ESSAYS ON ISSUES

THE FEDERAL RESERVE BANK OF CHICAGO

2016
NUMBER 357

Chicago Fed Letter

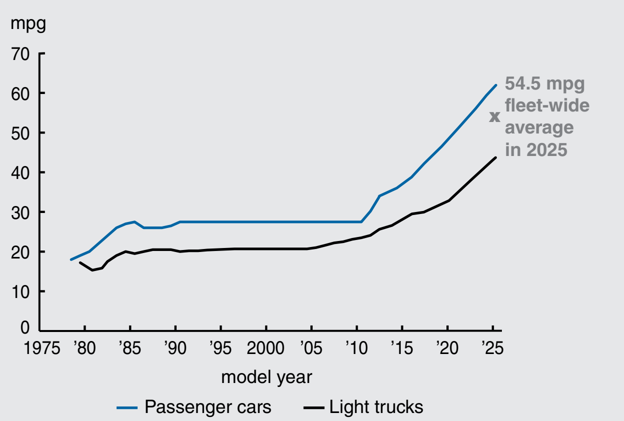
The VW scandal and evolving emissions regulations

by Thomas H. Klier, senior economist and research advisor, and Joshua Linn, senior fellow, Resources for the Future

In September 2015, Volkswagen (VW) admitted to having programmed nearly 11 million of its diesel vehicles to cheat on tailpipe emissions tests.[1] To put VW's emissions rigging into a broader context, the authors review the different approaches that the U.S. and Europe have historically taken in regulating automotive emissions and fuel economy. Moreover, they discuss the scandal's implications for regulatory changes in both regions.[2]

Automobiles are subject to emissions and fuel economy regulations in most regions of the world. Underlying the VW scandal are trade-offs between controlling a vehicle's emissions and improving its performance (i.e., its acceleration, power, etc.). VW, like most other European automakers, pursued diesel technology—which, compared with gasoline technology, provides greater fuel economy, resulting in lower greenhouse gas (GHG) emissions, such as carbon dioxide (CO_2). Yet, relative to gasoline engines, diesel engines tend to emit more nitrogen oxide (NO_x) and particulate matter,[3] which contribute to the formation of smog. VW pursued a "clean diesel" strategy rather aggressively; but when some of its diesel engines could not meet the stringent tailpipe emissions standards in the U.S. and Europe without sacrificing on-road performance, the company installed "defeat devices," which allowed its vehicles to circumvent lab tests.

1. U.S. fuel economy standards



Notes: The figure displays the evolution of corporate average fuel economy (CAFE) standards—measured in miles per gallon (mpg)—for new passenger cars and light trucks in the U.S. See the text for further details.

Source: Adapted from https://www.whitehouse.gov/blog/2012/08/30/what-new-fuel-economy-standards-mean-you.

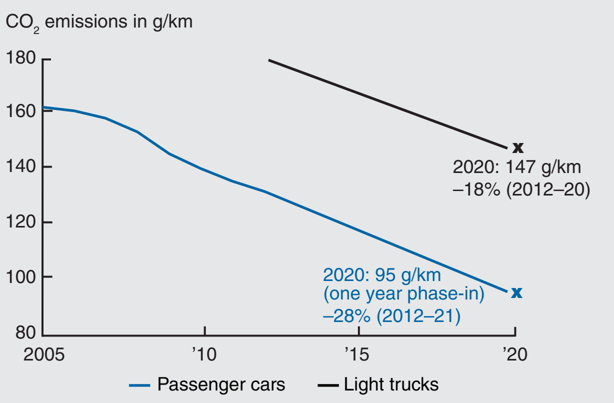
In this *Chicago Fed Letter*, we discuss the different approaches that the U.S. and Europe have historically taken in regulating the emissions and fuel economy of light-duty vehicles (i.e., cars and light trucks)[4] and some implications of the VW scandal for the regulation of the auto industry in both regions.

The history of U.S. regulations

Vehicles emit pollutants as byproducts of fuel combustion in their engines. According to the U.S. Environmental Protection Agency (EPA), light-duty vehicles accounted for one-third of carbon monoxide emissions, about one-fifth of nitrogen oxide emissions, and about one-quarter of carbon dioxide emissions in the U.S. in 2011.[5] Some of these tailpipe emissions are key ingredients in the formation of smog, which can be harmful to human health and the environment.

