Greening the drive: unpacking the impact and equity aspects of Germany’s EV subsidy programme

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Abstract
Public subsidies for the purchase of electric vehicles (EVs) have been introduced in various countries as a means of incentivising consumers to shift away from fossil-fuel powered personal transport. In Germany, as in many other European countries, the shift towards E-Mobility has gained particular attention due to the transport sector’s increasing need to decarbonise for the country to meet national and European climate neutrality targets. In this paper, we use data from the country’s national EV subsidy programme (the *Umweltbonus*) and a survey of the recipients of the subsidy to determine the free rider, rebound, and spillover effects, which have become indispensable to consider in the design and evaluation of contemporary energy policy. In addition, the distributive aspects of the subsidy programme are analysed, notably concerning income and regional inequalities. Our study suggests that there might be substantial inequalities in terms of the demographics of the recipients of the subsidy, whereas the rebound effects are smaller than what the literature might suggest. Future efforts to promote EV adoption might benefit if the corresponding subsidy programmes are better targeted towards recipients from economically disadvantaged groups and regions. The insights from this study contribute to the growing literature on the effectiveness of EV subsidy programmes using observed microdata as well as stated data. In addition, concrete lessons such as about the distributive effects of the policy can be gathered from this experience in Germany that might find application in transport policy in other jurisdictions. Further redesign of the subsidy should also consider including a corresponding disincentive for buyers to buy fossil-fuel driven cars, in addition to a subsidy towards EVs, which might increase distributional fairness as well as be more neutral towards the burden on state finances.

Introduction
Against the backdrop of structural change in the automotive industry, the “Umweltbonus” EV subsidy (hereafter called the “EV subsidy”) was a key climate policy measure of the German government for the electrification of road transport and thus for the decarbonisation of the transport sector as a whole (Bundesregierung, 2023). With the EV subsidy, private households and companies were granted a financial subsidy when purchasing or leasing an electrically powered vehicle. Since the introduction of the EV subsidy in 2016 up to and including 2022 (funding phases 1 and 2), state funding totalling €8.59 billion has been approved, supplemented by €4.48 billion in funding from vehicle manufacturers, which has been used to support the registration of 1.79 million vehicles. The German government’s goal is to achieve a fleet of 15 million purely battery-electric cars by 2030 (SPD Bündnis 90/Die Grünen und FDP, 2021).

In 2022, the federal government was still planning to phase out the EV subsidy in 2024. In light of the decision of the Federal Constitutional Court (BVerfG) of 15 November 2023 on the Second Supplementary Budget Act 2021 and the associated withdrawal of additional budget funds for the Climate and Transformation Fund (KTF), the EV subsidy was discontinued by the federal government ahead of schedule on 17 December 2023 (BMWK, 2023).

The EV subsidy is a subsidy for the purchase or leasing of an electric vehicle, which has been granted in varying amounts since 2016. The subsidy was jointly funded by the public and private sectors by granting rebates from the manufacturers of electric vehicles in addition to the federal subsidy. The subsidy amounts were granted based on the list price also set by the manufacturers.

The background to the introduction of the subsidy guideline was the structural change in the automotive industry (BMWi, 2016). The aim of the EV subsidy was to support E-Mobility in the market ramp-up phase and thus achieve the German government's transport sector emissions targets. At the beginning of the EV subsidy funding programme, the goal was defined of achieving a fleet of one million electrically powered vehicles (purely battery-electric and hybrid) by the end of 2020. This target was officially pursued from 2019 onwards, but without the target of fulfilment by the end of 2020, as at that time external experts did not consider it realistic to achieve it until the target year 2022.

Significant savings in motorised private transport are particularly necessary to achieve the climate protection targets in the transport sector: In 2022, around 148.5 million tonnes of GHG emissions were emitted in the transport sector, accounting for around a fifth of Germany's total GHG emissions. According to the amendment to the Climate Protection Act (KSG 2021) of 24 June 2021, emissions in the transport sector must be reduced to 83.5 million tonnes by 2030, i.e. by around 44 % (Expertenrat für Klimafragen, 2023).

In this article, we analyse some of the key aspects of the evaluation of the EV subsidy programme in Germany, specifically focussing on the free rider effect and the pull-forward effect (analogous to the free rider effect shifted to an earlier date), the rebound effect, the spillover effects of EV adoption, as well as important distributional effects such as across income groups. To our knowledge, this is the first analysis of such a kind for Germany that uses field data, and we therefore formulate policy recommendations to inform the development of future subsidy programmes in Germany and beyond. The results presented in this paper are based on an evaluation project conducted by the authors supported by the German Federal Ministry for the Economy and Climate Protection (Bundesministerium für Wirtschaft und Klimaschutz, BMWK) and conducted between March 2023 and January 2024.

