# Carbon Pricing and Household Finance: How Banks Price Transition Risk in Auto Loans*

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**Abstract**

We study the impact of carbon pricing on household finance using European microdata on loans for internal combustion engine vehicles. Exploiting cross-country variation in the same car models with a difference-in-differences design, we find that banks respond to Germany's carbon price announcement by raising interest rates by 0.5 percentage points, with larger increases for loans on fuel-intensive vehicles and for longer maturities. Banks also shorten loan maturity, reduce amounts, and shift to linear repayments, while households choose more fuel-efficient new cars. Captive banks respond more strongly than commercial banks. Collateral and default risk channels jointly explain these adjustments, highlighting household finance as a key transmission channel of climate policy.

**JEL codes:** G21, G50, G51, Q57

**Keywords:** Credit pricing, climate policies, climate transition risk, DiD

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# 1 Introduction

Economists broadly agree that carbon pricing is the most efficient way to reduce $CO_2$ emissions[1] and governments worldwide have implemented around 80 carbon pricing schemes covering 28% of global emissions (World-Bank, 2025). By increasing the relative cost of fossil fuels, carbon pricing raises the lifetime cost of carbon-intensive assets, potentially devaluating or even stranding assets under stringent policy scenarios (Dulong et al., 2023). Prior research has primarily examined the implications of firms climate transition risk in financial markets (Bolton and Kacperczyk, 2023; Pástor et al., 2022) and how corporate lending transmits climate policy shocks (Duan et al., 2023; Mueller and Sfrappini, 2025). However, households also hold carbon-intensive durables—vehicles and real estate—largely financed by banks. Although the economic intuition holds for any asset holders, the exposure of consumers and retail lenders to climate transition risks remain largely unexplored despite potentially significant implications for household finance and the low carbon transition.

In this paper, we examine whether and how banks adjust household financing conditions in response to increased climate transition risks caused by the introduction of a major carbon pricing scheme in Germany. We focus on loans for cars with internal combustion engines (ICE). Car purchases are central to household finance because, first, they represent one of the largest consumer expenditures (Gössling et al., 2022) and, second, a substantial share of cars is financed by banks in both the United States and Europe. In Germany, for instance, this applies to roughly 40% of all cars (Ipsos, 2023). We show how the announcement of a salient, steadily increasing carbon price—raising gasoline and diesel prices in Europe's largest car market by up to 18 cents per liter until 2026[2]—affects bank financing conditions. Thus, our paper provides novel evidence that household finance and consumer credit are important transmitters of climate policies that amplify the transition away from fossil fuels, extending prior research on transmission via stock markets and corporate lending.

Our core empirical challenge is to disentangle the effect of carbon pricing from other factors that influence the lending behavior of banks financing cars. We therefore begin with a conceptual model to clarify the mechanisms and derive clear predictions for

[1] https://www.econstatement.org/

[2] The national carbon price for road transport was announced in September 2019 and was implemented in January 2021. It imposes a carbon price of 25€/t $CO_2$ on transportation fuels starting in 2021. The price steadily increases to 55 to 65 €/t $CO_2$ in 2026. The latter corresponds to about 18 cents per liter.

our empirical analysis. As the carbon price increases fuel expenses for borrowers and shift their demand toward more fuel-efficient vehicles—two well-established first-order effects in the literature (Busse et al., 2013; Beresteanu and Li, 2011; Jacobsen and Van Benthem, 2015; Li et al., 2009)—the model predicts higher interest rates on ICE car loans through two channels: an increase in the probability of default due to higher operating costs and an increase in the loss-given-default due to lower resale values for used cars. In addition, we predict that this increase is larger for longer-maturity loans and for more fuel-intensive cars.

We proceed in our empirics exploiting microdata on 3.2 million loans and leases for both new and used ICE cars in Europe from October 2018 through June 2020, which are based on reporting requirements of the European Central Bank for issuers of auto loan asset-backed securities.[3] The data allows us to observe granular financing characteristic — such as interest rates, car values, and borrowers' incomes — for 175 carmaker-model combinations (e.g. BMW 3, 5, 7 series), which become subject to carbon pricing exclusively in Germany, while the very same models remain unaffected in other countries. Our difference-in-differences (DiD) analysis then compares the financing conditions in Germany across the same car models in other European countries before and after the announcement of the policy.

Our primary result is that the announcement of the carbon price leads banks to raise interest rates on loans for ICE vehicles in a quantitatively meaningful way. Following the 2019 policy announcement, interest rates for loans on treated German car models increased persistently by about 0.5 percentage points relative to loans for the same models in other European countries. This effect is driven by loans for fuel-intensive vehicles. Moreover, longer-term loans maturing after the 2021 carbon price implementation primarily drive the policy-induced interest rate premium, which is consistent with our theoretical prediction. A triple DiD specification, which leverages our theoretical prediction—validated in the data—that the carbon price has negligible effects on the most fuel-efficient cars, alleviates remaining concerns about time-varying confounders differentially affecting treatment and control groups and reinforces our main finding.

We have three additional results. First, we document broader policy effects on both lenders and borrowers. On the lender side, banks shorten loan maturities so that contracts expire before carbon prices reach higher levels, they provide smaller loan amounts, and show greater reluctance to finance large ICE vehicle purchases. They

[3] Given that three quarters of the observations in our sample are loans, we henceforth refer to all contracts as loans for brevity.

also shift toward contracts with linear repayment structures with regular monthly principal payments. These adjustments indicate that banks seek to limit their exposure to the rising carbon price schedule. On the borrower side, households respond to the policy announcement by choosing more fuel-efficient trims of the same car model when purchasing new vehicles.

Second, we document significant lender heterogeneity by distinguishing between captive and commercial banks. Manufacturer-owned captive banks, which account for 75% of loans in our data, are a distinctive feature of the automotive finance industry. Our triple DiD estimates indicate that they raise interest rates by an additional 0.44 percentage points relative to commercial banks. We find further notable differences between bank types when examining pricing of loans to investors in the securitized auto loan market: captive banks increase discounts to investors after the policy announcement. This pattern suggests that manufacturer-owned banks attempt to reduce the ICE loan exposures in their balance sheets to increase liquidity, but face difficulties offloading them to investors.

Third, consistent with our theoretical predictions, we present evidence that both the loss-given-default and the probability-of-default channels explain the policy-induced changes in financing terms. Firstly, using the value of used ICE cars as a proxy for collateral values, we show that the announcement of the carbon pricing scheme lead to a decline in reported used car prices at loan origination. This negative treatment effect is more pronounced for fuel-intensive cars. While this is only an indirect test, these findings are consistent with a shrinking collateral value that banks incorporate into loan pricing. Secondly, to test the probability-of-default (PD) channel,[4] we separately analyze high loan-to-value (LTV) and low LTV loans. We find a significantly stronger treatment effect for high-LTV loans, indicating that banks increase interest rates more for borrowers with higher repayment risk, consistent with the PD channel. Further empirical support comes from the larger interest rate increase for rural households, who rely more heavily on their vehicles, drive longer distances, and are therefore more exposed to rising fuel costs, translating into a higher default probability.

We contribute to three strands of the literature. First, our paper relates to the literature on the pricing of climate transition risks in financial markets. Prior research primarily focuses on the markets for equity (Bolton and Kacperczyk, 2023; Pástor et al., 2022), corporate bonds (Duan et al., 2023; Zerbib, 2019) and options (Ilhan et al., 2020)

[4] The average PD for individual car loan borrowers in Germany is roughly 3.3% (Fenner and Vollmar, 2023).

to estimate the market-based premia associated with transition risk. The evidence is mixed, with studies documenting either a brown premium or a green premium—variation that may partly reflect differences in how transition risk is measured through broad proxies such as total corporate emissions or ESG scores (Fliegel, 2025). Our study extends the literature to *household finance*. We provide first evidence that banks price transition risk when financing a major consumer durable—ICE vehicles. Moreover, we isolate the pricing of *policy-induced* transition risk arising from a specific climate policy shock, whereas prior studies typically capture a composite of transition risks stemming from policy, technological innovation, and evolving market preferences. In this respect, our study also relates to a small literature quantifying stranded-asset risk from climate policy, which documents significant stock market valuation effects for fossil fuel firms following climate target announcements, such as a coal phase-out (Sen and Von Schickfus, 2020) and the Paris Agreement pledges (Ramiah et al., 2013; Linn, 2010; Lemoine, 2017). By contrast, we focus on a specific and widely adopted policy instrument—carbon pricing. The carbon price's tangible financial effects allow us to measure policy exposure directly, avoiding the broad transition risk proxies common in prior literature.

Second, we contribute to a growing literature on financial intermediation as a channel to amplify climate policy effects and the climate transition. Most existing work focuses on corporate lending. For instance, Reghezza et al., 2022 show that European banks began to divest credit away from emission intensive firms after the 2015 Paris agreement, while Mueller and Sfrappini, 2025 find that banks diversified their loan portfolios toward firms benefiting from the transition, even as they continued supporting incumbents. Evidence on the role of banks financing consumer durables remains scarce. Hankins et al., 2025 study the impact of metal tariffs on car manufacturers and find that captive bank subsidiaries of affected manufacturers increase interest rates as a result of the tariff shock. Two recent studies, Bena et al., 2023 and Klee et al., 2024, study how banks price "green" vehicles. They find opposite results regarding risk perceptions and pricing: Bena et al., 2023 show higher interest rates for loans for hybrid vehicles, while Klee et al., 2024 suggest that electric vehicle loans enjoy a lower interest rate. We differ from these papers by focusing on the vast majority of loans for conventional vehicles with combustion engine, going beyond the scope on the niche segments of hybrid and electric cars.[5] Moreover, rather than studying bank's response to new, green technologies, we

[5] In the EU in 2023, only 3.2% of the passenger vehicle stock consists of hybrid and 3.9% of battery electric vehicles (ACEA, 2025).

identify changes in lending behavior induced by an actual climate policy.[6] Exploiting quasi-experimental policy variation, our study is an important step forward in credibly estimating the role of banks in transmitting climate policy shocks.

Finally, we add to the economics literature on the effects of carbon pricing. A large body of empirical evidence documents substantial direct impacts on emissions and technological innovation. For instance, Andersson, 2019 find that Sweden's $CO_2$ tax reduced transport emissions by roughly 11%, while Colmer et al., 2024, Dechezleprêtre et al., 2023 and Leroutier, 2022 show similar emission reductions in the power and industry sector, and Calel and Dechezleprêtre, 2016; Calel, 2020 present evidence for policy-induced green innovations of firms. Our contribution lies in highlighting indirect effects of carbon pricing through financial markets. Our findings that the policy led to declines in vehicle values and higher borrowing costs for households have important distributional implications that have received little attention so far. Since access to auto loans is critical for vehicle purchases, such policy-induced financing frictions may hinder both public support for ambitious carbon pricing policies (Dechezleprêtre et al., 2025).

## 2 Institutional background

In the 2015 Paris Agreement, the European Union (EU) legally committed itself to reduce greenhouse gas emissions by 40% relative to 2005 levels by 2030. The EU allocated this reduction target among Member States under the Effort Sharing Regulation (ESR), which requires richer countries to achieve larger emission cuts than poorer ones. Under the ESR, Germany must reduce emissions in the transport, heating, and agricultural sectors by 50% compared to 2005 levels by 2030 (Commission, 2023). Failure to comply may trigger infringement proceedings with substantial financial implications, potentially amounting to as much as 60 billion €by 2030 (Deutsch et al., 2018).