The hazards of smog were first recognized by state and federal officials in the U.S. during the 1950s and 1960s.[6] Rapid motorization in the U.S. led to smog becoming a major public health issue back then. On account of the unique weather conditions in the Los Angeles Basin, Southern California experienced some of the worst smog in the nation. The subsequent scientific and regulatory discussions were concentrated in that state. California passed the Motor Vehicle Pollution Control Act in 1959, but it was several years before the issue

2. European fuel economy standards



NOTES: The figure displays the evolution of carbon dioxide (CO_2) emissions standards in grams per kilometer (g/km) for new passenger cars and light trucks in the European Union. The CO_2 emissions rate is a measure of fuel economy. See the text for further details.

SOURCE: Adapted from http://www.theicct.org/sites/default/files/publications/ICCTupdate_EU-95gram_jan2014.pdf.

of vehicle emissions was taken up at the federal level. In 1965, Congress passed amendments to the Clean Air Act of 1963 and adopted the 1966 California vehicle emissions standards as the 1968 federal standards. In 1970, additional Clean Air Act amendments were passed and the EPA was established.[7] In subsequent negotiations, automakers, regulators, and legislators agreed to phase out lead as a gasoline additive. This was a crucial step in making catalytic technology (which converts harmful pollutants in tailpipe gas into less hazardous substances) commercially viable. The first catalytic converter, which reduced hydrocarbon and carbon monoxide emissions from vehicles, was introduced in 1975 models. By 1980, automakers developed an even better catalytic converter, which also reduced nitrogen oxide emissions. Tailpipe emissions requirements have evolved much further since the early 1980s: Today a rather complex set of federal and state regulations for a number of air pollutants is in place.[8]

Vehicle fuel economy became an important policy issue in the U.S. during the 1970s, when oil prices spiked multiple times.[9] Legislators enacted national corporate average fuel economy (CAFE) standards in 1975. Automakers needed to roughly double the average fuel economy of their new light-duty fleets by 1985—to 27.5 miles per gallon (mpg) for cars and to 19.5 mpg for light trucks. Fuel economy standards were tightened again starting in 2007—to 35.5 mpg for cars and light trucks combined, to be achieved by 2016.[10] In 2011, an even higher target of 54.5 mpg was set for light-duty vehicles, to be met by 2025.[11] (See figure 1 on front page.)

The particular rules for meeting fuel economy standards changed during the second CAFE regime (beginning in 2007). Originally, as established in the first CAFE regime (beginning in 1975), manufacturers needed to show compliance by meeting separate requirements for cars and light trucks. The compliance mechanism has since been refined: Manufacturers now face standards that for both cars and light trucks are based on the footprint (roughly the rectangle defined by the four wheels) of the vehicle. Consequently, automakers that sell more large vehicles than small ones are subject to lower average fuel economy requirements for their light-duty fleets. Because of this relationship between the vehicle's footprint and fuel economy, the recent decline in gasoline prices (which caused sales to shift toward large vehicles) has reduced the overall level of fuel economy required by the CAFE standards, albeit only slightly.[12]

The history of European regulations

In Europe, the regulatory goals for emissions control and fuel economy were addressed in reverse order: Controlling fuel consumption (measured in gallons per mile)—a concept that is largely interchangeable with fuel economy (measured in miles per gallon)—came first.[13] Numerous European countries responded to the oil shocks of the 1970s by substantially raising fuel taxes to lower fuel consumption.[14] Moreover, many of them decided to tax diesel at a lower rate than gasoline.[15] As a result, diesel's share among new passenger cars in Western Europe rose substantially, from around 15% in 1990 to 51.6% in 2015.[16]

In 1998 the European Commission reached an agreement with vehicle manufacturers to reduce the emissions rate of CO_2 (a measure of fuel efficiency) by 25% by 2008—to 140 grams per kilometer (g/km), which is equivalent to achieving a fuel economy of about 40 mpg.[17] Implemented in 2009, a mandatory requirement—backed by fines for noncompliance—set a new level of 130 g/km for CO_2 emissions, to be met by 2015. Even tighter regulations, including specific standards for light-duty trucks, were put in place in 2014: For passenger cars, the CO_2 emissions target was set to 95 g/km (equivalent to 57.9 mpg), to be achieved by 2021; and for light-duty trucks, the CO_2 emissions target was set to 147 g/km (equivalent to 43.3 mpg), to be reached by 2020.[18] (See figure 2.) Notably, whereas the U.S. fuel economy standards are based on a vehicle's footprint, European standards are based on a vehicle's weight.[19] Therefore, heavier vehicles are subject to a lower fuel economy requirement (higher CO_2 allowance) in Europe.