The estimation of free rider and rebound effects for EV purchase decisions are crucial because a high free rider effect might undermine the overall efficiency of the subsidy, since the emissions reductions aimed from the subsidy programme could have possibly been better achieved by other means. The importance of the free rider effect in this context is noted in the literature (Wang et al., 2023), and some studies such as Burra, Sommer and Vance, 2023 model the expected free rider effect in the context of EV subsidies (they estimate a free rider effect of about 19 % for private buyers and 43 % for company cars) but few studies use field data to estimate the free rider effects of EV subsidy uptake. An evaluation of an EV subsidy programme in California showed a free rider effect of about 50 % (Johnson et al., 2017).

The rebound effect in electric vehicle adoption has been discussed extensively in the literature. The scope of the rebound effect, however, varies across studies. While some studies study the rebound effects including the entire life cycle of EVs (Font Vivanco et al., 2014), some studies look at the quality rebound effect (i.e. the upgrade to a larger vehicle class while purchasing an EV) (Craglia and Cullen, 2019). These valuable perspectives might, however, be less relevant when it comes to policy evaluation in terms of rebound effects pertaining to actual usage of EVs. While some studies in the literature find higher rebound effects in the transport sector (between 10 % and 20 %) (Murray, 2013), a few studies pertaining to actual EV usage give insights into rebound effects dealing with the introduction of electric vehicles in Germany and other European countries (2 % to 4 %) (Whitehead, Franklin and Washington, 2015; Huwe and Gessner, 2020). Spillover effects of pro-environmental behaviours have also been studied in various contexts (Nilsson, Bergquist and Schultz, 2017), and specifically concerning EVs in Norway (Klöckner, Nayum and Mehmetoglu, 2013). Few studies, however, look at the within-domain spillovers of EV vehicle adoption on E-Mobility, or the cross-domain spillover on other energy-saving behaviours.

The distributional effects of EV subsidies have also been discussed in the literature. Due to a variety of factors such as purchase price, access to charging infrastructure, educational backgrounds of purchasers and vehicle characteristics, many EV subsidies (such as the US Clean Energy Tax Credits) have been seen to disproportionately benefit richer households than middle-income or low-income households (Borenstein and Davis, 2016; Best and Nazifi, 2023). Recent studies also suggest that policy interventions to target low- and middle-income households for EV adoption might be effective (Muehlegger and Rapson, 2022). Studies focusing on Germany, however, are scarce, and our article fills this gap by offering insights into the subsidy programme as designed in the German context.

Data and Methodology

DATA

The data on the applications in the funding programme was provided by the Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA) for the evaluation. A total of 1,840,097 observations were available in the funding dataset, whereby several subsidised vehicles can be behind one observation. 1,676,376 applications fell within the scope of the first and second funding periods, which are the subject of this paper.

The dataset was checked for outliers in the key variables (application dates and subsidy amounts) and none were found that were outside the expected limits. Of the total observations, one observation did not have an associated transaction number and was therefore discarded.

The dataset was split into two funding periods, the first one being between 2016 and mid-2020, and the second period between mid-2020 and the end of 2022. In the second funding period, the subsidies were substantially higher (up to €9,000 in total), whereas in the first funding period the subsidies were up to €4,000. There is, therefore, reason to indicate that the effects studied in this article might be different between the two funding periods.

METHODOLOGY – SURVEY

As an important methodological component of the evaluation, an online survey was conducted among the funding recipients. The survey serves to collect additional information on the funding cases that cannot be covered by the application data and other secondary data.

The results from the online survey are used in particular for net-impact monitoring (e.g. determining free rider and pull-forward effects to discount them from the gross impacts) as well as for other specific questions on target achievement (e.g. gender and income distribution) and efficiency (e.g. satisfaction with the application process).

For the survey, a representative sample of around 1 % of applicants was selected, who were then contacted for the survey. To ensure that the final sample was representative of the data set of applicants, a quota sample was used in terms of the split between private individuals and organisations and, within private individuals, between female, male and non-identified applicants. In addition, it was expected that the response rates for the survey would be different for organisations and private individuals and for applicants in the first and second funding period. These expected response rates were also taken into account in the quota sample. The survey was conducted using an online survey tool and the invitations were sent out by email. An official invitation letter from the BMWK was linked in the email.

