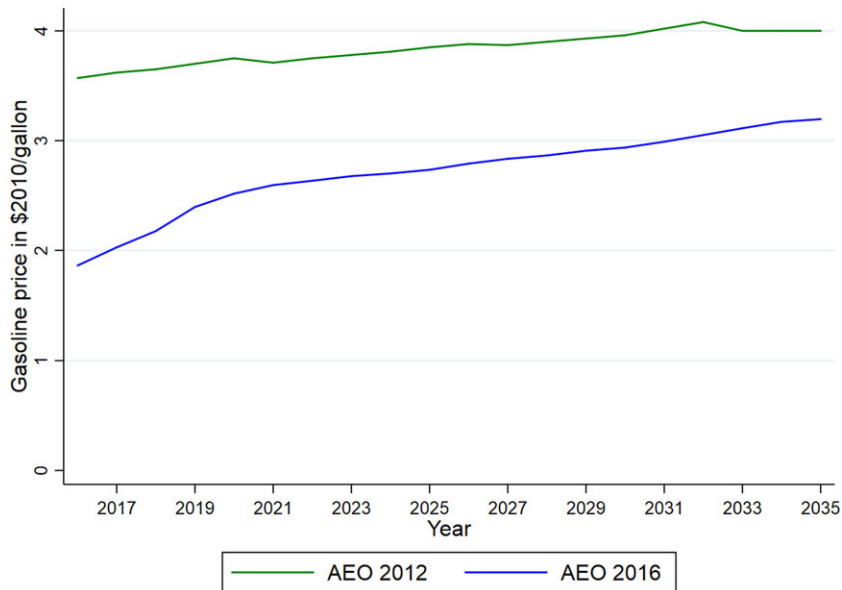


Notes: Reported is the difference in GDP between the baseline scenario and the combined price premium, supply chain innovation, and gasoline savings scenarios using the 2016 Low Perspective dataset. The sensitivity analysis varies the price of gasoline using the EIA (2016) low and high price projections.

Figure G2. Impact of CAFE Combined Scenarios on GDP With Sensitivity Analysis on the Price of Gasoline.

APPENDIX H: CHANGE IN GASOLINE PRICE PROJECTIONS BETWEEN 2012 AND 2016

Figure H1 shows the different trajectories in the gasoline price projections between the Annual Energy Outlook (AEO) 2012 and AEO 2016. Note that the difference between the two forecasts are rather large. For example, in year 2012 the Energy Information Administration predicted the price of gas for year 2025 as \$3.84 per gallon. By 2016, that projection, again for year 2025, was updated to \$2.74 per gallon, a 29 percent decrease.



Source: EIA (2012, 2016).

Figure H1. Gasoline Prices (in constant 2010 dollars per gallon) from the 2012 and 2016 Annual Energy Outlook.

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