Policy Brief No. 4

Policies to enhance vehicle fleet modernization

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Key Points

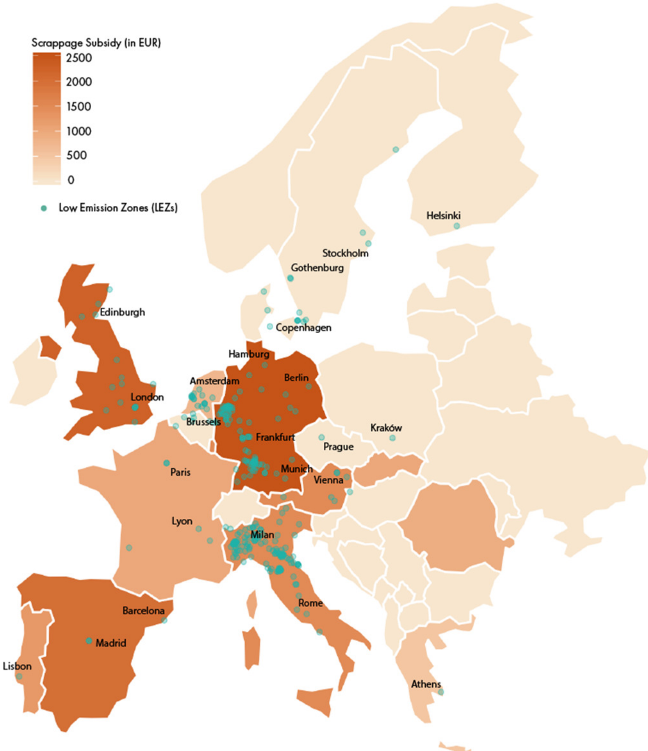
- There are environmentally effective policies to retire old vehicles and promote clean cars.
- Low emission zones (LEZs) improve air quality because drivers adopt low-emission vehicles to be able to access city centers.
- Even moderate reductions in air pollution caused by LEZs have meaningful long-term health benefits.
- Prudent scrappage subsidies improve local air quality by targeting owners of emission-intensive cars who would not purchase new vehicles without incentives.
- Scrappage programs have no major adverse CO_2 effects from a life-cycle perspective.
- Cost-effective greenhouse gas reductions require scrappage in favor of public transit, car-sharing or biking.

1. Clean cars for a healthy environment

Air pollution in EU Member States exceeds the EU's strict pollution limits, especially in larger cities. The European Commission has taken legal action against 13 Member States because of too high nitrogen dioxide concentrations and 16 Members States because of too high concentrations of particulate matter (European Commission 2018). In densely populated urban areas, road traffic is the major contributor to these ground-level emissions that are particularly harmful to human health and well-being (Currie and Walker 2011, Knittel et al. 2016, Landrigan et al. 2018).

Major efforts to accelerate clean car roll-out across Europe

Because older vehicles, especially if powered by diesel, are more emission-intensive than new ones, getting such "clunkers" off the road has become a widespread policy target. Two policy measures have gained prominence in the concerted effort to accelerate vehicle fleet modernization, which is ultimately tied to the goal of improving ambient air quality but also the transition to low-carbon road transportation (see figure). At the national level, various governments provide subsidies to buy environmentally friendly cars conditional on scrapping an old one. At the local level, many European cities implement low emission zones (LEZs) that limit access to vehicles meeting certain pollution standards. For instance, Athens, Brussels, Madrid, Milan and Paris either already ban older diesel cars or have pledged to ban diesel cars altogether in the near future. In 2018, Germany's Federal Administrative Court has confirmed that city councils have the right to ban diesel cars from city centers. To alleviate the burden of such restrictions, scrappage programs can help households to upgrade to cleaner cars.



Policy effectiveness is unclear

Policymakers' enthusiasm for these two policies and their widespread use raise the question as to whether they are effective at meeting their economic and environmental goals. Both policies are controversial, mainly because of the costs imposed on drivers required to upgrade their vehicles in the case of LEZs and the large fiscal costs in the case of scrappage programs. The policies' controversial effectiveness makes informed decisions among policy options difficult. Against this backdrop, this policy brief synthesizes key findings from the scientific literature and our own ongoing research on two flagship policy programs in Germany.