The promotion of the EV subsidy as a broad-based funding programme appeals to different target groups. Accordingly, the first step in designing the online survey was to define different groups of applicants, and namely (i) Private Individuals: Private individuals who have submitted one (or more) subsidy applications for privately used electric vehicles. (ii) Users in companies: Company cars or commercially used vehicles for which the applicants themselves know details about the exact use of the vehicle (e.g. self-employed/small companies). (iii) Fleet managers/purchasers in companies: Company cars or commercially used vehicles where the person making the application is not personally informed about the use of the individual vehicle (e.g. in large companies).

The questions in the online survey were then tailored to the allocation to these three groups. In particular, each group was asked to provide additional data on the use of the subsidised vehicles, the reasons for the purchase decision and the application process.

For some questions in the online survey, particularly on the use of subsidised vehicles, there is a risk that respondents' answers will be influenced by social desirability effects. Social desirability effects are the tendency of survey participants to answer questions in such a way that they are rated positively by others. This bias can cause answers in a survey to deviate from reality. In order to counteract distortions caused by social desirability, the survey was designed using "cheap talk", in which possible distortions were explicitly pointed out. Specifically, it was pointed out in the introductory text of the survey that the answers in the survey should be truthful and that the answers would have no influence on past, current or future funding applications. In addition, further such information was introduced into the survey immediately before critical question blocks. In this way, the survey follows the standard commonly used in science to minimise the effects of social desirability in surveys. At the same time, it must be pointed out that, despite the measures taken, it cannot be ruled out that the results of the survey may show a certain bias.

A total of 14,885 applicants were contacted and invited to take part in the survey. 10,152 of the applicants were organisations and 4,733 were private individuals. The survey was conducted in two phases. In the first phase, 9,147 people were invited between 25.08.2023 and 04.09.2023 (the invitations for Bavaria and Baden-Württemberg were sent out on 04.09.2023, shortly before the end of the summer holidays in these federal states). A reminder email was sent on 14.09.2023. In the second phase between 12.10.2023 and 13.10.2023, 5,738 applicants were contacted. A reminder email was sent on 06.11.2023.

A total of 2,519 valid responses to the online survey were registered. This corresponds to an overall response rate of 16.9 %. 1,309 responses came from private individuals (response rate of 27.76 %). 1,210 responses came from companies and organisations (response rate of 11.9 %).

DETERMINATION OF THE FREE RIDER AND PULL-FORWARD EFFECTS

The free rider and pull-forward effects were calculated on the basis of the responses to the survey. They were calculated slightly differently for private individuals and users of the subsidised vehicles in companies and for fleet managers (who do not know the exact use of the subsidised vehicles).

The free rider effect describes the proportion of applicants who would have bought or leased an electric vehicle even without the subsidy. For applicants for whom the EV subsidy programme was only one of the reasons for purchasing an electric vehicle, a proportional free rider effect is assumed. The effect is specified by distinguishing between a strong and a weak free rider loss. In the case of a strong free rider effect, it is assumed that the subsidy recipient would have purchased an EV even without the existence of the subsidy programme. A weak free rider effect exists if the EV subsidy was one of the reasons for purchasing an electric vehicle, but not the only one. The pull-forward effect is already included in the calculation of the free rider effect. The logic is that the purchase would have been made at a later date even without the subsidy. There is therefore no free rider effect for the period up to the actual planned purchase. However, there is a free rider effect from the time of the actual planned purchase. In practice, this effect is estimated with the information that the purchase would have been made at a later date.

With regard to the validity of the information on the free rider effect, biased answers cannot be ruled out, as the calculation is based on a survey of subsidy recipients after the application was submitted. On the one hand, the answers could underestimate the free rider effect because the applicants have an interest in the continuation of such funding programmes. In this case, they would not honestly answer the question of whether they would have made the investment without funding in the affirmative, but rather in the negative. On the other hand, social desirability may overestimate the free rider effect. Respondents may answer the above question positively because they are now convinced of the purchase of the electric vehicle and think that they would have bought it even without financial support. Before the purchase, however, they may have been less interested in E-Mobility or the purchase of an electric vehicle. Therefore, they would not have implemented the measure. In addition, individuals and companies may have an interest in presenting themselves in a particularly positive light and answering in terms of social desirability that they purchased the electric vehicle not because of the subsidy, but out of environmental conviction. Nevertheless, the survey is a suitable means of calculating the free rider loss effect, taking into account the reasonable effort involved and the quality of the results. The design of the survey also utilises a "cheap talk" design which is typical for such survey designs and attempts to reduce the social desirability bias.