As a direct consequence of the ambitious reduction obligation under the ESR, Germany faced mounting pressure in 2019 to implement concrete climate policy measures. In response, the federal government established a "climate cabinet" that same year, with the Chancellor coordinating relevant ministries engaged in intensive discussions of policy options. In the early morning of September 20, 2019, after an overnight session, the governing coalition adopted the Federal Government's "Climate Action Program 2030".

[6] See also Billio et al., 2022 for evidence how banks price green technology in housing, Latino et al., 2025 for an analysis of mutual funds investments into Auto ABS, and Kontz, 2025 for for evidence how ABS investors in the auto loan market price ESG performance.

This represented a paradigm shift: despite considerable opposition, carbon pricing was introduced as the central instrument of German climate policy, designed to ensure compliance with the EU-mandated annual emission reduction targets (Edenhofer et al., 2020).

The carbon pricing system entered into force on January 1, 2021, through a national emissions trading scheme for the heating and transport sectors. Every distributor supplying gasoline, diesel, heating oil, natural gas, or liquefied gas must purchase emission certificates that match the $CO_2$ content of the fuel they sell. Certificate prices are set at fixed levels of 25, 30, 35, 45, and 55 €/t $\text{CO}_2$ from 2021 to 2025. From 2026 onward, prices are determined within a price corridor initially set between 55 and 65 euros per ton under free trading conditions, with the system set to integrate into a new European emissions trading system starting in 2027. Distributors pass the carbon price on to consumers, creating a tangible carbon cost for households using ICE vehicles and fossil-fuel heating systems. A carbon price of 65 €/t $\text{CO}_2$ increases gasoline and diesel prices by about 18 cents per liter (UBA, 2024).

# 3 Conceptual framework and predictions

The announcement of the German carbon price provided firms, households, and financial intermediaries with a clear and steadily increasing carbon price trajectory. There is clear evidence that firms supplying fuels almost fully pass carbon prices on to consumers (Dovern et al., 2023; Montag et al., 2023), and that consumers facing higher fuel prices can only reduce driving to a limited extent (Anderson and Sallee, 2016)[7] and instead buy more fuel efficient vehicles and sell their older cars (Busse et al., 2013; Beresteanu and Li, 2011; Jacobsen and Van Benthem, 2015; Li et al., 2009). However, our understanding remains limited regarding how banks respond when consumer loans become directly subject to a carbon price. To address this, we present a simple conceptual framework that illustrates the mechanism and generates empirically testable predictions.

**Decision problem of the bank** We assume that banks provide loans with maturity $T$ priced at the interest rate $r$ according to the following simple rationale[8]

[7] Studies suggest a fuel price elasticity of distance traveled between -0.10 and -0.30.

[8] For a related simple PD-LGD framework see Barbiero et al., 2024, who study the interdependency between borrower and collateral risk.

$$r = f(EL(T, PD, LGD)) \tag{1}$$

The function $f$ is positive and increasing in the expected loss $EL(T, PD, LGD)$, $f(0) > 0$, $\frac{\mathrm{d}f}{\mathrm{d}EL} > 0$.

The expected loss over the whole life of a loan with maturity $T$ is determined by the probability of default $PD$ and the loss-given-default $LGD$ as follows

$$EL(T, PD, LGD) = \sum_{t=1}^{T} S(t-1) \cdot PD \cdot LGD, \tag{2}$$

with $S(t)$ denoting the probability of survival until time $t$. Assuming for simplicity that both loss-given-default and probability of default are constant during the life of the loan, we can write the probability of survival

$$S(t) = (1 - PD)^t. \tag{3}$$

$PD$ is a function of the borrower's auto loan payment-to-income ratio $PTI$ and other credit risk factors $CR$ that include loan-to-value ratio, income, and credit scores,

$$PD = g(PTI, CR). \tag{4}$$

$g$ is increasing in $PTI$ and in $CR$, $\frac{\partial g}{\partial PTI} > 0$, $\frac{\partial g}{\partial CR} > 0$, and $\frac{\partial^2 g}{\partial PTI \partial CR} > 0$, i.e. an increase in the payment-to-income ratio increases the probability of default more if the other credit risk factors are higher, e.g. if the borrower has a higher loan-to-value ratio. In line with Klee et al., 2024 we assume that the $PTI$ is a measure of cost of ownership that includes loan payments $LP$, fuel expenditures $FE$ and other costs $OC$, that include insurance, maintenance, and depreciation

$$PTI = \frac{LP + FE + OC}{Income}. \tag{5}$$

The expected loss-given-default at the time of origination is simply given by

$$LGD = \frac{\textit{Loan Amount-CV*RR}}{\textit{Loan Amount}}, \tag{6}$$

with the collateral value being the car value $CV$ multiplied by the recovery rate $RR$, which is an increasing function of the price for used cars $p_u$,

$$RR = h(p_u), \tag{7}$$

with $\frac{\mathrm{d}h}{dp_u} > 0$.

With this framework, we can assess the effect of the introduction of a carbon price for the interest rate.

**The policy impact** The carbon price has two important effects, that drive changes in the interest rate. First, the carbon price increases fuel expenses for the borrowers, and second, higher fuel costs lead to an increase in supply and decrease in demand on the market for used cars (Jacobsen and Van Benthem, 2015; Li et al., 2009), resulting in lower prices for used cars $p_u$.

Increasing fuel expenses lead to an increase in $PTI$ for the borrower as

$$\frac{\partial PTI}{\partial FE} = \frac{1}{\text{Income}} > 0. \tag{8}$$

and as $g$ is increasing in $PTI$, ceteris paribus, this also leads to a higher $PD$

$$\frac{\partial g}{\partial FE} = \frac{\partial g}{\partial PTI}\frac{1}{\text{Income}} > 0. \tag{9}$$

We expect this channel to have a relevant effect as German households spend on average 12.3% of monthly income on transportation (Statistisches Bundesamt, 2024). Moreover, transportation expenses are relatively inelastic (Bertrand and Morse, 2016).[9]
Lower prices on the market for used cars decrease the recovery rate for the car as $\frac{\mathrm{d}h}{dp_u} > 0$, which affects loss-given-default as follows

$$\frac{\partial LGD}{\partial RR} = -\frac{CV}{\text{Loan Amount}} < 0. \tag{10}$$

Thus, the introduction of carbon prices also increases the loss-given-default.
The increases in $PD$ and $LGD$ that are induced by the carbon price in turn lead to an increase in the interest rate:

[9] Klee et al., 2024 also find that higher gas prices lead to higher monthly default rates, using data from U.S. auto loans.

$$\frac{\partial EL}{\partial PD} = LGD \cdot T(1 - PD)^{T-1}, \quad (11)$$

$$\frac{\partial EL}{\partial LGD} = 1 - (1 - PD)^T, \quad (12)$$

and

$$\frac{\partial^2 EL}{\partial PD \partial LGD} = T(1 - PD)^{T-1}. \quad (13)$$

Given these two impact channels of a carbon price on the interest rate $r$ for ICE loans, we summarize

**Prediction 1.** *For ICE cars, the introduction of a carbon price leads to an increase in the interest rate for loans through both a PD and a LGD channel.*

As the interest rate increase through both the $PD$ and the $LGD$ channel is caused by rising fuel expenditures for car owners, which increase with the fuel-intensity of cars, we further predict

**Prediction 2.** *The positive effect of the introduction of a carbon price on the interest rate for ICE cars is increasing in the fuel intensity of cars.*

In turn, for very efficient cars, we expect a very small effect.

Considering the increase of $PD$ and $LGD$ across loans of different maturities, we derive the following prediction in Appendix 8.1:

**Prediction 3.** *Loans with longer maturities experience a stronger interest rate increase due to the introduction of a carbon price than loans with shorter maturities.*

Intuitively, the maturity effect comes from the timing of the increase in default risk. In the baseline with constant $PD$ and $LGD$, the break-even rate is independent of maturity, so the term structure is flat. The announcement of a carbon price raises $LGD$ for all future periods (via lower expected resale values), which shifts required rates up, but does not by itself generate a maturity differential, as all horizons are affected proportionally. The implementation of the carbon price, however, increases $PD$ only in post-implementation periods, reflecting higher running costs. Short-maturity loans that are repaid before implementation are unaffected by this additional default risk, whereas longer-maturity loans have a larger share of their cash flows exposed to the higher-$PD$ regime. As banks charge a constant rate over the life of the loan, this raises the average required compensation for longer loans more than for shorter loans. Any additional increase in $LGD$ at implementation ($\delta_i \geq 0$) reinforces this effect but is not necessary for it.

Finally, due to the stronger effect of the $PD$ channel for loans with higher loan-to-value ratio, $\frac{\partial^2 g}{\partial PTI \partial CR} > 0$, we predict that

**Prediction 4.** *The positive effect of the introduction of a carbon price on the interest rate is increasing in the loan-to-value ratio of credits.*

# 4 Data

We first describe the data sets used in our analysis before explaining how we combine them. Finally, we provide descriptive statistics.

**Car loan data** Our paper builds on data for securitized car loans and leases from European Data Warehouse (EDW), created under EU Regulation 2017/2402 in response to the 2008 financial crisis to enhance standardization and transparency in securitization markets. This regulation requires financial institutions that securitize assets to disclose comprehensive information at the level of the individual asset. The European Central Bank (ECB) supervises the disclosure while EDW collects and assembles the information on securitized assets on the ECB's behalf, including information on securitized car loans and leases.

We use EDW data for the period from October 2018 to June 2020 for the following countries: Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Poland, Portugal, Spain, and the United Kingdom (UK). The data gives a rich set of information on the loan details, including interest rates, loan amount and maturity, amortization type, credit type, borrower income, as well as borrower residency at the country and NUTS-3 level. For the financed cars, we observe the manufacturer, the car model, the year of registration, whether it is a new or used vehicle, and the car values at loan origination. We use monthly exchange rates by the European Central Bank to convert national currencies from the United Kingdom and Poland.

While not all banks securitize, those that do must securitize a representative sample of their car loan stock (Latino et al., 2024). A potential concern is that the data on securitized loans is biased and not representative of the banks actual balance sheet. However, Ertan et al., 2017 show that the credit quality in terms of defaults is actually higher for securitized loans compared to other loans.

**Car attribute data** The German Department for Motor Vehicles (KBA) holds comprehensive data sets on approximately 10,000 car models. In addition to the manufacturer and the car model, information is available on technical characteristics such as weight in kg and fuel efficiency in liters. Because $CO_2$ emissions from driving, and therefore the costs induced by carbon pricing, are a direct function of vehicle fuel efficiency, this additional information allows us to granularly quantity each car's exposure to the policy.

**Data set construction** We construct our final data set by merging EDW and KBA data. We limit our observations to the matched sample. We only retain private household observations and discard all loans that lack critical informations such as the country of origin. We apply standard data validation steps to account for potential reporting inaccuracies and remove some observations with implausible loan characteristics, such as negative loan amounts, maturities before origination, or non-positive interest rates.

We also limit our sample to cars with internal combustion engines, including hybrid vehicles that improve fuel efficiency through engine-driven charging and regenerative braking. Moreover, we only retain car models that we observe in Germany and at least one control country in every month of our sample to limit potential compositional changes in the car models between treated and control countries.

We additionally hand-label and align manufacturer definitions in the dataset and use ChatGPT-o1 to assist in aligning model categories per manufacturer and powertrain (EV, ICE, Hybrid). This procedure yields 175 unique car maker-model combinations. Finally, we winsorize our data at the 1% level.[10]

Our final dataset comprises 3.2m car loans across 11 European countries. About 1.8m loans originate in Germany, followed by Spain with 0.38m and the UK with 0.35m.[11] We also create a binary indicator separating loans issued by captive banks from those issued by commercial banks. Captive banks account for about 75% of all contracts.[12] We also relabel credit types into loans and leases and repayment structures into linear and balloon type credits. Roughly 75% of observations are loans and roughly 60% are

[10] In table 10 of the Appendix, we show that our results are virtually unchanged when retaining the full dataset without any drops.

