The impact of carbon pricing on the credit market: Evidence from securitized loans in the transportation sector*

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Abstract

We study the causal impact of the introduction of the German national CO2 price on car loans for combustion engine vehicles. The CO2 price specifically targets the transportation sector and entails a steadily rising price path from €25 per ton of CO2 in 2021 to €55 in 2025. By combining data on 24 million European car loans with detailed vehicle information, we apply a tight differences-in-differences design that compares the within-variation in similar car models across treated and control countries. We find a sizable treatment effect of 0.5 and 0.3 percentage points higher interest rates for affected cars for the policy announcement in 2019 and the policy implementation in 2021. Given the average German auto loan carries a 4% interest rate, the estimated treatment effects is sizable. We also find shrinking lending volumes, reduced credit duration and a shrinking propensity for balloon type credits as a result of the policy announcement. For the policy implementation, we find falling car values indicating falling collateral values for affected vehicles. Further analysis reveals notable heterogeneity: A triple differences design shows that banks differentiate their lending decisions based on fuel efficiency as the increase in interest rates is higher for more fuel-intensive cars. Concerning banks, we find stronger interest increases for manufacturer-owned captive banks. Moreover, captive banks increase discounts, which may show difficulties to sell riskier loans to investors after the policy shock. These results provide first evidence that carbon pricing policies not only have direct effects on emissions through increasing fuel prices but also impact emissions indirectly, through consumer credits.

JEL codes: G21, G50, G51, Q57

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

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1 Introduction

Climate policies such as emission trading systems (ETS) or CO2 taxes increase the costs of fossil fuels and thereby burden consumers who own fossil fuel-emitting products. In consequence, the ownership of fossil-fuel intensive consumer products becomes more expensive. Banks that are financing such consumer products are faced with increasing default risks as well as shrinking collateral values. In the case of very stringent climate policies such as prohibitively high carbon prices or outright bans of specific products, durable consumer products might even become stranded (Dulong et al., 2023) – we coin this risk: "household stranded asset risk".

In this paper we investigate the lending behavior of banks financing fossil fuel-intensive consumer products. Most notably, we are interested in how banks take household stranded asset risk into account when financing durable consumer products and how this behavior changes after the implementation of salient climate policies. Rational banks should increase the interest rate for loans financing durable fossil products as the default risk of such loans increases with the CO2 price, that is, given constant household income, the total cost of ownership can rise to such an extent that servicing the loan becomes infeasible. At the same time, the value of the collateral, the durable consumer product, shrinks since fossil-fuel emitting products become relatively less competitive. Moreover, banks could attach a brown risk premium to fossil fuel-intensive consumer products, reflecting climate policy induced risks. Such a brown risk premium reflects the risk for increasing climate policy ambition. If any of these channels actually changes banks lending behavior, there might be an indirect channel, how climate policies can reduce emissions beyond directly increasing the costs of fossil fuels, namely through worsening credit conditions for affected consumer products.

The focus of this study is internal combustion engine (ICE) vehicle financing in the automotive sector. The purchase of a car is key for household finances, as it is among the most expensive consumer purchases (Gössling et al., 2022). A large portion of cars are financed through the credit market in both the US and Europe. In Germany for instance, roughly 40% of all vehicles are financed through credits (Ipsos GmbH, 2023). At the same time, the automotive sector is responsible for a large part of global emissions, thus, reducing transportation sector emissions is a key policy objective (European Environment Agency, 2024). In order to analyze how climate policies influence banks' lending to fossil fuel-intensive durable consumer products, we rely on a unique dataset covering more than 24 million European auto-loans from 2005 until 2024. This dataset combines granular loan data from the ECB with detailed vehicle information for 10,000 different car models. We group these car models into 314 carmaker-model-power combinations, that is, for each car manufacturer, we separate the main car models (e.g. BMW 3, 5, 7 series etc.) by energy technology (ICE, Hybrid, EV).