A detailed explanation of the calculation for private individuals and users in companies can be found in Table 1 and Table 2. Essentially, the respondents were asked two questions about their decision to purchase the electric vehicle (labelled M1 and M2 here), namely whether they would have purchased the vehicle even without the subsidy, and secondly whether the subsidy was a main reason for their decision to purchase the electric vehicle. If they would have purchased the vehicle without the subsidy and the existence of the subsidy did not play a role in their purchase decision, this would indicate a strong free rider loss.

For fleets in organisations, respondents (fleet managers) were asked to answer very similar questions to those for private individuals and corporate users, but in relation to their entire fleet of subsidised vehicles. In practice, this meant that they were asked to indicate the percentage of their fleet of subsidised vehicles to which each answer option applied. The questions for fleet managers, private individuals and company users were kept similar to ensure equivalence in the calculation methods for the two groups. As the survey ensures the representativeness of the group of applicants, the answers of the three user types (private individuals, corporate users, fleet managers) are treated as equivalent. The answers of the different user types to this question in the survey were weighted equally so as not to distort the effect calculations disproportionately towards those user types (especially fleet managers) who may have purchased several subsidised vehicles.

The two factors resulting from the two questions were then combined to obtain a single value that includes the free-rider and pull-forward effects. A combined factor of 1 corresponds to a strong free-rider and pull-forward effect (100 %), while weaker free-rider and pull-forward effects would receive values of 0.5 (50 %) or 0.75 (75 %).

DETERMINATION OF THE REBOUND AND SPILLOVER EFFECTS

Rebound effects are effects that run counter to the actual intended effect of a measure. For example, lower costs per kilometre driven in electric vehicles compared to combustion engines can lead to increased use of the vehicle and thus to higher energy consumption. In addition to an economic rebound, behavioural aspects can also play a role in that users of electric vehicles may feel justified in driving a little more because they have (presumably) made an environmentally friendly decision by purchasing an electric vehicle. A positive rebound effect can lead to an overall increase in emissions and contribute to weakening the overall impact of the programme.

In this evaluation, the extent of the rebound effect is calculated on the basis of the survey described previously. The par-

Table 1. Calculation of the free rider effect.

Question	Response options	Factor
Would you have purchased the EV even without the subsidy?	Yes, at the same point in time	$M_1 = 1$
	Yes, at a later point in time	(pull-forward effect) $M_1 = 1$
	No	$M_1 = 0$
	Do not know/No response	–

Source: Authors' presentation.

Table 2. Calculation of the free rider effect.

Question	Response options	Factor
Was the subsidy the primary reason why you purchased an EV or why the purchase became an option for you?	Yes, it was the primary reason	$M_2 = 0{,}5$; 1 x 0,5 = 0,5
	Yes, but it was only one of the reasons	$M_2 = 0{,}75$; 1 x 0,75 = 0,75
	No, it was not a relevant reason	$M_2 = 1$; 1 x 1 = 1
	Do not know/No response	M_1 remains unchanged

Source: Authors' presentation.

ticipants were asked how much their annual kilometres driven had changed after purchasing the electric vehicle. The rebound effect is calculated in two ways, (i) By calculating the total additional kilometres driven, which is based directly on the responses to the survey, and (ii) and secondly, the rebound effect can also be calculated as a percentage of the average annual mileage of each vehicle (data also collected in the survey).

Spillover effects can be described as secondary effects of the programme that spillover to the actions of actors in other domains or, if they occur within the same domain, cannot be attributed to the direct effects of the funding programme. These two variants of the spillover effect are referred to as within-domain and cross-domain spillover. In the evaluation of the funding programme, the spillover effects are not taken into account in the effect adjustment, but are described separately.

In this evaluation, within-domain spillover refers to spillover that takes place within the E-Mobility domain and more specifically within the EV subsidy funding programme. If, for example, an applicant has recommended other people in their environment to switch to electric mobility after purchasing a subsidised electric vehicle, this would be a positive within-domain spillover.

A cross-domain spillover would be the spillover to the applicant's behaviour and actions in other energy, climate or environmentally relevant domains. For example, if an applicant replaced their heating system with a more efficient heating system after purchasing a subsidised electric vehicle, this would represent a positive cross-domain spillover.

The spillover effects were calculated based on respondents' answers to various questions about their behaviour and actions, as shown in the survey. The answers were given on a Likert scale of 1–5, where 1 stands for "Does not apply" and 5 for "Applies totally".

The total number of approvals over the funding periods is shown in Table 3. The total number of approvals (and applications) are clearly higher in the second funding period, likely due to a combination of higher subsidies per EV (up to €9,000 in total versus €4,000 in the first funding period) and an increasing popularity of EVs in general (including improving charging infrastructure).