Compared with the U.S., Europe came late to regulating vehicle emissions of pollutants. It started with the Euro 1 requirements that set the NO_x emissions limit to 780 milligrams per kilometer (mg/km) in 1992.[20] Catalytic converters were required in new cars in Europe at the beginning of the 1990s, and the sale of leaded fuel was largely prohibited across the region by 2000.[21] The U.S. was ahead of Europe by a decade on both counts: Catalytic converters were ubiquitous in new cars by the early 1980s, and leaded gas was phased out almost entirely by 1990.[22] Currently, the Euro 6 emissions rules are being implemented. These rules require NO_x emissions to be cut from 1992 levels by 90% starting in September 2015.[23] However, those emissions standards are still less stringent than the ones currently in place in the U.S.[24]

The role of compliance tests

Auto manufacturers play a key role in testing and reporting emissions of their vehicles. For each model year, new vehicles are tested in a laboratory, where they are subjected to standardized testing protocols. These tests are required for vehicles to be certified for sale in a market. The outcomes of those tests do not necessarily reflect real-life driving conditions.[25] For example, the EPA adjusts fuel economy ratings of vehicles communicated to U.S. consumers from the lab results in order to better reflect actual driving conditions. Typically, the test results are reduced by about one-fifth, meaning that the EPA estimates that the testing overstates fuel economy by around 20%.[26] In addition, the EPA conducts in-use (on-road) testing of vehicles—both at low mileage (at least 10,000 miles) and at high mileage (more than 50,000 miles).[27] Europe's regulators pursue a similar testing approach, but European tests tend to be less restrictive and have not included an on-road component.[28]

In Europe, there is evidence that the gap between the reported lab test results and real-world emissions has been growing. For example, a recent study reports a remarkable increase in the divergence between official lab-based and real-world CO_2 emissions values in Europe from about 8% in 2001 to 40% in 2014; it attributes the growing gap to manufacturers' exploitation of tolerances and flexibilities in the testing procedure.[29] Another study, also based on on-road testing, finds the average level of NO_x emissions from vehicles in Europe to be seven times the certified Euro 6 emissions limit.[30]

In the U.S., in several instances manufacturers have been penalized for reporting incorrect data: For instance, Hyundai and Kia were fined for overstating the mpg claims on the majority of their 2012 and 2013 models in the U.S., and Ford had to restate the mpg claim of one of its hybrid vehicles in 2013.[31]

The VW scandal dwarfs these previous cases—both in terms of potential fines and lost sales for the offending company. In the 12 months prior to September 2015, diesel vehicles represented slightly more than 13% of VW's U.S. sales.[32] The company has since been prohibited from selling any diesel light-duty vehicles in the U.S.[33]

Longer-term implications

Besides reducing VW's profits and affecting its reputation, the scandal will likely have broader implications for the regulation of vehicle emissions and fuel economy. Following VW's admission of circumventing emissions requirements, officials in the U.S. and Europe have discussed test improvements to address the gap between lab-based test values and real-world observations. Thus far, the discussions among lawmakers and regulators have focused on the emissions of pollutants, but the divergence between fuel economy testing and real-world performance raises similar concerns. Some have suggested giving more weight to in-use testing—i.e., measuring emissions and fuel economy of vehicles while on the road, possibly over their lifetimes and not just at the point of certification.

Thus far, U.S. and European regulators have responded quite differently to the VW case, partly because of Europe's relatively greater reliance on diesel technology. In the U.S., the EPA has changed its emissions certification procedure, adding several tests and more time to the process.[34] In contrast, European officials weakened the testing framework in response to widespread noncompliance with emissions standards in order to provide more time for the auto industry to adjust before the Euro 6 standards are fully applied. Manufacturers will be allowed to exceed the NO_x emissions standard under real-world driving conditions by 110% between September 2017 and the start of 2020 and by 50% afterward.[35]

The choices that policymakers, regulators, and automakers make to address their respective goals for vehicle emissions and fuel economy will depend on both local conditions and public sensitivities. For example, recent occurrences of smog in London and Paris may have begun shifting public sentiment and policy in Europe away from favoring diesel vehicles.[36] In the U.S., prior to the VW scandal, diesel fuel vehicles accounted for a small but growing share of the overall market. Whether the scandal or more-reliable testing affects the long-term prospects of diesel vehicles in either Europe or the U.S. is an open question. If their share were to fall, the auto industry's reliance on other technologies, such as hybrid and plug-in electric powertrains, would likely rise in order to meet the increasingly stringent emissions and fuel economy standards in the U.S. and Europe.