[11] table 17 in the Appendix summarizes loan observations per country.

[12] table 18 in the Appendix summarizes loan observations per bank.

linear type credits.

**Descriptive statistics** Table 1 provides descriptive statistics. The average interest rate is roughly 5% for a 15,000€loan with an average maturity of 4 years for a car value of about 25,000€. Roughly 50% of all loans are for new cars. Note that coverage is more limited for some of our potential control variables, in particular income.

**Table 1:** Summary statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Interest rate | 3209548 | 4.94 | 2.40 | 0.06 | 11.50 |
| Car weight | 3209987 | 1931.25 | 376.88 | 1240.00 | 3300.00 |
| Fuel consumption | 3206605 | 5.82 | 0.92 | 3.94 | 8.61 |
| Car value | 2542899 | 23953.78 | 13615.91 | 5500.00 | 76600.00 |
| New car | 3204183 | 0.54 | 0.50 | 0.00 | 1.00 |
| Car registration year | 2440223 | 2017.84 | 2.11 | 1970.00 | 2021.00 |
| Bank type | 3209987 | 0.76 | 0.43 | 0.00 | 1.00 |
| Loan amount | 3209987 | 14967.77 | 8710.02 | 1950.06 | 45635.81 |
| Loan maturity | 3203378 | 50.94 | 17.64 | 1.00 | 144.00 |
| Annual gross income | 2191740 | 29733.68 | 23744.98 | 0.00 | 163000.00 |
| Loan to Value ratio | 3206396 | 81.87 | 24.52 | 0.84 | 125.00 |
| Linear credit | 3209987 | 0.60 | 0.49 | 0.00 | 1.00 |
| Balloon credit | 3209987 | 0.36 | 0.48 | 0.00 | 1.00 |

# 5 Empirical Strategy

To identify the causal effect of climate policy on car loans, we exploit the announcement of the German national carbon price on the 20th of September 2019 and its implementation in January 2021. Our focus is on loans for vehicles with internal combustion engines (ICE). We use differences-in-differences (DiD) to compare car loans in Germany pre and post of the policy shock to a control group of loans from 10 other European countries. In particular, our DiD setup exploits within-variation before and after treatment across 175 similar car models [13] across treatment and control countries.[14] This is possible as most car models in our sample exist in both the treatment and control countries.

While we prefer to use the announcement of the policy as the treatment—signaling to

[13] A full list of all car models by manufacturer is provided in Table 19 in the Appendix

[14] Note that we have repeated cross-sectional data for loans and cannot follow an individual loan across time.

consumers and banks a clear commitment of the German government to achieve its ambitious climate policy target with a salient and ever more stringent carbon price (see Section 2)—we also run models for the implementation. This choice is also motivated by data from Google Trends, for which we observe a notable spike in the number of times the word ‘emission trading‘ was used in the Google search engine for Germany in September of 2019 (Figure 5 in the Appendix). By restricting the sample period to ten months before and after the announcement in Germany, we ensure that control group countries are not themselves exposed to carbon price treatments.[15] The absence of spikes in Google searches in the other European countries confirms that the policy announcement in Germany constitutes a single shock for the chosen time period (Figure 6 in the Appendix).

Our baseline specification is:

$$Y_{ictb} = \tau \cdot \text{Germany} \cdot \text{Post} + \mu_i + \mu_c + \mu_b + \mu_t + \varepsilon_{ictb} \ , \tag{14}$$

where $Y_{ictb}$ is the loan outcome of interest for maker-model $i$ in country $c$ during month-year $t$ financed by bank $b$. Binary variable *Germany* is 1 for car loans from Germany. Binary indicator *Post* is 1 for the period after the announcement (or implementation) of the carbon price in Germany. The coefficient $\tau$ captures the treatment effect. Car maker-model fixed effects $\mu_i$ control for time-invariant characteristics specific to each car model, country fixed effects $\mu_c$ account for unobserved heterogeneity across countries, and bank-type fixed effects $\mu_b$ absorb different lending rationales among banks, either between manufacturer-owned captive banks and commercial banks (preferred specification) or individual banks. Finally, month-year fixed effects $\mu_t$ capture common temporal shocks. We double cluster standard errors at the country and month-year level.

Our identifying assumption is that loan characteristics for given car models in Germany would have continued on a parallel trend with those in our control countries conditional on our fixed effects. We provide event studies that support the parallel trends assumption. In addition, we must rule out the possibility of cross-border spillovers. Although European countries share a common market, there are substantial legal, bureaucratic, tax, information, and language barriers that hamper the cross-border importing and financing of cars.

[15] Most notably, longer-standing carbon pricing schemes in France, Finland and Portugal remained unchanged in the sample period. The announcements for the introduction of carbon pricing in Austria and the Netherlands fall outside of our sample period.

To ensure the robustness of our DiD model, we show that our results are robust to (i) more stringent fixed effect settings, such as interactions of car model and country fixed effects to reflect that the effect of the car models may vary by country, and (ii) specifications with additional control variables such as car weight, fuel efficiency, registration year, borrower's income, or an indicator for whether the car is new. Our preferred specification excludes these controls because they may themselves be affected by the treatment.

Finally (iii), we also turn to a triple DiD analysis (Olden and Møen, 2022) that continues to compare differences in loan characteristics between the pre- and post-treatment periods and between treated and control countries. What differs is that it leverages yet another difference in the fuel efficiency of vehicles. In line with our theoretical framework (Prediction 2), the introduction of the carbon price should barely affect the most fuel-efficient vehicles. Using this subgroup of non-treated cars to take a third difference can eliminate any remaining biases in our $\tau$ estimates from time-varying factors that impact the treatment and control groups differently, as long as those factors affect the two subgroups of fuel-efficient and fuel-inefficient cars in a similar way. We implement variants of the following triple DiD specification:

$$\begin{aligned} Y_{ictb} = {} & \beta_1 \cdot \text{Germany} \cdot \text{Group} + \beta_2 \cdot \text{Germany} \cdot \text{Post} + \beta_3 \cdot \text{Group} \cdot \text{Post} \\ & + \beta_4 \cdot \text{Germany} \cdot \text{Group} \cdot \text{Post} + \mu_i + \mu_c + \mu_b + \mu_t + \varepsilon_{ictb} \end{aligned} \tag{15}$$

where *Group* is a discrete variable grouping loans by fuel consumption (10% most efficient car versus all others), or a centered continuous variable for the fuel consumption measured in liters per 100 kilometers. In the discrete setting, $\beta_4$ captures the triple difference effect, i.e. the impact of the policy on the subgroup of affected cars, net of other trends. In the continuous setting, $\beta_4$ measures how the treatment effect varies with the fuel efficiency, i.e. a heterogeneous treatment effect.

# 6 Results

## 6.1 Policy effect on interest rate

**Baseline estimate** We begin by presenting the results for the effect of the policy announcement in September 2019 on loan interest rates. Table 2 consistently shows significant positive treatment effects. Our preferred baseline estimate from equation 14 suggests an increase in interest rates of about 0.5 percentage points which is in line with our theoretical Prediction 1. This effect is economically meaningful: with an average household paying an interest rate of 3.9% for a car loan in Germany, the policy causes an increase in their financing costs of more than 10%.

The estimated treatment effect is robust across specifications: In column 2, we add car and borrower characteristics as controls—variables excluded from our preferred specification because they may themselves be affected by the treatment—which results in a slightly larger estimated effect. In column 3, we employ a more stringent fixed effect setup with interacted car model and country fixed effects and find a consistent effect. In column 4, we use fixed effects for individual banks instead of captive banks and add credit type fixed effects to account for unobserved lending factors for different financial contracts (balloon loan, amortizing loan, hire purchase, lease purchase, finance lease, lease or operating lease) resulting in a lower estimated effect.[16] Finally, in column 5, we add repayment structure fixed effects to control for different lending rationales linked to balloon-type and linear repayment structures and find a comparable result.[17]

Figure 1 presents event study estimates for the policy announcement effect on interest rates. The coefficients for the ten months prior to treatment are close to zero and statistically insignificant. This is in line with the parallel trends assumption. Immediately following the announcement, interest rates rise sharply and stabilize at a persistently higher level after 3 months. This suggests a sustained change in banks' lending behavior. Notably, the confidence intervals widen substantially in the first months after treatment, suggesting an increase in uncertainty induced by the policy announcement.

The results are robust to several additional checks. First, to address concerns that our analysis period partly overlaps with the onset of the COVID-19 pandemic, Appendix table 16 and figure1 show that excluding the COVID period yields similar results. Second, Appendix table 15 reports results for both used and new cars from separate regressions and finds consistent effects. Third, while our baseline estimates rely on standard errors double clustered at the country-month level to account for both the level of treatment and the repeated cross-sectional sampling structure (following Abadie et al., 2023), Appendix table 11 documents that results are robust to alternative clustering choices. Table 12 and figure2 further show baseline results using the wild bootstrap

[16] One quarter of the observations in our sample are leases. Appendix table 9 reports separate estimates for loans and leases, showing that our effect stems from loans.

[17] 60% of the observations in our sample are loans with linear repayment structure. Appendix table 14 also reports separate estimates for linear and balloon-type loans.

**Table 2:** Effect of the German carbon price announcement on loan interest rates

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **Dep. variable** | Loan interest rate | | | | |
| Germany · Post | $0.53^{***}$<br>(0.07) | $0.61^{***}$<br>(0.14) | $0.52^{***}$<br>(0.07) | $0.26^{***}$<br>(0.02) | $0.46^{***}$<br>(0.05) |
| Controls | No | Yes | No | No | No |
| Model FE | Yes | Yes | No | Yes | Yes |
| Country FE | Yes | Yes | No | Yes | Yes |
| Captive FE | Yes | Yes | Yes | No | Yes |
| Month-year FE | Yes | Yes | Yes | Yes | Yes |
| Model · Country FE | No | No | Yes | No | No |
| Credit type FE | No | No | No | Yes | No |
| Bank FE | No | No | No | Yes | No |
| Repayment structure FE | No | No | No | No | Yes |
| # Loans | 3,209,548 | 1,753,026 | 3,209,548 | 3,209,548 | 3,209,458 |

Note: This table reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on interest rates. The specification in column (1) is our preferred one based on equation 14. Columns (2) to (5) show robustness across specifications that add control variables or more stringent fixed effects. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 months before and after treatment from October 2018 through June 2020. Standard errors in parentheses are double clustered at the country and month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

designed for a small number of clusters following MacKinnon and Webb (2018). Finally, we also examine the effect of the actual policy implementation in January 2021. Figure 7 in the Appendix shows a further increase in interest rates, but the effect appears to level off six months after the carbon price took effect, and estimates are noisier—the average treatment effects is only significant at the 10% significance level. This suggests that banks anticipated most of the policy's impact.