Results

GEOGRAPHICAL DISPARITIES

The distribution of subsidised vehicles across the federal states is shown in Figure 1 per funding period. It can be seen that the distribution of the number of subsidised vehicles across the

Table 3. Total number of successful subsidy applications per funding period.

Number of successful applications	2016–2020	2020–2022
	190,264	1,479,827

Source: BAFA. Authors' presentation.

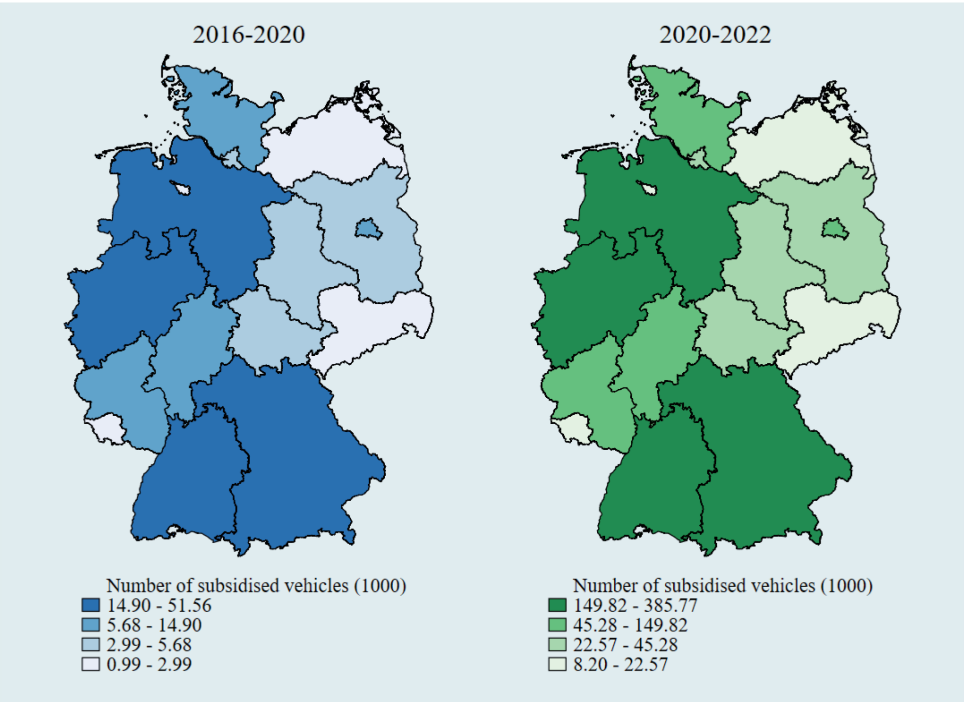

Figure 1. Geographical distribution of subsidised vehicles. Source: authors' depiction, BAFA.

federal states remains relatively similar between the first and second funding periods. The regional differences between the old and new federal states are particularly striking. The number of subsidised vehicles can also be viewed in relation to the number of inhabitants of the individual federal states, as shown in Figure 2. The federal states coloured brown are below the median, while those shaded green are above the median (the intensity of the shading indicates the distance from the median). The relatively low values for the city states of Berlin, Hamburg and Bremen could be due to their relatively high population density compared to their surrounding areas. In general, the gap between the new and old federal states is clearly visible. It is possible that the differences found here between the old and new federal states are due to fundamental structural differences, including in population density, the economy and the demographics of the federal states. The differences between the funding periods appear to be marginal, with the exception of Schleswig-Holstein and Saarland, which received a higher proportion of subsidised vehicles in relation to their population in the first and second funding periods respectively.

The distribution of funding must be viewed in the context of the gross domestic product (GDP) of the federal states to which the funding actually flows, which is shown in Figure 3. It should be noted that the federal states coloured in brown are below the median and those shaded in green are above the median (the intensity of the shading indicates the distance to the median). The relatively low values for the city states of Berlin, Hamburg and Bremen could be due to the relatively high GDP of these regions and the higher degree of urbanisation compared to their surrounding areas, which could have an impact on vehicle ownership rates. To a limited extent, this could also apply to the Saarland. In general, the gap between the new and old federal states is clearly visible, with one exception for Thuringia in the first funding period. It is possible that the differences found here between the old and new federal states are due to fundamental structural differences in the economies of the federal states. The differences between the funding periods appear to be marginal, with the exception of Thuringia and Saarland, which received a higher proportion of funding in relation to their GDP in the first and second funding periods respectively.

The distribution of the number of approvals between private individuals and companies/organisations is shown in Table 4, showing the development by funding period and over the years. While companies/organisations accounted for 62 % of approvals in the first funding period, this figure falls to 55 % in the second funding period, with the proportion of private individuals receiving funding increasing accordingly.