2. Low Emission Zones

While there are many LEZs in Europe, the academic literature on their efficacy is limited. Tangible evaluations are available only for Germany, where 58 LEZs have been implemented since 2008 in order to reduce particulate matter (PM) emissions. The zones rarely span a complete county but mostly ban PM-intensive vehicles from inner-city areas.

To gain robust insights on the causal policy effect, studies exploit the fact that cities across Germany adopt LEZs at different times. For instance, Hannover and Cologne have introduced LEZs in 2008, while Leipzig followed in 2011. By comparing pollution and health outcomes in cities before and after LEZ implementation to those in cities that have not yet implemented one, it is possible to estimate causal effects. A comparison between adopters and soon-to-be-adopters is important in order to prevent that the potential strategic introduction of LEZs in more polluted cities distorts the estimation results.

LEZs reduce air pollution

Based on analyses applying such robust empirical evaluation methods, there is strong evidence that a LEZ introduction causes air quality improvements in Germany. A series of studies shows that ambient PM pollution declines between 4% and 9% in cities with a LEZ compared to cities without (Wolff 2014, Gehrsitz 2017, Pestel and Wozny 2019, Koch et al. 2019). A recent study also suggests that LEZs could also reduce nitrogen oxide (NO_x) levels by up to 5% (Pestel and Wozny 2019).

Substitution towards low emission vehicles

These pollution reductions accrue because households and companies adopt low-emission vehicles to be able to drive into LEZs. The probability of adopting cleaner cars increases with proximity to the LEZ (Wolff 2014): In particular, the number of privately used lower-emission vehicles increased by about 5%. In comparison, commercially owned lower-emission vehicles, which depend heavily on access to city centers, increased sharply by 88%.

Benefits may outweigh costs

To evaluate whether LEZs are a cost effective command and control measure, back-of-the-envelope cost-benefit analysis is applied. Based on long-term mortality rates from PM emissions (Medina et al. 2004) and the Value of the Statistical Life, the health benefits of the first wave of LEZs in Germany are estimated to reach approximately $2 billion (Wolff 2014, Malina and Scheffler 2015). Accounting for the combined costs of LEZ implementation and vehicle substitution worth $1 billion, there is a net benefit of about $1 billion (Wolff 2014).

In contrast to these back-of-the-envelope calculations, there are also studies using data from actual hospitalizations (Gehrsitz 2017, Pestel and Wozny 2019). With respect to infant health, they arrive at mixed conclusions. One finds that LEZs reduce the incidence of stillbirths by about 16%, while they have no effect on birthweight (Gehrsitz 2017). The other finds that LEZs decrease incidences of low birthweight (Pestel and Wozny 2019). In the general population, low-emission zones significantly reduce hospitalizations for cardiovascular and respiratory diseases (Pestel and Wozny 2019).

Substantial long-term health benefits

Our own research extends the literature in several ways. We focus exclusively on children to analyze the effect of PM pollution in the first year of life on health outcomes over the first five years of childhood. This is an important contribution because the effect of pollution on health accrues over time. Moreover, children are more likely to suffer more heavily from pollutants than adults. Also, children's medical history begins with their conception. We are able to compare children who benefitted from LEZs since their conception to children that did not. Adults, however, may have long medical histories and have likely been exposed to a battery of pollutants during the course of their lives. This aspect is often impossible to account for in a robust study design. We consider children's entire medical history including (i) outpatient doctoral care, (ii) pharmaceutical prescriptions, and (iii) hospital stays. Using comprehensive data from Germany's largest public health insurer AOK that comprises about a third of Germany's population, we show that the pollution reduction translates into substantial health benefits for children. For example, children who benefit from LEZs in their first year of life experience a 4% reduction in drug prescriptions for respiratory disorders over the course of their first five years of life. Moreover, LEZs seem to improve morbidity in general. Children in cities with an LEZ require about 4.5% less doctor treatments and 3.4% fewer drug prescriptions regarding infectious diseases (Klauber et al. 2019).

This newly acquired evidence suggests that even small improvements in air quality at relatively low pollution levels cause major improvements in human health and significant reductions in health costs.

3. Scrappage Schemes

Scrappage schemes have two objectives: stimulating domestic consumption and reducing emissions of local pollutants and greenhouse gases. Empirical studies on scrappage schemes show that prudent policy design is crucial to meet both objectives.