**By fuel efficiency** We next turn to our triple DiD estimates based on equation 15, which leverage our theoretical Prediction 2 that the treatment effect increases with the fuel intensity of cars. We first confirm this prediction empirically in columns (1) and (2) of Panel A in table 3 by presenting estimates separately for the most and least fuel-efficient 10% of cars. Our results confirm that highly efficient cars show no statistically significant effects, while less efficient, gas-guzzling cars exhibit a clear and significant effect. Our triple DiD then exploits the observation that the carbon price has only a

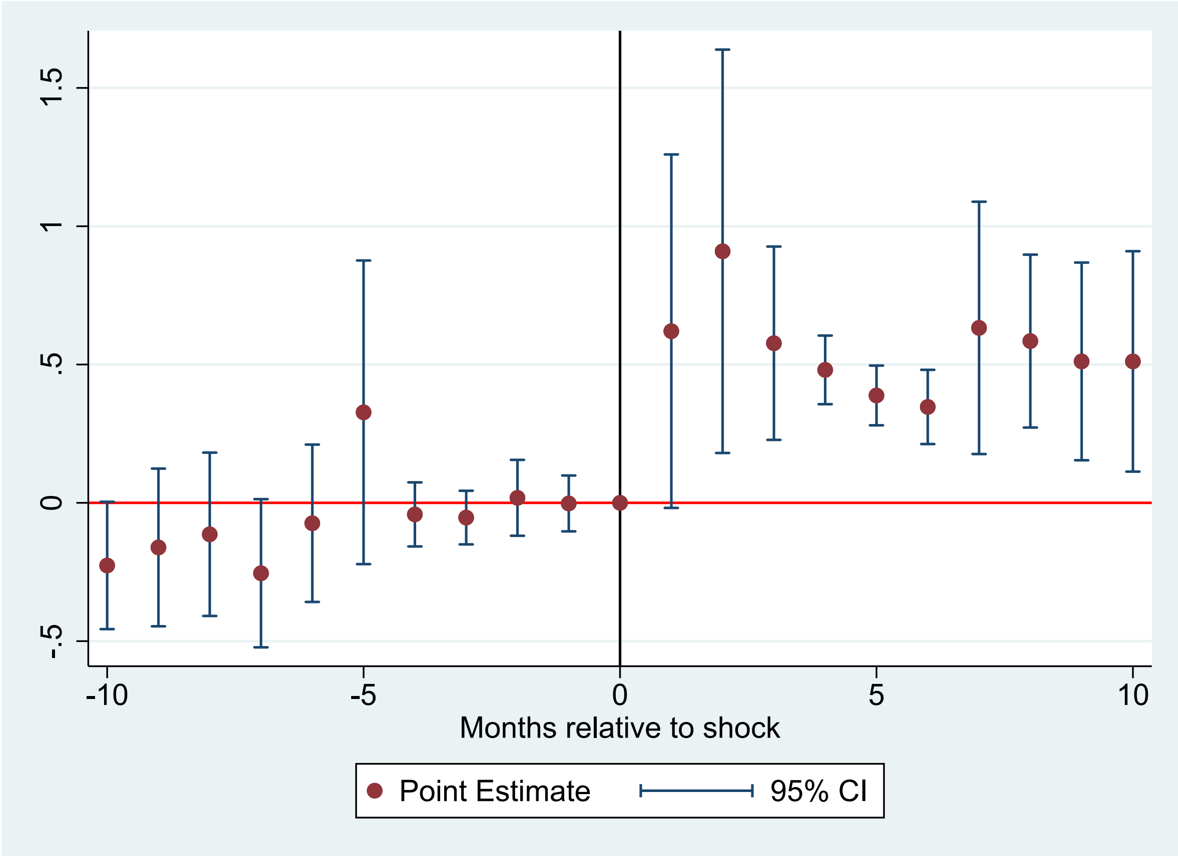


**Figure 1:** Event study estimates for the carbon price announcement on loan interest rates

minimal impact on the most fuel-efficient cars. By taking a third difference between the 10% most efficient cars and all others, we address remaining concerns about time-varying factors that may differentially affect the treatment and control groups and that our fixed effects may not absorb. The triple DiD estimate in Column (3) indicates a 0.44 percentage point rise in interest rates for the 90% of cars with non-negligible fuel consumption—using highly efficient cars in Germany as an internal control group. We also estimate the triple DiD model with the continuous fuel efficiency variable and find that the treatment effect increases by 0.15 percentage points for every additional liter off fuel consumption (with a standard error of 0.08; not reported in the table for the sake of brevity).

**By loan maturity** Consistent with Prediction 3, we also find a stronger treatment effect for loans with longer maturities. To show this, we group loan maturities into short-, medium-, and long-term categories and present separate effects for each group in Columns (1)-(3) of Panel B in table 3. Loans with short maturity below 3 years exhibit a much smaller increase in interest rates following the policy announcement in September 2019. This aligns with the fact that these loans are barely exposed to the carbon price, which only takes effect from January 2021 onward. By contrast, loans with maturities exceeding 4 years—thus spanning multiple years of rising carbon prices—are most exposed to the policy, and we consistently find significantly larger treatment effects for this group.

**Table 3:** Effect of the German carbon price announcement on the loan interest rates by treatment intensity

| | **(1)** | **(2)** | **(3)** |
|---|---|---|---|
| **Panel A: By fuel consumption** | | | |
| | Top 10% | Bottom 10% | Triple DiD |
| Germany · Post · Fuel | | | $0.44^{***}$ |
| | | | (0.11) |
| Germany · Post | $0.46^{***}$ | 0.09 | 0.14 |
| | (0.10) | (0.11) | (0.12) |
| Controls | No | No | No |
| Model FE | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes |
| # Loans | 302,620 | 370,116 | 3,209,548 |
| **Panel B: By loan maturity** | | | |
| | Below 3 years | 3-4 years | 4 years and above |
| Germany · Post | $0.27^{***}$ | $0.30^{***}$ | $0.62^{***}$ |
| | (0.06) | (0.05) | (0.14) |
| Controls | No | No | No |
| Model FE | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes |
| # Loans | 778,294 | 948,564 | 1,476,081 |

*Notes:* Panel A reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on interest rates by the fuel consumption of financed cars. Columns (1) and (2) are based on equation 14 for the top and bottom 10% of vehicles in terms of fuel consumption (liters per 100 kilometers). Column (3) are based on the triple DiD specification in equation 15 that uses the 10% most fuel efficient vehicles as a third control group. Panel B reports estimates for the effect of the policy announcement on interest rates by loan maturity. Columns (1) to (3) are based on equation 14 and estimated on sub-samples grouping loan maturities into short-term (below 3 years), medium-term (4 years), and long-term (above 4 years). The unit of observation is the monthly loan. The sample is restricted to car models with complete country-month coverage. The period spans October 2018 to June 2020 (10 months before and after treatment). Standard errors in parentheses are double clustered at the country and month-year level. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

## 6.2 Policy effects on broader lender behavior

**Captive versus commercial banks** First, we document significant lender heterogeneity by distinguishing between captive and commercial banks. Manufacturer-owned captive banks play a central role in providing households with vehicle financing options, accounting for roughly 75% of loans in our data. Their lending behavior may differ from that of more diversified commercial banks, and their close ties to automakers may give them greater insights into the climate transition risk of specific car models. In column (1) of Table 4 we therefore present triple DiD estimates for the policy-induced increase in interest rates for the subgroup of captive banks. We find that captive banks raise interest rates by an additional 0.44 percentage points relative to commercial banks.

Our ability to investigate the drivers of lender heterogeneity is constrained by the small number of captive banks in our sample (N=8) and by the fact that these captives operate both in Germany and in the control countries. To gain some additional insight into the potential mechanism, we examine the discounts that captive and commercial banks apply to investors who purchase securitized auto loans. Table 8 in the Appendix shows that captive banks substantially increase discounts following the policy announcement. This pattern is consistent with manufacturer-owned banks that attempt to reduce their ICE loan exposures in order to increase liquidity, but face difficulties selling these loans to ABS investors.

**Other loan characteristics** Next, we extend the analysis beyond interest rates and examine how banks adjust other loan characteristics in response to the policy announcement. Columns (2) to (5) of Table 4 present these estimates—with corresponding event studies in Figure 3 in the Appendix, which provide further support for the parallel trends assumption. We find a negative policy effect on loan maturities, indicating that banks shift to contracts that expire before carbon prices reach higher levels. We also find a strong negative effect on loan amounts, suggesting increased reluctance to finance large ICE vehicle purchases. Moreover, there is tentative evidence that banks may change the repayment structure as a result of the policy announcement: we find that they increase the use of linear schedules (at the 10% significance level), while the effect on loans with balloon repayments is negative but statistically insignificant. The potential shift towards linear credits is indicative of more risk-averse bank behavior, given that balloon loans expose lenders to higher end-of-contract default risk. Taken together, these adjustments provide evidence that banks seek to limit their exposure to the rising carbon price path through broad changes in loan contract terms.[18]

A potential concern is that the observed increase in interest rates might be driven solely by the shift toward linear repayment contracts, as banks earn less interest income in absolute terms on linear loans. To compensate for this lower income, banks may raise interest rates on linear contracts. To rule out this explanation, we re-estimate our baseline specification separately for balloon and linear loans. As shown in Appendix table 14, we consistently find positive and statistically significant treatment effects for both repayment types, indicating that the interest rate increase cannot be explained merely by changes in the repayment structure.[19]

**Table 4:** Effect of the German carbon price announcement on broader lender behavior

| | (1) Interest rate, triple DiD | (2) Maturity | (3) Amount repayment | (4) Linear repayment | (5) Balloon repayment |
|---|---|---|---|---|---|
| Germany · Post · Captive | 0.44** | | | | |
| | (0.16) | | | | |
| Germany · Post | 0.18*** | -1.85*** | -1,573.03*** | 0.06* | -0.03 |
| | (0.05) | (0.53) | (220.63) | (0.03) | (0.03) |
| Controls | No | No | No | No | No |
| Model FE | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes | Yes | Yes |
| # Loans | 3,209,548 | 3,203,378 | 3,209,987 | 3,209,987 | 3,209,987 |

Note: Column (1) reports estimates for lender heterogeneity in the effect of the policy announcement of the German carbon price on interest rates. It is based on the triple DiD specification in equation 15 with a third dummy variable for captive banks. Columns (2) to (5) report estimates for the effect of the policy announcement of the German carbon price in September 2019 on a range of other loan outcomes variables described in the data section based on equation 14. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country and month-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[18] To address concerns about multiple hypothesis testing, Table 13 in the Appendix shows that our results are robust when controlling the false discovery rate using Benjamini and Hochberg (1995).

[19] In addition, column 5 of Table 2 shows that we obtain similar estimates when we add repayment structure fixed effects to our baseline specification.

## 6.3 Policy effect on borrower behavior

Finally, Table 5 provides tentative evidence, consistent with prior work (Busse et al., 2013; Beresteanu and Li, 2011), that households adjust their car purchases in response to higher policy-induced fuel costs by buying more fuel-efficient cars. Using the fuel consumption of purchased new and used cars as the outcome, we estimate equation 14 with and without car model fixed effects to distinguish between shifts across trims of the same model and shifts across different models. For new cars, we find a negative and statistically significant effect at the 10% level only when including model fixed effects, suggesting that households move toward more efficient trims within a given model. Estimates for used cars are also negative but imprecisely estimated.

**Table 5:** Effect of the German carbon price announcement on fuel consumption of purchased cars

| | (1)<br>New car | (2)<br>Used car | (3)<br>New car | (4)<br>Used car |
|---|---|---|---|---|
| Germany · Post | -0.13* | -0.08 | -0.11 | -0.04 |
| | (0.07) | (0.06) | (0.06) | (0.06) |
| Controls | No | No | No | No |
| Model FE | Yes | Yes | No | No |
| Country FE | Yes | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes | Yes |
| # Loans | 1,720,415 | 1,480,385 | 1,720,416 | 1,480,385 |

Note: This table reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on the fuel consumption of purchased new cars (columns 1 and 3) and used cars (columns 2 and 4). Columns (1) and (2) are based on our baseline specification 14 with model fixed effects, while columns (3) and (4) show results without this fixed effect. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country and month-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 6.4 Mechanisms

Our conceptional framework highlights two mechanisms that can theoretically explain the results documented so far: a probability-of-default (PD) channel as well as a loss-given-default (LGD) channel (see Prediction 1). We subsequently examine the empirical relevance of both mechanisms.