INCOME GROUPS OF BUYERS

Table 5 below describes the income structure among applicants to the funding programme by funding period. Income is measured by the net monthly income of the household as reported by the respondents (private individuals and users in companies). Overall, it can be seen that the distribution of applicants across income groups shows a clear imbalance in favour of income groups with a higher monthly net income. In view of the fact that the average monthly net household income in 2021 was €3,813 nationwide, it can be seen that most households that received funding had an above-average monthly net income. Around 60 % of applicants had a monthly net household income of more than €4,500 and around 30 % even more than €6,000. This indicates that the subsidy programme has a redistributive effect in favour of households with higher incomes.

The trends over time and the subsidy period remain relatively stable. It is also striking that the €2,600–€3,200 income group has had a slightly higher proportion of applications since

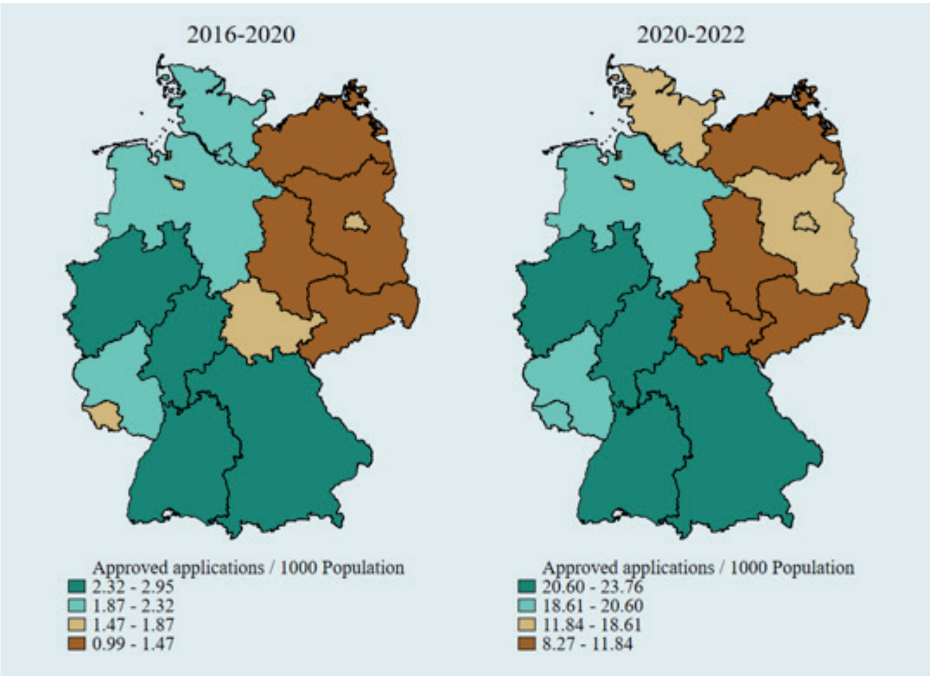

Figure 2. Geographical distribution of subsidised vehicles per 1,000 population. Source: Authors' depiction/Destatis.