To test the causal influence of rising carbon pricing risk on financing conditions for durable consumer products, we analyze the introduction of a salient climate policy directed at the transportation sector, the introduction of the German national emission tradings scheme in 2021. It imposes a fixed carbon price on those sectors that are not covered by the EU ETS, that is, residential heating and transportation. The policy proposal includes a rising CO2 price path for fossil fuels such as gasoline, coal, gas or oil starting at 25€ in 2021. The price path then increases to 30€, 35€, 45€ and 55€ in 2025. Particularly in times of high oil prices or personal financial crises such costs may increase the probability to default on a consumer loan. At the same time, the collateral value of the car may shrink due to the higher costs of owning an ICE vehicle compared to low/no emissions cars, which makes ICE vehicles relatively less competitive. If investors perceived the policy as an announcement that, ultimately, ICE vehicles will be banned altogether, the collateral value would decrease toward zero, as the ICE vehicle would become a household stranded asset. To test whether such effects are actually at play, we exploit both regional and temporal heterogeneity with respect to the policy implementation. Regionally, we compare the pricing of German car loans against multiple neighboring European control countries. From a timing perspective, we analyze both the announcement- as well as the implementation effect of the policy since the political agreement for the national CO2 price was reached in September 2019, while the implementation of the policy followed in January of 2021.

We test the influence of this policy on German auto loans using a differences-in-differences (DiD) research design. Most notably, we compare the monthly pricing of German auto loans compared to European auto loans before and after the announcement and introduction of the climate policy (the treatment). For our identification, we exploit the unique policy setting at hand: While the policy is implemented at the country level, affected car models are distributed throughout Europe. Thus, we can compare the loan pricing for affected car models, such as Mercedes C-classes in Germany, with similar control models from other European countries. By adding car features, borrower characteristics as well as time, country, model and bank fixed effects (FE), we can identify the treatment effect for the carbon price in a very tight empirical specification. This approach mimics a matching-based DiD design as we compare the within variation in similar car models across treatment and control countries.

We find statistically and economically significant treatment effects on loan interest rates for both the announcement of the policy in late 2019, as well as the actual policy implementation in 2021. For the policy announcement in September 2019, we document a roughly 0.5% interest rate increase in treated German car loans relative to a control group of European car loans. The event study graphs reveal that the treatment effect persists for up to 1 year after the treatment event. Interestingly, the confidence intervals widen sharply after the event, suggesting heightened uncertainty introduced by the policy announcement. The actual policy implementation was not unexpected, however, we still find a sizable treatment effect for the policy implementation. We explain the large magnitude of the effect with the risk of further even more stringent climate policies, as policy announcements are oftentimes followed by further more stringent climate policies, and indeed there are plans of linking the German national CO2 price to the EU wide ETS, which would materially increase average German CO2 prices.

Next, we investigate whether the interest premium for German ICE loans after the introduction of the CO2 price is higher for more fuel-intensive vehicles. Therefore, we separately run the baseline DiD specification for the top 20% and bottom 20% of car loans in terms of fuel efficiency. We only find a strong treatment effect of 0.58% for the inefficient and therefore more affected vehicles. We further corroborate this finding through a triple DiD, which shows that fuel-intensive vehicles receive a 0.27 percentage point higher interest rate premium after the policy announcement. These results clearly show that banks take into account how much the total cost of ownership of treated vehicles will increase due to the CO2 price as only fuel-intensive cars face higher interest rates. Fuel-efficient cars on the other hand are relatively more competitive as the total cost of ownership increases less. Potentially, this protects fuel-efficient cars, from rising interest rates.