**Probability of default** The average PD of individual consumers in Germany for auto loans is substantial, at roughly 3.3% (Fenner and Vollmar, 2023). An increase in the default risk of ICE loans induced by the carbon price is one channel that may explain banks' changes in financing terms.

As a first test of the PD channel—and guided by Prediction 4—we use the loan-to-value (LTV) ratio as a proxy for default risk. Panel A of Table 6 reports separate estimates of the policy announcement's effect on interest rates for high- and low-LTV loans. Consistent with our prediction, we find a significantly stronger treatment effect for high-LTV loans relative to low-LTV loans, indicating that banks raise interest rates more for borrowers with higher repayment risk. A triple DiD regression using the continuous LTV measure further shows that each unit increase in LTV increases the treatment effects by about 0.003 percentage points. While these findings support the relevance of a PD channel, they cannot rule out that part of the effects also reflects changes in collateral values.

As a second test of the PD channel, we examine regional heterogeneity in policy effects. Rural households tend to rely more heavily on their cars and typically drive longer distances, making them more exposed to higher fuel costs and, consequently, a higher risk of default under rising carbon prices. To test this, we leverage the granularity of our dataset, which includes NUTS3 region information to classify households as urban or rural based on a Eurostat typology.[20]. For NUTS3 regions that cannot be classified, we use ChatGPT 5-Thinking. Over 85% of loan observations are assigned to urban, rural or intermediate categories. Separate estimates for urban and rural areas as well as a triple DiD estimation in Panel C of Table 6 show that the announcement effect on interest rates is stronger for rural borrowers, providing additional empirical support for the role of the PD channel.

[20] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual_-_urban-rural_typology

**Table 6:** Evidence consistent with probability of default channel

| | (1) | (2) | (3) |
|---|---|---|---|
| **Panel A: Interest rate effect by Loan-To-Value ratio** | | | |
| | High LTV | Low LTV | Triple DiD |
| Germany · Post · LTV | | | 0.003*** |
| | | | (0.001) |
| Germany · Post | 0.55*** | 0.38*** | 0.52*** |
| | (0.09) | (0.05) | (0.07) |
| Controls | No | No | No |
| Model FE | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes |
| # Loans | 1,863,286 | 1,342,671 | 3,205,957 |
| **Panel B: Interest rate effect by NUTS3 region** | | | |
| | Urban | Rural | Triple DiD |
| Germany · Post · Region | | | 0.09** |
| | | | (0.04) |
| Germany · Post | 0.52*** | 0.60*** | 0.50*** |
| | (0.08) | (0.11) | (0.06) |
| Controls | No | No | No |
| Model FE | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes |
| # Loans | 1,330,025 | 355,274 | 3,209,548 |

*Notes:* Panel A reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on interest rates by Loan-To-Value (LTV) ratios. Columns (1) and (2) are based on equation 14 and show results for subsamples with above and below mean loan-to-value loans. Column (3) is based on the triple DiD specification in equation 15 where the binary variables Post and Germany are interacted with the centered loan-to-value. Panel B reports estimates for the effect of the policy announcement on interest rates by NUTS3 region. Columns (1) and (2) are based on 14 and show results for the urban and rural subsamples. Column (3) is based on the triple DiD specification in equation 15 where the dummies Post and Germany are interacted with a dummy variable that is 0 for urban observations and 1 otherwise. The unit of observation is the monthly loan. The sample is restricted to car models with complete country-month coverage. The period spans October 2018 to June 2020 (10 months before and after treatment). Standard errors in parentheses are double clustered at the country and month-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

**Loss given default** Prior research shows that households sell their older, less fuel-efficient vehicles when faced with higher fuel prices by policy shocks (Jacobsen and Van Benthem, 2015; Li et al., 2009). This shift increases supply and decreases demand in the used car market, driving down prices for used cars. Lower collateral values at the time of default caused by the carbon price therefore represent a second channel that may help explain our findings.

While we cannot observe the collateral value at the time of default, we use the value of used ICE cars at loan origination as a proxy. Table 7 shows that the announcement of the carbon pricing scheme leads to a decline in reported used car prices (Figure 4 in the Appendix provides corresponding event study estimates). This policy-induced devaluation is more pronounced for the most fuel-intensive used cars. Although this is an indirect test, the results are consistent with an increase in LGD that banks incorporate into loan pricing.

A more direct test of the LGD channel comes from our earlier finding in Panel B of Table 3 for short term loans. According to our theoretical model, these loans can only experience a treatment effect through declining collateral values, not through rising PDs, because carbon prices do not yet meaningfully increase fuel expenses. The presence of significant effects for short-term loans thus provides additional support for the relevance of the LGD channel.

**Table 7:** Evidence consistent with loss given default channel

| | (1)<br>Used car values | (2)<br>Fuel-intensive<br>used car values |
|---|---|---|
| Germany · Post | -808.34*** | -997.49*** |
| | (165.54) | (271.76) |
| Controls | No | No |
| Model FE | Yes | Yes |
| Country FE | Yes | Yes |
| Captive FE | Yes | Yes |
| Month-year FE | Yes | Yes |
| # Loans | 1,066,323 | 218,959 |

Note: This table reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on car values at loan origination based on equation 14. Columns 1 shows the treatment effect for all used cars, while column 2 presents estimates for the top 20% most fuel-intensive used cars. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country and month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

# 7 Conclusion

This paper investigates how carbon pricing affects household finance by focusing on auto loans for internal combustion engine vehicles. Using a rich European dataset covering millions of new and used car loans, the study exploits a difference-in-differences design comparing the same car models in Germany (treated) and other European countries (controls) before and after the 2019 announcement of a national carbon price. By doing so, we contribute to the nascent literature on the pricing of climate transition risks in financial markets, documenting that banks incorporate policy-induced transition risk into household lending—complementing prior research focused on equities and corporate lending.

The analysis shows that banks respond to the policy by raising interest rates—particularly for fuel-intensive cars and long-maturity loans—shortening loan terms, reducing loan amounts, and shifting toward linear repayment schedules. Captive banks respond more strongly than commercial banks. Consistent with our guiding theoretical framework, we find that both the probability-of-default and loss-given-default channels drive these lender adjustments.

These findings highlight that carbon pricing not only affects emissions, but also has distributional consequences through household finance: higher borrowing costs and falling used car values disproportionately impact households purchasing fuel-intensive vehicles. These policy-induced financing frictions suggest that carbon pricing can create unintended burdens, which have received little attention from policymakers seeking to design socially acceptable climate policies.

Future research could extend our analysis in several directions. First, applying similar methods to carbon pricing policies in other countries and regions would help assess how geographic and institutional differences influence the transmission of climate policy through household finance. Second, studies examining market-based policies, like carbon pricing, against non-market interventions—such as fuel efficiency standards, bans, or subsidies for low-emission vehicles—could reveal how the design of climate policies shape both borrower behavior and bank responses. Finally, additional work could explore long-term consequences for household financial stability, vehicle markets, and the broader adoption of low-carbon technologies, providing a more comprehensive understanding of policy-induced distributional effects.

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# 8 Appendix

## 8.1 Derivation of Prediction 3

To derive a closed-form expression for expected loss as a function of maturity, we first consider a loan with a constant per-period default probability $PD$ and a constant loss-given-default $LGD$. Using (3), we can simplify[21] (2) to

$$EL(T, PD, LGD) = \sum_{t=1}^{T} S(t-1) \cdot PD \cdot LGD = LGD\left(1 - (1 - PD)^T\right). \qquad (16)$$

Let us now further specify $f$ (the loan pricing rationale of banks), and assume that banks price loans at the breakeven rate, so that expected interest payments equal expected losses, $r(T)A(T) = EL(T)$, which gives

$$r(T) = \frac{EL(T)}{A(T)}, \qquad (17)$$

with the (survival-weighted) annuity factor $A(T) = \sum_{t=1}^{T} S(t)$.

We focus on the effects of a $CO_2$-price announcement and implementation and assume that, in the absence of the policy, $PD$ and $LGD$ would be constant during the whole life of the loan, $PD = p$ and $LGD = L$. Then the baseline before policy announcement is

$$EL_0(T) = L\Big(1 - (1-p)^T\Big), \qquad (18)$$

and[22]

$$A_0(T) = (1-p)\frac{1-(1-p)^T}{p}, \qquad (19)$$

which, inserting in (17), gives

$$r_0(T) = \frac{L\Big(1-(1-p)^T\Big)}{(1-p)\frac{1-(1-p)^T}{p}} = \frac{pL}{1-p}. \qquad (20)$$

We see that $r_0$ is independent of $T$.

---

[21] We define $k = t - 1$ to rewrite $\sum_{t=1}^{T}(1-PD)^{t-1} \cdot PD \cdot LGD = PD \cdot LGD \cdot \sum_{k=0}^{T-1}(1-PD)^k$. Applying the formula for a finite geometric series we get $\sum_{k=0}^{T-1}(1-PD)^k = \frac{1-(1-PD)^T}{1-(1-PD)}$, which yields the simplified right-hand side of (16).

[22] Here we apply the formula for a finite geometric series again.

Concerning the announcement and implementation effects of the $CO_2$-price, we assume that the policy announcement has an immediate effect on the market for used cars, as market participants price in higher fuel costs that reduce the use value of cars in the future and thereby increase $LGD$ by $\delta_a > 0$, whereas the announcement has no direct effect on the probability of default. The implementation of the policy, in contrast, affects both probability of default by $\gamma > 0$ and loss-given-default (again) by $\delta_i \geq 0$ as outlined in Section 3. Denoting the time of implementation by $T_1$, we have the following time structure for $PD'_t$ and $LGD'_t$ after the $CO_2$-price announcement:

$$PD'_t = \begin{cases} p, & t < T_1, \\ p + \gamma, & t \geq T_1, \end{cases} \qquad LGD'_t = \begin{cases} L + \delta_a, & t < T_1, \\ L + \delta_a + \delta_i, & t \geq T_1, \end{cases} \tag{21}$$

with $p + \gamma < 1$.

Let $S'(t)$ denote the survival probability under the policy, and define

$$EL_1(T) = \sum_{t=1}^{T} S'(t-1)\, PD'_t\, LGD'_t, \qquad A_1(T) = \sum_{t=1}^{T} S'(t), \tag{22}$$

so that the policy breakeven rate is

$$r_1(T) = \frac{EL_1(T)}{A_1(T)}. \tag{23}$$

Defining

$$e_t := S'(t-1)\, PD'_t\, LGD'_t, \qquad a_t := S'(t), \qquad k_t := \frac{e_t}{a_t}, \tag{24}$$

and using $S'(t) = S'(t-1)\big(1 - PD'_t\big)$, we obtain

$$k_t = \frac{S'(t-1)\, PD'_t\, LGD'_t}{S'(t)} = \frac{PD'_t\, LGD'_t}{1 - PD'_t}, \tag{25}$$

and

$$r_1(T) = \frac{\sum_{t=1}^{T} e_t}{\sum_{t=1}^{T} a_t} = \frac{\sum_{t=1}^{T} a_t k_t}{\sum_{t=1}^{T} a_t}. \tag{26}$$

Once the $CO_2$-price is announced, we have for the pre- and post-implementation periods

$$k_t = \begin{cases} k_{\text{pre}} := \dfrac{p\,(L + \delta_a)}{1 - p}, & t < T_1, \\ k_{\text{post}} := \dfrac{(p + \gamma)\,(L + \delta_a + \delta_i)}{1 - p - \gamma}, & t \geq T_1. \end{cases} \tag{27}$$

**Proposition 1.** Suppose

$$k_{\text{post}} > k_{\text{pre}} \quad \iff \quad \frac{(p+\gamma)\,(L+\delta_a+\delta_i)}{1-p-\gamma} \; > \; \frac{p\,(L+\delta_a)}{1-p},$$

and $p+\gamma<1$ so that $S'(t)>0$ for all $t$. Then $r_1(T)$ is constant for $T<T_1$ and strictly increasing in $T$ for $T \geq T_1$.