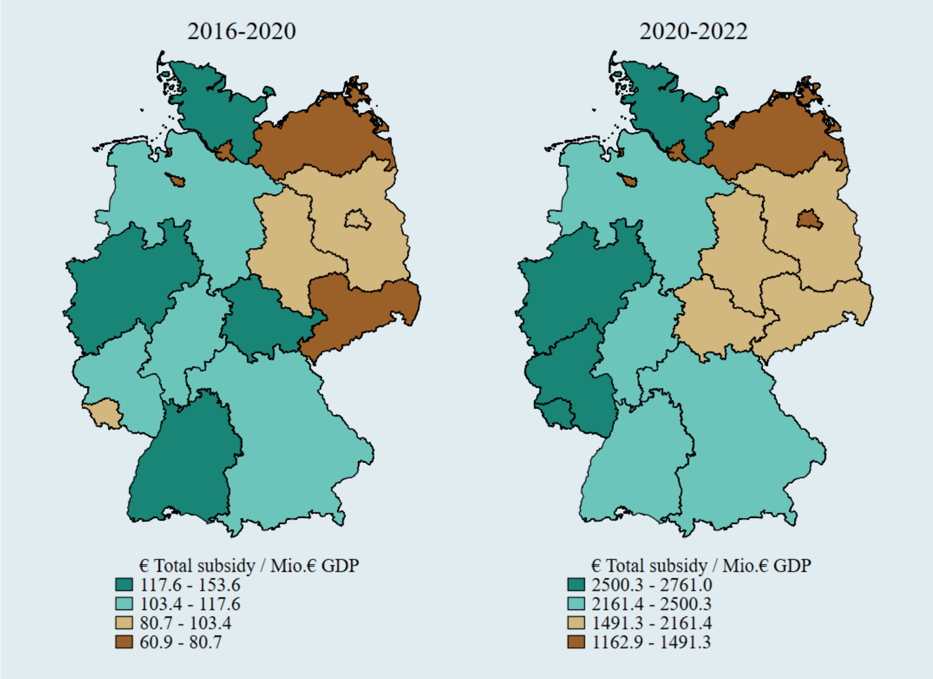

Figure 3. Geographical distribution of subsidy per unit GDP. Source: Authors' depiction/Destatis.

Table 4. Distribution of approved subsidies between private individuals and companies/organisations.

Distribution of approved subsidies between private individuals and companies/organisations [percent]	2016–2020	2020–2022
Private individuals	38 %	45 %
Companies/organisations	62 %	55 %
Total	100 %	100 %

Source: BAFA. Authors' presentation.

Table 5. Income structure of applicants.

Income structure of applicants [Proportion of applicants with a monthly net household income of, (per cent)]	2016–2020	2020–2022
Below €900	0 %	0 %
€900–€1,300	1 %	1 %
€1,300–€1,500	1 %	1 %
€1,500–€2,000	3 %	3 %
€2,000–€2,600	6 %	6 %
€2,600–€3,200	8 %	9 %
€3,200–€4,500	22 %	21 %
€4,500–€6,000	25 %	30 %
€6,000–€8,000	17 %	15 %
Above €8,000	18 %	14 %
Total	100 %	100 %

Source: Authors' representative survey of the applicants. Authors' presentation.

2019 than in previous years. Similar trends cannot be reliably observed for the other income groups.

FREE RIDER AND PULL-FORWARD EFFECTS

The free-rider effect is shown separately for private individuals, for users in organisations and for fleets, as it can be assumed that the processes leading to the purchase decisions are different in these different user groups. The effects for fleets are calculated slightly differently, but in such a way that the figures are equivalent and comparable with the other groups. The answers of the different user types to this question in the survey were weighted equally so as not to distort the effect calculations disproportionately towards those user types (especially fleet managers) who may have purchased several subsidised vehicles.

The values of the free-ride and pull-forward effects over the subsidy periods are shown for the three user categories in Table 6.

In general, the free-rider effect is thus somewhat lower than in the literature that has examined similar funding programmes in other countries, particularly in the USA (Johnson *et al.*, 2017). However, the study from the USA is from 2017, and therefore the values shown in the table for the free-rider effect for the first funding period are close to the values observed in the USA in 2017 (around 50 % free-rider effect). The free-rider effect has decreased significantly in the second funding period compared to the first funding period and shows a generally decreasing trend over the years. This could be due to the early adopter effect, which was predominant in the first funding period and generally decreases as E-Mobility matures.

REBOUND AND SPILLOVER EFFECTS

Table 7 shows the rebound effect over the funding periods, and shows a slight increase from 2.2 % between 2016–2020 to 2.8 % between 2020–2022. Whereas some studies in the literature find higher rebound effects in the transport sector (between 10 % and 20 %) (Murray, 2013), the direct rebound effects measured here generally correspond to what is seen in the literature on rebound effects specifically dealing with the introduction of electric vehicles in Germany and other European countries (2 % to 4 %) (Whitehead, Franklin and Washington, 2015; Huwe and Gessner, 2020).

The spillover effects were calculated on the basis of the respondents' answers to various questions about their behaviour and actions, as shown in Table 8. The answers were given on a Likert scale of 1–5, where 1 stands for "Does not apply to me at all" and 5 for "Fully applies to me". The mean values of the answers to the individual questions are listed in the table, as is the deviation from the mean value (2.5). The deviation indicates the spillover effect. The statements listed at the bottom of the table are preceded by the sentence "Compared to the period before the purchase of the electric vehicle:"

The within-domain spillovers of the support programme are generally positive. On average, the spillover to other people in relation to E-Mobility in general is significantly higher than the spillover in relation to the EV subsidy in particular. Between the funding periods, the positive spillover is higher in the first funding period than in the second. This can possibly be explained by the fact that E-Mobility occupies a relatively niche position on the market in the first funding period and the enthusiasm of applicants for E-Mobility is higher in the first funding period than in the second.