Short-term vehicle sales stimulus

Scrappage schemes are appealing because they immediately stabilize car sales by stimulating consumer demand, as shown for Europe and the U.S. (Adda and Cooper 2000, Mian and Sufi 2012, Li et al. 2013, Green et al. 2016, Grigolon et al. 2016). However, these short-run gains do not necessarily persist in the long term. For instance, a scrappage program in 2009 in the U.S. provided a $2.85 billion stimulus, which initially increased vehicle sales but which was subject to a strong reversal in vehicle purchases at the end of the program. Total new vehicle spending even decreased between \$2 and \$5 billion as a result of the program (Hoekstra et al. 2017). Research suggests that consumers generally benefit in monetary terms from scrappage schemes because competition prevents car dealers from reaping much of the subsidy (Busse et al. 2012, Kaul et al. 2016).

German "Umweltprämie" incentivized car purchases over the long run

Germany's scrappage program of 2009 is an exception in terms of stimulating long-term consumer demand. Our new research suggests that the policy caused about 1 million additional car sales in the same year (Helm et al. 2019). This is equivalent to a 70% sales increase relative to 2008. Given that in total 2 million cars received the subsidy, about half of the car sales would have occurred in the absence of the scrappage scheme. Sales revert to their usual level after the end of the program. Had sales been preponed, there would have been a decline below the usual level. The measurable success of Germany's scrappage program is likely because of its size and duration. It was considerably larger than all other existing programs. The total budget of €5 billion was sufficient to replace 4.8% of the passenger vehicle stock. Moreover, the program lasted considerably longer (9 months in Germany vs. 2 months in the U.S.) than comparable programs.

Schemes targeted at electric vehicles

California's Enhanced Fleet Modernization Program is a more recent retire-and-replace program that incentivizes the trade-in of old vehicles for electric vehicles (EVs) and targets low- and middle-income consumers. It shows that an EV price reduction of 10% increases EV demand by 65% for these consumers who are generally less likely to purchase EVs. Yet, \$4.5 billion in subsidies would be required to achieve California's target of 1.5 million EVs by 2025 (Muehlegger and Rapson 2018). This financial requirement shows the limitations of using scrappage programs to foster the mass market adoption of EVs. A combination of scrappage programs with taxes and tighter vehicle standards is more effective in supporting a large-scale EV adoption (Beresteanu and Li 2011, Wei and Li 2016).

Direct environmental benefits differ across schemes

The evidence regarding whether scrappage programs convey environmental benefits is mixed and depends on whether one focuses on direct and indirect emissions of carbon dioxide (CO_2) or other air pollutants. Concerning vehicle CO_2 emissions, estimations for the 2009 U.S. program suggest moderate reductions of 9.0-28.2 million tons of CO_2 at relatively high costs between \$92 and \$288 per ton of CO_2 (Li et al. 2013). The CO_2 reductions for the U.S. scrappage program trace back to the fact that eligible households purchased significantly smaller and more fuel-efficient vehicles; these households also did not drive more despite the lower operating costs of their new vehicles (West et al. 2017). While there is evidence that the German scrappage program benefitted the adoption of smaller vehicles, there is no compelling evidence for reduced CO_2 emissions (Pfeifer and Kloessner 2018).

Significant emissions savings from retirement programs targeting transportation mode switches

Scrappage schemes targeted at reducing vehicle usage and ownership fare better in terms of cost-effectiveness and emission reductions compared to traditional retire-and-replace programs. Most notably, a vehicle retirement program in British Columbia, Canada has been the first of its kind to offer a low subsidy of C\$300 for vehicle purchases but up to C\$2250 for alternative forms of transportation, for example bicycles, public transit, or memberships in ride- or car-sharing programs. This has been shown to incentivize substantial reductions in CO_2 and local pollutants (Antweiler and Gulati 2015). On average, each scrapped vehicle reduces emissions by a quantity worth C\$566. These savings increase to C\$1002 for program participants who chose the higher subsidy for public transit without purchasing any used vehicles later on. Against these benefits, the average cost per participant was C\$886.