*Proof.* For $T<T_1$ we have $PD'_t = p$ and $LGD'_t = L+\delta_a$ for all $t \leq T$, hence $k_t = k_{\text{pre}}$ for all such $t$ and therefore

$$r_1(T) = \frac{\sum_{t=1}^{T} a_t k_{\text{pre}}}{\sum_{t=1}^{T} a_t} = k_{\text{pre}}, \tag{28}$$

so $r_1(T)$ is constant on $\{1,\dots,T_1-1\}$.

Now fix $T \geq 1$ and write

$$A_T := \sum_{t=1}^{T} a_t, \qquad E_T := \sum_{t=1}^{T} e_t, \tag{29}$$

so that $r_1(T) = \dfrac{E_T}{A_T}$. Then

$$r_1(T+1) = \frac{E_T + e_{T+1}}{A_T + a_{T+1}} = \frac{A_T r_1(T) + a_{T+1} k_{T+1}}{A_T + a_{T+1}}, \tag{30}$$

and hence

$$r_1(T+1) - r_1(T) = \frac{A_T r_1(T) + a_{T+1} k_{T+1}}{A_T + a_{T+1}} - r_1(T) = \frac{a_{T+1}\big(k_{T+1} - r_1(T)\big)}{A_T + a_{T+1}}. \tag{31}$$

Since $a_{T+1}>0$ and $A_T + a_{T+1} > 0$, the sign of $r_1(T+1)-r_1(T)$ is the sign of $k_{T+1}-r_1(T)$.

Because $k_{\text{post}} > k_{\text{pre}}$, the sequence $(k_t)$ is nondecreasing: for $t<T_1$ we have $k_t = k_{\text{pre}}$, and for $t \geq T_1$ we have $k_t = k_{\text{post}} > k_{\text{pre}}$. For any $T \geq T_1$, $r_1(T)$ is a convex combination of $\{k_1,\dots,k_T\}$ with strictly positive weights $a_t$, so

$$k_{\text{pre}} < r_1(T) < k_{\text{post}}.$$

For $T+1 \geq T_1$ we have $k_{T+1} = k_{\text{post}} > r_1(T)$, hence $k_{T+1} - r_1(T) > 0$ and thus $r_1(T+1) - r_1(T) > 0$. Therefore $r_1(T)$ is strictly increasing for $T \geq T_1$. □

Thus, the policy-induced spread $\Delta r(T) = r_1(T) - r_0(T)$ is larger for longer maturities, so the announcement and subsequent implementation of the $CO_2$-price raise interest rates more strongly for long-term loans than for short-term loans.

## 8.2 Additional event studies

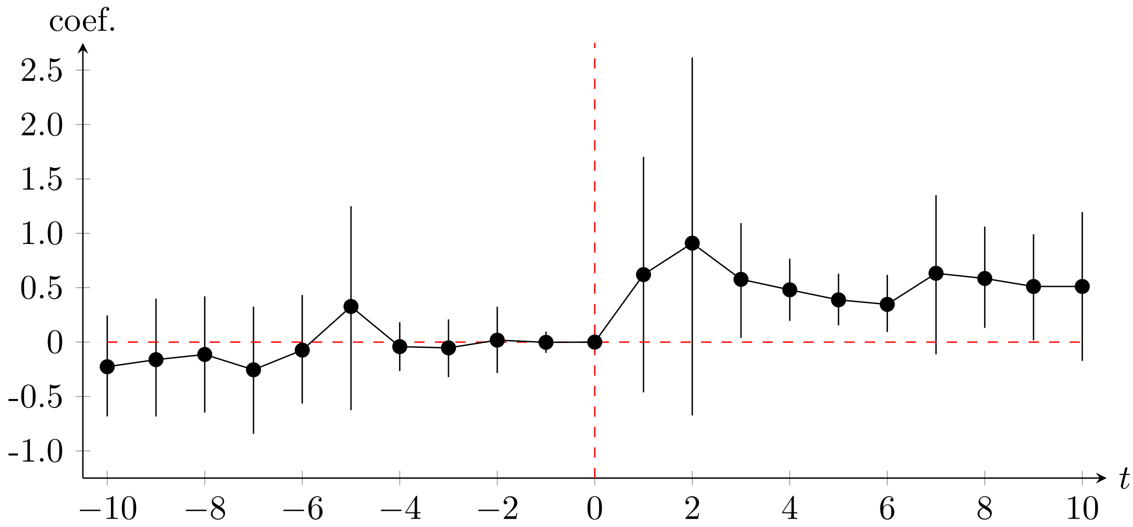


**Figure 2:** Event study estimates for the carbon price announcement on loan interest rates using wild bootstrap with standard error clustering on the country level and sub-clustering on the loan level as suggest by MacKinnon and Webb, 2018