1 See Jack Ewing, 2016, "VW scandal clouds prospects for other diesel makers at Geneva motor show," *New York Times*, March 3, http://www.nytimes.com/2016/03/04/automobiles/wheels/vw-scandal-clouds-prospects-for-other-diesel-makers-at-geneva-motor-show.html. See also http://www.theicct.org/news/epas-notice-violation-clean-air-act-volkswagen-press-statement.

2 A Resources for the Future policy brief (No. 16-03) based on this *Chicago Fed Letter* will be available at http://www.rff.org/research.

3 For an explanation of particulate matter, see https://www3.epa.gov/pm/.

4 We exclude from our discussion medium- and heavy-duty trucks, as well as off-road vehicles, because they are subject to different sets of regulations in both regions.

5 See https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data.

6 Tom McCarthy, 2007, *Auto Mania: Cars, Consumers, and the Environment*, New Haven, CT: Yale University Press. The rest of this paragraph draws heavily on this source.

7 The Clean Air Act amendments of 1970 required substantial reductions—90% within less than ten years—in the emissions of hydrocarbons, carbon monoxide, and

Chicago Fed Letter is published by the Economic Research Department of the Federal Reserve Bank of Chicago. The views expressed are the authors' and do not necessarily reflect the views of the Federal Reserve Bank of Chicago or the Federal Reserve System.

ISSN 0895-0164

nitrogen oxide by new motor vehicles (McCarthy, 2007, p. 182).

[8] For light-duty vehicles, the federal "Tier 3" standards were adopted in 2014 and will be phased in over the period 2017–25 (see https://www3.epa.gov/otaq/documents/tier3/420f14009.pdf). Those standards represent about an 80% reduction from today's fleet average in tailpipe emissions. They also require lowering the sulfur content of gasoline.

[9] See http://www.federalreservehistory.org/Events/DetailView/36 and http://www.federalreservehistory.org/Events/DetailView/40.

[10] The 2007 CAFE regulations also introduced controls on vehicle GHG emissions, and added the EPA as a regulator (the U.S. Department of Transportation alone administered the previous CAFE standards); see Thomas Klier and Joshua Linn, 2011, "Corporate average fuel economy standards and the market for new vehicles," *Annual Review of Resource Economics*, Vol. 3, October, pp. 445–462. Initially, the 2007 regulations required compliance of at least 35 mpg for light-duty fleets by 2020, but in 2009 the compliance date was moved up to 2016; see http://www.eesi.org/papers/view/fact-sheet-vehicle-efficiency-and-emissions-standards.

[11] Compliance with the 54.5 mpg target for light-duty vehicles will be based on the EPA's lab tests. Notably, manufacturers can receive "emissions credits" from the EPA by introducing electric or plug-in hybrid technologies and off-cycle technologies (such as automated engine start–stop systems, which reduce engine idling time). Additional credits can be earned for improving air conditioning efficiency, which reduces GHG emissions. These credits can be used to offset low-mileage vehicles, thereby keeping an automaker's fleet-wide fuel economy average in compliance with the target. See https://www3.epa.gov/otaq/climate/documents/420f12051.pdf.

[12] Benjamin Leard, Joshua Linn, and Virginia McConnell, 2016, "Fuel prices, new vehicle fuel economy, and implications for attribute-based standards," Resources for the Future, discussion paper, No. 16-04, February, http://www.rff.org/files/document/file/RFF-DP-16-04.pdf.

[13] Note that unlike fuel economy, fuel consumption is a linear metric (e.g., reducing consumption from, say, eight to seven gallons per 100 miles saves the same amount of fuel as reducing it from three to two gallons per 100 miles).