Beneficial impact on local air quality

Comprehensive evidence regarding the impact of scrappage schemes on ambient air quality is just emerging. Our recent research suggests that Germany's 2009 program has decreased nitrogen dioxide (NO_2) emissions by about 1 microgram per cubic meter air, which equals a 6% reduction compared to NO_2 levels in 2008 (Helm et al. 2019). There is tentative evidence that the policy has also reduced PM_{10} emissions by a similar magnitude but the evidence is less robust. Related research on a long-running regional vehicle retirement program in California's Bay Area, however, indicates the long-run limitations of vehicle retirement programs for reducing air pollutants (Sandler 2012). At first, scrappage programs retire the oldest and most emission-intensive vehicles. This conveys the greatest benefits. However, with the most emission-intensive vehicles removed from the stock, the program retires ever less emission-intensive vehicles and, therefore, loses efficiency. To retain a meaningful level of efficiency, scrappage programs must focus on the most emission-intensive vehicles.

No major adverse CO_2 effects from life-cycle perspective

So far, the discussion has focused on environmental benefits only in terms of direct emissions from fuel combustion. However, indirect emissions from vehicle production and disposal as well as fuel production also contribute considerably to the overall detrimental environmental impacts of vehicles, especially in the case of new vehicle technologies such as EVs. A limited number of studies evaluate the life-cycle performance of specific scrappage programs. They find moderate life-cycle CO_2 effects, if any. An evaluation of the U.S. scrappage scheme estimates a life-cycle saving of 4.4 million tons of CO_2 (0.4% of annual light duty vehicle emissions), but results are sensitive to vehicle lifetime reductions (Lenski et al. 2010; Lenski et al. 2013). Similarly, a moderate life-cycle reduction of about 1 million ton of CO_2 is attributed to a Japanese scrappage scheme if participants in the scheme retain their new cars for at least

4.7 years (Kagawa et al. 2013). If replacements in the Japanese scheme were restricted to hybrid cars, the CO_2 reductions would be 6–8.5 times higher than with gasoline vehicles. Our recent research for Germany's 2009 program corroborates the finding of limited CO_2 effects and also highlights the related uncertainties (Nistad et al. 2019). Depending on assumptions about annual kilometers driven and the lifetime reduction of the replaced vehicles, the analysis suggests a slight increase in life-cycle CO_2 emissions by 1 to 1.9 million tons, because fuel economy improvements do not outbalance production and disposal emissions; yet, increasing the lifetime of replacement cars to 225,000-235,000 km instead of 200,000 km leads to a net zero effect on CO_2 emissions. A hypothetical program of similar scale, replacing old diesel vehicles with battery EVs in German cities exceeding the NO_2 concentration limit, is estimated to deliver reductions in direct NO_x emissions that are by far large enough to offset the increase in indirect emissions. Its effect on CO_2 emissions depends on the electricity mix used for charging EVs. Life-cycle CO_2 emissions decrease if replacement EVs are charged with the current marginal German electricity mix. With a more decarbonized electricity mix in 2030 that is in line with a climate change mitigation scenario, the hypothetical replacement scheme would yield lower life-cycle CO_2 emissions both when the average and marginal electricity mix is used for charging (Nistad et al. 2019).

References

J. Adda and R. Cooper, „Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies", *Journal of Political Economy*, 108(4), p. 778-806, 2000.

W. Antweiler and S. Gulati, „Scrapping for Clean Air: Emissions Savings from the BC SCRAP-IT Program", *Journal of Environmental Economics and Management*, 71, p. 198-214, 2015.

A. Beresteanu and S. Li, „Gasoline Prices, Government Support, And The Demand For Hybrid Vehicles In The United States", *International Economic Review*, 52, p. 161-182, 2011.

M.R. Busse, C.R. Knittel, J. Silva-Risso and F. Zettelmeyer, „Did "Cash for Clunkers" Deliver? The Consumer Effects of the Car Allowance Rebate System", *CEEPR WP 2013-009, MIT Center for Energy and Environmental Policy Research,* 2012.

J. Currie and W. R. Walker, „Traffic Congestion and Infant Health: Evidence from E-ZPass," *American Economic Journal: Applied Economics*, 3, p. 65-90, 2011.

European Commission, "Air quality: Commission takes action to protect citizens from air pollution," Press release, IP/18/3450, 2018.

D. Green, B.T. Melzer, J.A. Parker and A. Rojas, „Accelerator or Brake? Cash for Clunkers, Household Liquidity, and Aggregate Demand", *National Bureau of Economic Research Working Paper Series,* 22878, 2016.