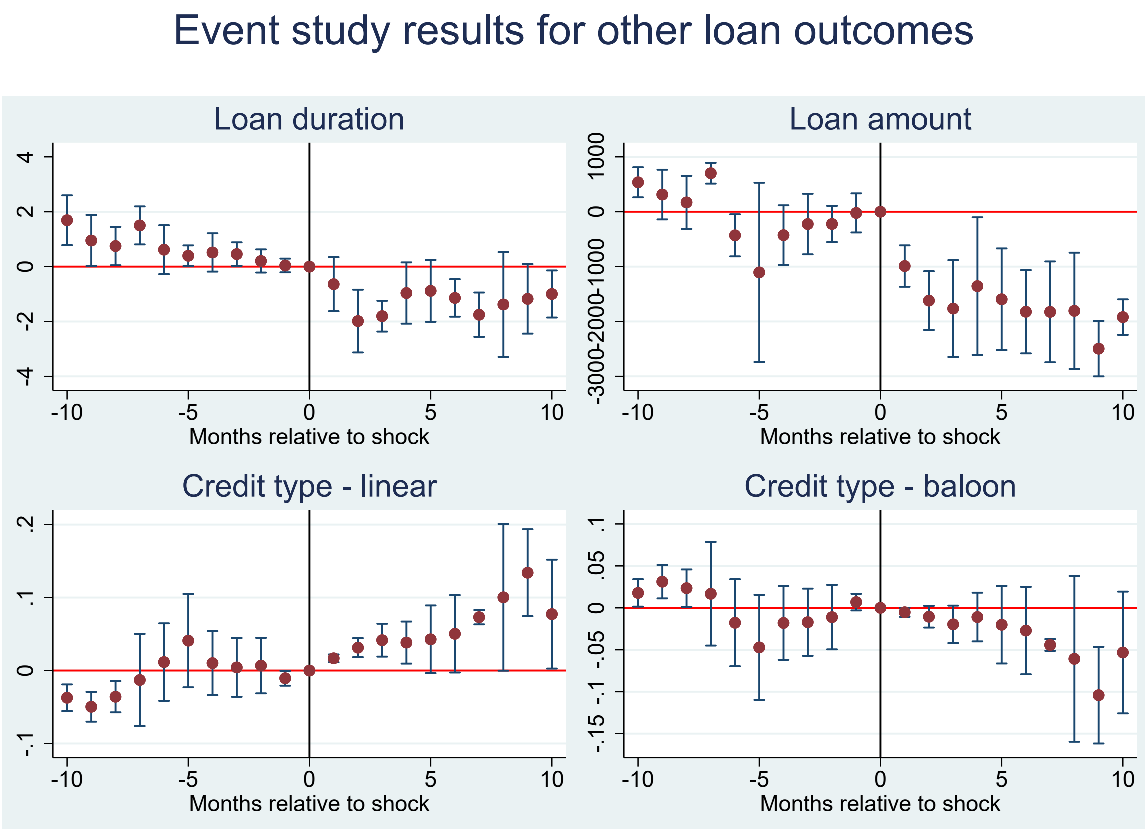


**Figure 3:** Event study estimates for the carbon price announcement on other loan characteristics

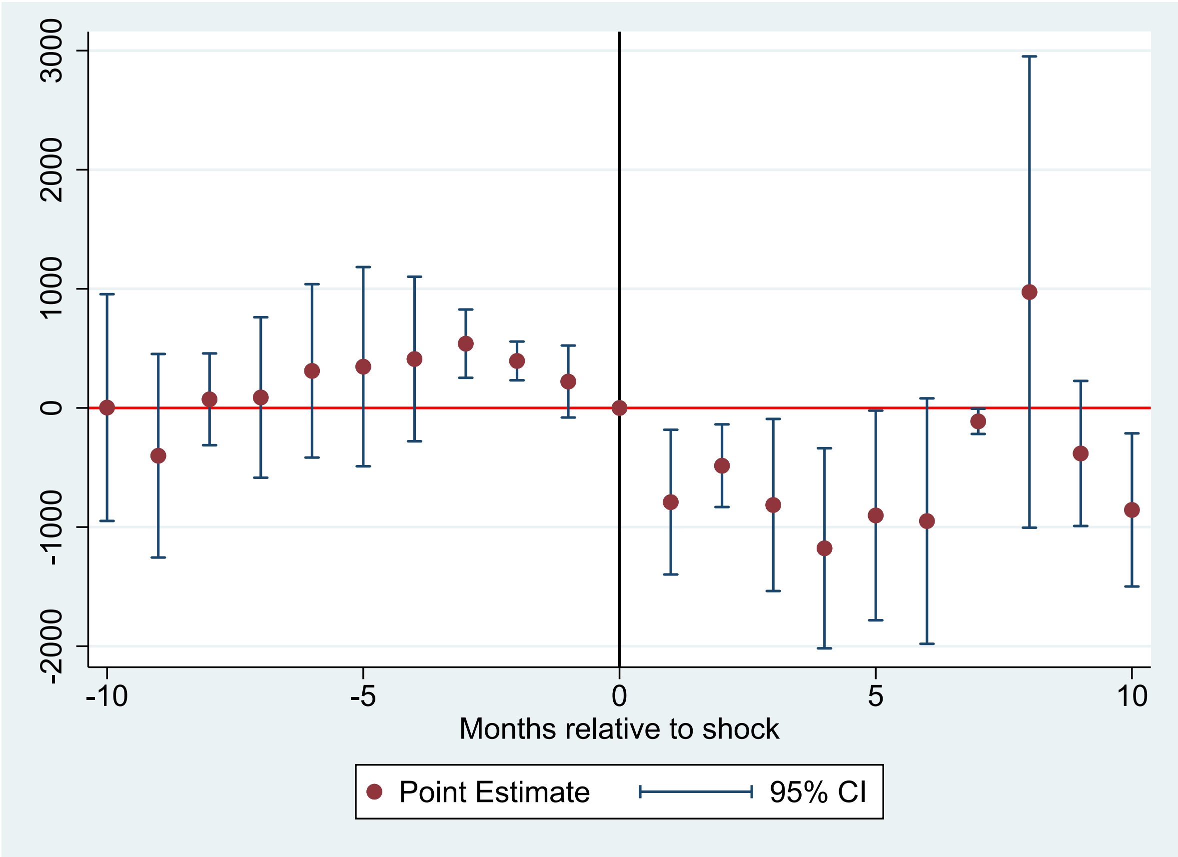


**Figure 4:** Event study estimates for the carbon price announcement on the value of used cars

### 8.3 Google Trend Figures

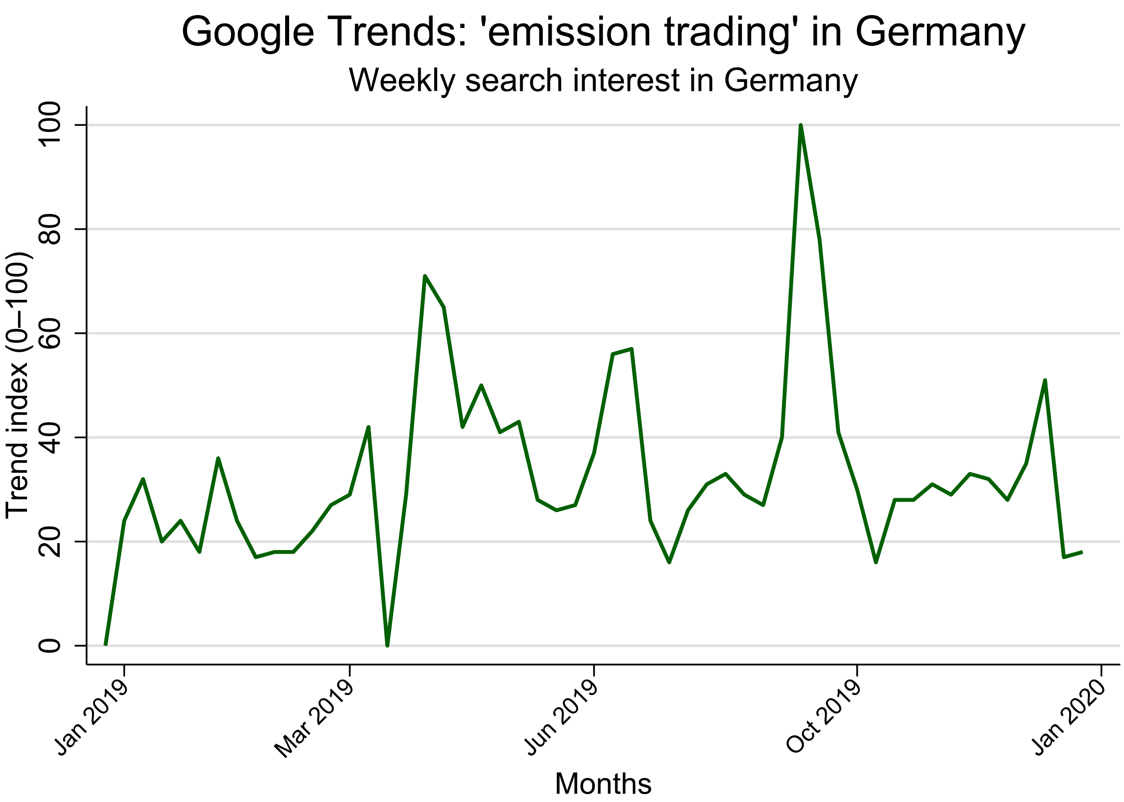


**Figure 5:** Google Trends for the word "Emissionshandel" in Germany for 2019.

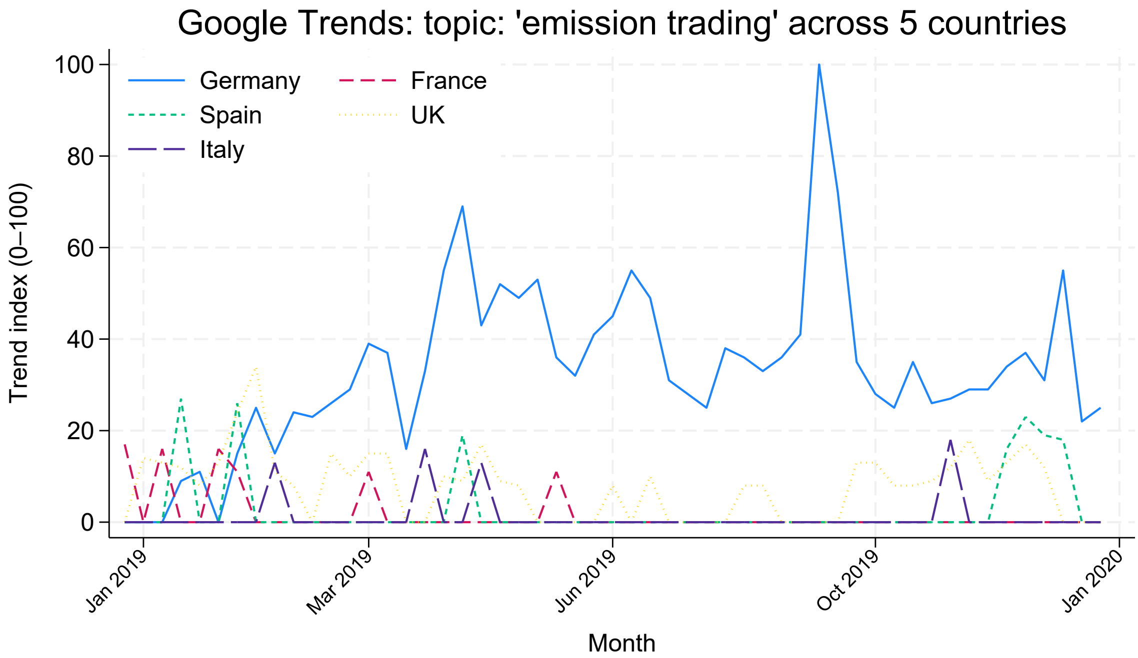


**Figure 6:** Google Trends for the topic "Emission Trading Scheme" in 5 European countries for 2019.

## 8.4 The discount rate for sold loans

**Table 8:** Effect of the German national carbon price announcement on the loan discount rate.

| | (1) | (2) | (3) |
|---|---|---|---|
| **Dep. variable** | | Loan discount rate | |
| Germany · Post | 0.83 | 1.20* | -0.13 |
| | (0.50) | (0.61) | (0.08) |
| Model FE | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes |
| Observations | 3,206,791 | 2,444,690 | 762,101 |

This table shows the results for the DiD estimation for the policy announcement of the German carbon price in September 2019 based on 14 for the loan discount rate.The first column shows the overall sample. The second and third column split the sample for captive and commercial banks respectively. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 8.5 Loans and leases

**Table 9:** Effect of the German carbon price announcement on the loan interest rate for loans and leases.

| | (1)<br>Lease<br>interest rate | (2)<br>Loan<br>interest rate |
|---|---|---|
| Germany · Post | -0.23 | 0.57*** |
| | (0.23) | (0.10) |
| Model FE | Yes | Yes |
| Country FE | Yes | Yes |
| Bank FE | Yes | Yes |
| Month-year FE | Yes | Yes |
| # Loans | 612,950 | 1,895,841 |

Note: This table shows the results for the DiD estimation for the policy announcement of the German carbon price in September 2019 based on 14 differentiated for loans and leases. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 8.6 Results for the full sample without data drops

**Table 10:** Effect of the German carbon price announcement on loan interest rates

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **Dep. variable** | | | Loan interest rate | | |
| Germany · Post | 0.51*** | 0.55*** | 0.48*** | 0.24*** | 0.43*** |
| | (0.05) | (0.12) | (0.06) | (0.02) | (0.04) |
| Controls | No | Yes | No | No | No |
| Model FE | Yes | Yes | No | Yes | Yes |
| Country FE | Yes | Yes | No | Yes | Yes |
| Captive FE | Yes | Yes | Yes | No | Yes |
| Month-year FE | Yes | Yes | Yes | Yes | Yes |
| Model · Country FE | No | No | Yes | No | No |
| Credit type FE | No | No | No | Yes | No |
| Bank FE | No | No | No | Yes | No |
| Repayment structure FE | No | No | No | No | Yes |
| # Loans | 3553798 | 1932361 | 3553576 | 3553798 | 3553798 |

Note: This table reports estimates for the effect of the policy announcement of the German carbon price in September 2019 on interest rates. The specification in column (1) is our preferred one based on equation 14. Columns (2) to (5) show robustness across specifications that add control variables or more stringent fixed effects. The unit of observation is the monthly loan level. The sample only excludes improbable observations but does not exclude incomplete car models. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country and month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 8.7 Results for different standard error clusters

**Table 11:** Effect of the German national carbon price announcement on the loan interest rate. Different clustering methodologies.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **Dep. variable** | | | Loan interest rate | | |
| Germany · Post | $0.53^{***}$ | $0.53^{***}$ | $0.53^{***}$ | $0.53^{***}$ | $0.53^{***}$ |
| | (0.07) | (0.08) | (0.07) | (0.07) | (0.03) |
| Model FE | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Captive FE | Yes | Yes | Yes | Yes | Yes |
| Month-year FE | Yes | Yes | Yes | Yes | Yes |
| # Loans | 3209548 | 3209548 | 3209548 | 3209548 | 3209548 |

This table shows the results for the DiD estimation for the policy announcement of the German carbon price in September 2019 based on 14. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors are double clustered at the country month-year level (1), clustered at the country level (2), clustered at the car model level (3), double clustered at the car model country level (4), clustered at the nuts2 level (5). $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

## 8.8 Standard errors clustering

In their seminal paper, Abadie et al. (2023) offer two justifications for clustering: First, standard errors need to be clustered at the level of the treatment. Second, the clustering has to reflect the sampling of the data. Following Abadie et al. (2023), we therefore cluster our standard errors at the country level at which the treatment is applied and at the monthly level because our data consists of monthly repeated cross sections. Nevertheless, we also present evidence in Table 12 that our main results from Table 2 hold when we apply one-way clustering at the country level accounting for the small number of clusters using the wild bootstrap with subclusters suggested by MacKinnon and Webb (2018).

**Table 12:** Small number of clusters

| Model | $p - value$ | $p$(few) |
|---|---|---|
| (1) | 0.0000 | 0.0030 |
| (2) | 0.0028 | 0.0200 |
| (3) | 0.0000 | 0.0000 |
| (4) | 0.0000 | 0.0060 |
| (5) | 0.0000 | 0.0040 |

This Table shows $p$-values for our baseline results using a two-way clustering at the country and month-year level. The first column indicates the model from Table 2, the second column holds the corresponding $p$-values, while the final column labeled $p(few)$ holds adjusted $p$-value using the wild bootstrap with subclusters designed for a small number of clusters following MacKinnon and Webb (2018). We cluster at the country level and subcluster at the level of the individual loan.

## 8.9 Multiple hypothesis testing

We apply the metdhodology by Benjamini and Hochberg (1995) to demonstrate that our results are robust to multiple hypothesis testing. To this end, we collect results with different dependent variables in Table 13, highlight their $p$-values in column 2 and compare them to the adjusted $p$-value in the ultimate column. With the exception of the coefficient from Table 4 Column 4, the $p$-value adjustment by Benjamini and Hochberg (1995) has no impact on the statistical significance.

**Table 13:** Multiple hypothesis testing

| Table | Model | $p - value$ | $p(BH)$ |
|---|---|---|---|
| 2 | 1 | 0.0000 | 0.0001 |
| 4 | 2 | 0.0056 | 0.0094 |
| 4 | 3 | 0.0000 | 0.0001 |
| 4 | 4 | 0.0848 | 0.1059 |
| 4 | 5 | 0.3655 | 0.3655 |

This Table shows $p$-values for our baseline results. The first column indicates the model from Table 2, the second column holds $p$-values, while the final column labeled $p(BH)$ holds adjusted $p$-value following Benjamini and Hochberg (1995).