As far as cross-domain spillovers are concerned, the effects are also generally positive, with the strongest positive spillover being the spillover on energy-saving everyday habits. The effect is somewhat less positive for the other aspects of the cross-domain spillover. The numerical value of the spillover is negative for only one aspect (abolition of appliances). However, this does not mean that it is a negative spillover, as the mere absence of the abolition of appliances does not necessarily directly imply environmentally harmful behaviour.

Conclusion and policy recommendations

This article analyses the EV subsidy programme in Germany that was introduced in 2016 and focuses specifically on the free rider, rebound, and spillover effects of the programme, as well as the distributional impacts. The free-rider and pull-forward effects calculated on the basis of the survey of programme partici-

Table 6. Extent of free-rider and pull-forward effects.

Extent of free-rider and pull-forward effects (pull-forward effect corresponds to a delayed free-rider effect) [per cent]	2016–2020	2020–2022
Private individuals	51,5 %	33,8 %
Users in companies/organisations	40,8 %	27,0 %
Fleet managers	38,1 %	36,1 %

Source: Authors' representative survey of the applicants. Authors' presentation.

Table 7. Extent of rebound effects.

Extent of direct rebound effects	2016–2020	2020–2022
Average additional kilometres driven due to rebound [km/vehicle/year]	519	388
As a share of average annual mileage [per cent]	2,2 %	2,8 %

Source: Authors' representative survey of the applicants. Authors' presentation.

Table 8. Extent of spillover effects.

Compared to the period before the purchase of the electrically powered vehicle:	Funding period	Mean	Deviation from mean	Does not apply to me at all (1)	Moderately does not apply to me (2)	Neutral (3)	Moderately applies to me (4)	Fully applies to me (5)
Within-domain spillover								
I have convinced other people in my environment to switch to E-mobility	*1*	3.35	**0.85**	13 %	6 %	14 %	31 %	28 %
	2	3.08	**0.58**	17 %	10 %	17 %	28 %	22 %
have successfully convinced other people in my environment to use the EV subsidy	*1*	2.58	**0.08**	28 %	9 %	19 %	17 %	18 %
	2	2.53	**0.03**	28 %	10 %	20 %	18 %	15 %
Cross-domain spillover								
I got rid of appliances to save energy	*1*	2.29	**-0.21**	34 %	13 %	22 %	12 %	12 %
	2	2.37	**-0.13**	74 %	28 %	48 %	27 %	27 %
I have made further investments to save energy	*1*	3.04	**0.54**	24 %	6 %	15 %	21 %	28 %
	2	3.05	**0.55**	23 %	6 %	17 %	21 %	27 %
I make a greater effort to save energy in everyday life	*1*	3.51	**1.01**	13 %	5 %	13 %	32 %	32 %
	2	3.57	**1.07**	12 %	6 %	11 %	32 %	34 %
I pay more attention to using self-generated electricity	*1*	2.98	**0.48**	21 %	2 %	9 %	11 %	40 %
	2	2.90	**0.40**	23 %	4 %	10 %	11 %	37 %
I am endeavouring to reduce my water consumption	*1*	2.99	**0.49**	22 %	5 %	22 %	26 %	20 %
	2	3.08	**0.58**	19 %	8 %	22 %	26 %	21 %

Source: Authors' representative survey of the applicants. Authors' presentation.

pants were on average within the expected range across all user groups and rather below the values known from the literature for comparable programmes. At 46 % in the first period and 33 % in the second period, there was a clear downward trend between the two funding periods. The rebound effect was calculated using the additional kilometres driven due to the purchase of the EV, which was also determined from the survey. At 2–3 %, the rebound effect calculated in this evaluation is at the lower end of what is seen in the literature for similar programmes and is significantly lower than is assumed in some studies for the entire transport sector. It can be seen that there are considerable regional differences between the old and new federal states in the utilisation of the subsidy. In addition, the subsidy programme was used disproportionately by private households with higher net incomes, which suggests an undesirable distributional effect.

These findings feed into the broader ongoing policy debates on the design of EV subsidy programmes. The principal policy recommendation concerns the distributional aspects of the subsidy, in order to reduce the regressive nature of the subsidy distribution to favour low-income and middle-income households. Better targeting of the subsidy based on household income characteristics would be necessary to ensure fairer distribution, since (perceived) unfair distribution of public spending might negatively affect the acceptability of such programmes. A more precise targeting of the subsidy might also serve to reduce the free rider effects associated with EV adoption. In addition, complementing an EV subsidy programme with a corresponding disincentive to buying conventional (fossil-fuel driven) cars might be advantageous in many aspects, notably in terms of incentivising buyers from lower income groups to switch, hence reducing disparity in the uptake of the subsidy, as well as being more neutral in terms of state finances.

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