L. Grigolon, N. Leheyda and F. Verboven, „Scrapping Subsidies During the Financial Crisis: Evidence from Europe", *International Journal of Industrial Organization*, 44, p. 41-59, 2016.

I. Helm, N. Koch and A. Rohlf, "The Effects of Cash for Clunkers on Local Air Quality", Working Paper, Mercator Research Institute on Global Commons and Climate Change, *to be published*, 2019.

M. Hoekstra, S.L. Puller and J. West, „Cash for Corollas: When Stimulus Reduces Spending", *American Economic Journal: Applied Economics*, 9(3), p. 1-35, 2017.

S. Kagawa et al., "Better cars or older cars?: Assessing CO 2 emission reduction potential of passenger vehicle replacement programs," Global Environmental Change, 23 (6), pp. 1807–1818, 2013.

A. Kaul, G. Pfeifer and S. Witte, „The Incidence of Cash for Clunkers: Evidence from the 2009 Car Scrappage Scheme in Germany", *International Tax Public Finance*, 23, p. 1093-1125, 2016.

H. Klauber, N. Koch, N. Ritter, A. Rohlf, F. Holub, "The long-term health benefits of early-life protection by Low Emission Zones: Evidence from the medical histories of newborns in Germany," Working Paper, Mercator Research Institute on Global Commons and Climate Change, *to be published*, 2019.

C. Knittel, D. Miller and N. Sanders, „Caution, Drivers! Children Present: Traffic, Pollution, and Infant Health," *The Review of Economics and Statistics*, 98, p. 350-366, 2016.

P. J. Landrigan et al., „The Lancet Commission on pollution and health," *The Lancet*, 391, p. 462-512, 2018.

S. M. Lenski, G. A. Keoleian, and K. M. Bolon, "The impact of 'Cash for Clunkers' on greenhouse gas emissions: A life cycle perspective," Environmental Research Letters, 5(4), 2010.

S. M. Lenski, G. A. Keoleian, and M. R. Moore, "An assessment of two environmental and economic benefits of Cash for Clunkers," *Ecological Economics*, 96, p. 173–180, 2013.

S. Li, J. Linn and E. Spiller, „Evaluating "Cash-for-Clunkers": Program Effects on Auto Sales and the Environment", *Journal of Environmental Economics and Management*, 65, p. 175-193, 2013.

C. Malina and F. Scheffler, "The Impact of Low Emission Zones on Particulate Matter Concentrations and Public Health," *Transportation Research Part A: Policy and Practice*, 77, p. 372-385, 2015.

S. Medina, A. Plasencia, F. Ballester, H.G. Mucke and J. Schwartz, "Apheis: public health impact of PM10 in 19 European cities," *Journal of Epidemiology and Community Health*, 58(10), p. 831-836, 2004

A. Mian and A. Sufi, „The Effects of Fiscal Stimulus: Evidence from the 2009 Cash for Clunkers Program", *The Quarterly Journal of Economics*, p. 1107-1142, 2012.

E. Muehlegger and D.S. Rapson, „Subsidizing Mass Adoption of Electric Vehicles: Quasi-Experimental Evidence from California", *National Bureau of Economic Research Working Paper Series*, 25359, 2018.

A. Nistad, C. Mutel and C. Bauer, "RETIRE-AND-REPLACE SUBSIDY PROGRAMS: the life-cycle perspective", Research Report, Paul Scherrer Institut, *to be published*, 2019.

G. Pfeifer and S. Kloessner, „Synthesizing Cash for Clunkers: Stabilizing the Car Market, Hurting the Environment?", *Munich Personal RePEc Archive*, 88175, 2018.

R. Sandler, „Clunkers or Junkers? Adverse Selection in a Vehicle Retirement Program", *American Economic Journal: Economic Policy,* 4(4), p. 253-281, 2012.

C. Wei and S. Li, „The Cost of Greening Stimulus: A Dynamic Discrete Choice Analysis of Vehicle Scrappage Programs", *Working Paper,* 2016.

J. West, M. Hoekstra, J. Meer and S.L. Puller, „Vehicle Miles (Not) Traveled: Fuel Economy Requirements, Vehicle Characteristics, and Household Driving", *Journal of Public Economics*, 145, p. 65-81, 2017.

For more information

https://www.mcc-berlin.net/next-generation-policies

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