## 8.10 Accounting for different repayment structures

**Table 14:** Effect of the German national carbon price announcement on the loan interest rate.

| | (1) | (2) |
|---|---|---|
| **Dep. variable** | Loan interest rate | |
| Germany*Post | 0.32*** | 0.26** |
| | (0.10) | (0.09) |
| Model FE | Yes | Yes |
| Country FE | Yes | Yes |
| Captive FE | Yes | Yes |
| Month-year FE | Yes | Yes |
| Observations | 1,941,097 | 1,169,020 |

This table shows the results for the DiD estimation for the policy announcement of the German carbon price in September 2019 based on 14 with special emphasis on the type of credit contract.The first and second columns are separate estimations for linear and balloon type credits. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors in parentheses are double clustered at the country month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 8.11 New and used cars

**Table 15:** Separate results for new and used cars

| | (1) Loan interest rate | (2) Loan interest rate |
|---|---|---|
| Germany*Post | 0.55*** | 0.60*** |
| | (0.11) | (0.10) |
| Model FE | Yes | Yes |
| Country FE | Yes | Yes |
| Captive FE | Yes | Yes |
| Month-year FE | Yes | Yes |
| # Loans | 1,721,709 | 1,482,034 |

Note: This table shows the results for the DiD estimation for the announcement of the German carbon price in September 2019 based on 14 for new cars in column 1 and used cars in column 2. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers 10 month before and after treatment: from October 2018 to June 2020. Standard errors are double clustered at the country month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

## 8.12 Excluding the Covid shock

**Table 16:** Effect of the German national carbon price announcement excluding covid.

| | (1)<br>Loan interest rate |
|---|---|
| Germany*Post | 0.54*** |
| | (0.12) |
| Model FE | Yes |
| Country FE | Yes |
| Captive FE | Yes |
| Month-year FE | Yes |
| # Loans | 2,892,318 |

Note: This table shows the results for the DiD estimation for the announcement of the German carbon price in September 2019 based on 14 before April 2020. The unit of observation is the monthly loan level. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers October 2018 to June 2020. Standard errors in parentheses are double clustered at the country month-year level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 8.13 The policy implementation

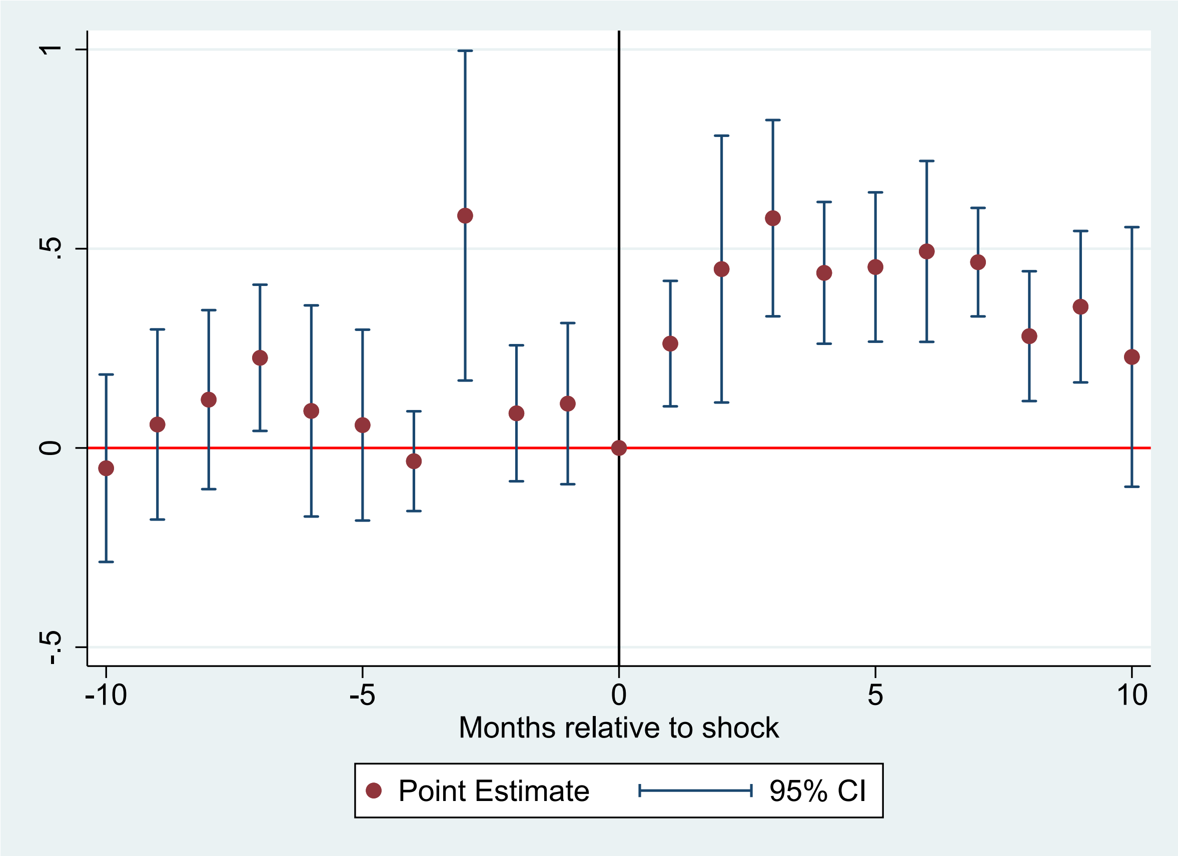


**Figure 7:** Event study estimates for the carbon price announcement on the value of used cars

## 8.14 Observations per country

**Table 17:** Observations per country.

| Country | Frequency | Percent |
|---|---|---|
| Austria | 11,924 | 0.37 |
| Belgium | 6,801 | 0.21 |
| Finland | 16,817 | 0.52 |
| France | 177,312 | 5.52 |
| Germany | 1,877,090 | 58.48 |
| Italy | 324,865 | 10.12 |
| Netherlands | 15,215 | 0.47 |
| Poland | 1,130 | 0.04 |
| Portugal | 48,635 | 1.52 |
| Spain | 380,418 | 11.85 |
| United Kingdom | 349,780 | 10.90 |
| Total | 3,209,987 | 100.00 |

Note: Observations split by country. The sample is restricted to car models, which have complete observations for all month within a country. The time period covers October 2018 to June 2020.

## 8.15 Observations per bank

**Table 18:** Observations per bank.

| Category | Freq. | Percent |
|---|---|---|
| Captive-BMW | 88,309 | 2.75 |
| Captive-FCA | 212,667 | 6.63 |
| Captive-Ford | 54,694 | 1.70 |
| Captive-PSA | 321,100 | 10.00 |
| Captive-RCI | 163,894 | 5.11 |
| Captive-TOYOTA | 52,716 | 1.64 |
| Captive-VW | 1,509,674 | 47.03 |
| Captive-other | 42,479 | 1.32 |
| Commercial-BNP | 15,884 | 0.49 |
| Commercial-Kraftfahrzeuggewerbe | 89,879 | 2.80 |
| Commercial-Santander | 499,874 | 15.57 |
| Commercial-smaller | 158,817 | 4.95 |
| Total | 3,209,987 | 100.00 |

Note: Observations split by bank for the time period from 2019 until the end of 2021. We also indicate whether the bank is captive or commercial.

## 8.16 Car models for in baseline analysis

Table 19 summarizes all car models with full monthly availability across treatment and control countries. In total the table lists 175 car models across 26 manufacturers.

**Table 19:** Car Models by Manufacturer

| Manufacturer | Model |
|---|---|
| Alfa Romeo | Giulia |
| | Stelvio |
| Audi | A1 |
| | A3 |
| | A4 |
| | A5 |
| | A6 |
| | A7 |
| | Q2 |
| | Q3 |
| | Q5 |
| | Q7 |
| | Q8 |
| | S3 |
| | TT |
| BMW | 1 Series |
| | 2 Series |
| | 3 Series |
| | 5 Series |
| Citroën | C1 |
| | C3 |
| | C4 |
| | C5 |
| | Berlingo |
| | Jumper |
| | DS3 |
| | DS4 |

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| Manufacturer | Model |
|---|---|
| | DS5 |
| Dacia | Dokker |
| | Duster |
| | Lodgy |
| | Logan |
| | Sandero |
| FCA | Ghibli |
| Fiat | 500 Series |
| | Doblo |
| | Ducato |
| | Fiorino |
| | Panda |
| | Punto |
| Ford | C-Max |
| | EcoSport |
| | Fiesta |
| | Focus |
| | Galaxy |
| | Ka |
| | Mondeo |
| | Tourneo |
| | Transit |
| Honda | Civic |
| | CR-V |
| | HR-V |
| Hyundai | i10 |
| | i20 |
| | i30 |
| | i40 |
| | ix20 |
| | Santa Fe |

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| **Manufacturer** | **Model** |
|---|---|
| | Tucson |
| Jaguar–Land Rover | Range Rover |
| | XF |
| Kia | Ceed |
| | Niro |
| | Optima |
| | Picanto |
| | Rio |
| | Sportage |
| | Stonic |
| Mazda | Mazda 2 |
| | Mazda 3 |
| | Mazda 5 |
| | Mazda 6 |
| | Mazda CX-3 |
| | Mazda CX-5 |
| Mercedes-Benz | A-Class |
| | C-Class |
| | CLA |
| | Sprinter |
| | Vito |
| Mitsubishi | ASX |
| | Outlander |
| | Space Star |
| Nissan | Juke |
| | Micra |
| | Note |
| | Pulsar |
| | Qashqai |
| | X-Trail |

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| Manufacturer | Model |
|---|---|
| | NV-Series |
| Opel | Adam |
| | Astra |
| | Combo |
| | Corsa |
| | Crossland |
| | Grandland |
| | Insignia |
| | Mokka |
| | Movano |
| | Vivaro |
| | Zafira |
| Peugeot | 107 |
| | 108 |
| | 2008 |
| | 206 |
| | 207 |
| | 208 |
| | 3008 |
| | 307 |
| | 308 |
| | 5008 |
| | 508 |
| | Boxer |
| | Expert |
| | RCZ |
| Porsche | 911 Carrera |
| | Boxster |
| | Cayenne |
| | Macan |
| | Panamera |

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| Manufacturer | Model |
|---|---|
| Renault | Clio |
| | Kadjar |
| | Kangoo |
| | Laguna |
| | Megane |
| | Master |
| | Scenic |
| | Talisman |
| | Trafic |
| | Twingo |
| SEAT | Alhambra |
| | Altea |
| | Arona |
| | Ateca |
| | Ibiza |
| | Leon |
| | Mii |
| Skoda | Citigo |
| | Fabia |
| | Karoq |
| | Kodiaq |
| | Octavia |
| | Rapid |
| | Superb |
| | Yeti |
| Suzuki | Ignis |
| | Swift |
| | SX4 |
| | Vitara |
| Toyota | Auris |
| | Avensis |

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| **Manufacturer** | **Model** |
| --- | --- |
| | Aygo |
| | Corolla |
| | RAV4 |
| | Yaris |
| Volkswagen | Arteon |
| | Beetle |
| | Caddy |
| | Caravelle |
| | Crafter |
| | Golf |
| | Multivan |
| | Passat |
| | Polo |
| | Scirocco |
| | Sharan |
| | T-Roc |
| | Tiguan |
| | Touareg |
| | Touran |
| | Transporter |
| | Up! |
| Volvo | V40 |
| | V60 |
| | V70 |
| | XC60 |