[14] See, e.g., Eugenio J. Miravete, María J. Moral, and Jeff Thurk, 2015, "Innovation, emissions policy, and competitive advantage in the diffusion of European diesel automobiles," University of Notre Dame, working paper, August 13, https://www3.nd.edu/~jthurk/Papers/MMT.pdf. There is agreement in the economics literature that compared with enacting stricter fuel economy standards, levying higher fuel taxes is more cost effective in reducing fuel consumption.

[15] Thomas Klier and Joshua Linn, 2013, "Fuel prices and new vehicle fuel economy—Comparing the United States and Western Europe," *Journal of Environmental Economics and Management*, Vol. 66, No. 2, pp. 280–300; and Miravete, Moral, and Thurk (2015).

[16] See Ewing (2016). In the U.S., diesel's share of light-duty vehicle sales was zero between 1990 and 2003. In 2015 it stood at just under 3% (authors' calculations based on data from WardsAuto InfoBank, database by subscription).

[17] Klier and Linn (2013).

[18] http://www.theicct.org/sites/default/files/info-tools/pvstds/EU_PVstds-facts_dec2014.pdf.

[19] http://www.theicct.org/sites/default/files/publications/ICCTupdate_EU-95gram_jan2014.pdf.

[20] http://www.spiked-online.com/newsite/article/vw-a-panto-of-green-politics/17488#.VwQ163IUXcs.

[21] http://ec.europa.eu/finland/news/press/101/pdf/catalytic_converters_reduce_traffic_emissions_en.pdf (accessed on April 15, 2016).

[22] Timothy F. Bresnahan and Dennis A. Yao, 1985, "The nonpecuniary costs of automobile emissions standards," *RAND Journal of Economics*, Vol. 16, No. 4, Winter, pp. 437–455; and Richard G. Newell and Kristian Rogers, 2003, "The U.S. experience with the phasedown of lead in gasoline," Resources for the Future, discussion paper, June, http://web.mit.edu/ckolstad/www/Newell.pdf.

[23] Authors' calculations based on data from http://www.spiked-online.com/newsite/article/vw-a-panto-of-green-politics/17488#.VwQ163IUXcs.

[24] http://www.theicct.org/sites/default/files/ICCT_comparison%20Euro%20v%20US.pdf.

[25] However, in-use (on-road) testing seems impractical for a large number of vehicles and is likely not as precise as lab testing. See Danny Hakim and Jad Mouawad, 2015, "Galvanized by VW scandal, E.P.A. expands on-road emissions testing," *New York Times*, November 8, http://www.nytimes.com/2015/11/09/business/energy-environment/epa-expands-on-road-emissions-testing-to-all-diesel-models.html.

[26] https://www3.epa.gov/otaq/cert/mpg/fetrends/1975-2015/420s15001.pdf.

[27] http://www.theicct.org/sites/default/files/publications/ICCT_InUse_working_paper_2012_Eng.pdf.

[28] Ewing (2016); and Hakim and Mouawad (2015).

[29] http://www.theicct.org/sites/default/files/Fact%20sheet_FromLabToRoad_2015.pdf.

[30] http://www.theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141013.pdf.

[31] See https://www.epa.gov/enforcement/hyundai-and-kia-clean-air-act-settlement and https://www3.epa.gov/otaq/documents/fueleconomy/420f13044.pdf.

[32] Authors' calculations based on data from WardsAuto InfoBank.

[33] Ryan Beene, 2015, "VW's diesel sales frozen until compliance is proven, EPA official says," *Automotive News*, September 21, http://www.autonews.com/article/20150921/OEM11/150929980/vws-diesel-sales-frozen-until-compliance-is-proven-epa-official-says.

[34] Ryan Beene, 2016, "After VW cheated, tests got tougher," *Automotive News*, March 7, http://www.autonews.com/article/20160307/OEM11/303079956/after-vw-cheated-tests-got-tougher.

[35] Hakim and Mouawad (2015); and Financial Times Limited, 2015, "Europe has ducked its obligations on diesel cars," *Financial Times*, November 1, available by subscription at http://www.ft.com/cms/s/0/afc4d66a-7efd-11e5-98fb-5a6d4728f74e.html.

[36] Mathieu Rosemain, 2015, "Paris smog obscuring Eiffel Tower threatens diesel-car dominance," Bloomberg, June 19, http://www.bloomberg.com/news/articles/2015-06-19/paris-smog-obscuring-eiffel-tower-threatens-diesel-car-dominance.