After having established that banks react to the implementation of climate policies with higher interest rates for more fuel-inefficient vehicles, we further analyze lender heterogeneity by differentiating between captive banks owned by car manufacturers, and commercial banks. Therefore, we group all banks in the dataset onto their ultimate owner and perform separate analyzes for captive and commercial banks. We find an economically and statistically significant effects on interest rates for both types of banks. However, commercial banks increase interest less compared to captive banks. Again, we corroborate this observations with a triple DiD. Results indicate that captive banks increase interest rates 0.23 percentage beyond commercial banks. This observation is in line with Klee et al., 2024, who show that captive banks strongly reduce interest rates for more efficient electric vehicles (EV). Another notable bank pricing difference concerns the discount rate since commercial banks reduce discounts to investors after the policy announcement, while captive banks increase discounts. This may indicate that manufacturer-owned banks want to get ICE loans of their balance sheet, but have trouble selling ICE loans to investors after the policy announcement.

Finally, we investigate further outcomes of the policy announcement and the policy implementation. First, we show that the average loan duration is negatively affected by the policy. This suggests that banks reduce exposure to rising carbon prices in the future, by providing shorter loan durations that expire before carbon prices reach salient levels or even more ambitious climate policies are adopted. For both the policy announcement and the policy implementation, we find economically and statistically significant negative effects for the loan amount, suggesting that banks are more hesitant to provide large financing for ICE vehicles in Germany due to mounting carbon pricing risks. We also find a change in credit contracts away from balloon-type payments at the end of the credit term, toward linear payments that include monthly principal repayments. In line with the shortened credit duration, linear credit contracts reduce medium- to long term risks by avoiding a large payment at the end of the term, which may increase the probability of default when carbon prices also rise during that time. Interestingly, we only see an effect on car values for the policy implementation. This fall in car values indicates shrinking collateral values as a result of the carbon pricing policy implementation. A hypothesis that we must reject based on our results is that banks shift lending toward wealthier households as we can not find a treatment effects for borrowers income. We also do not find that interest rates rise stronger for lower income households.

We offer three potential explanations for our results: an increased probability of default, shrinking collateral values of cars, and banks' green preferences. First, the introduction of the CO2 price increases the total cost of ownership and might increase the probability of default beyond the current 3.3% in Germany (Fenner and Vollmar, 2023). We view this explanation as unlikely, given that the initial CO2 prices are relatively small. Moreover, we do not find significant effects for income, which partly rules out the default probability explanation for the increase in interest rates, since this probability is naturally higher for poorer households. However, if such an effect existed, it could be offset by richer households buying more fuel-intensive vehicles - as we found higher interest rate increases for more fuel-intensive cars. Second, inefficient ICE vehicles are less competitive relative to more fuel-efficient cars and EVs. Thus, the collateral value of ICE vehicles could shrink as a result of the carbon price. We find supporting evidence, since car values decrease significantly after the policy implementation. However, the decrease in collateral value is too small to explain the magnitude of the results. Thus, banks seem to price the risk of further more ambitious climate policies in the future. Such household stranded asset risk would materialize in the event of driving bans for ICE vehicles or very large CO2 prices. Finally, banks could develop green preferences as a result of the policy shock. However, this would not explain the large effect of the policy on credit contract terms away from balloon payments. Moreover, commercial banks are more likely to develop green preferences, but we find higher treatment effects for captive banks. Overall, we view the collateral channel as the most likely explanation for our results. Banks seem to price the risk of future, more stringent, climate policies, and as a result, increase interest rates, reduce loan duration and shift credit contracts toward linear repayments. More fuel-efficient vehicles are less affected.

Our empirical results are robust to controlling for a range of car and borrower characteristics. Results are also highly robust to using model, model-country, country, captive, balloon/linear credit type, bank type and time FE. We also reach similar conclusions by including/excluding incomplete loan-car model observations. Finally, we show that results are robust to using standard errors that are clustered at the car model, country, country-month and country-car model level. We can show graphical support for the parallel trends assumption in our empirical DiD design for both the policy announcement in 2019 and the policy implementation in 2021 for most outcomes variables. We also make sure that no comparable climate policy specifically directed at the automotive sector was introduced in any other European control country during the two event dates.

We contribute to three distinct literatures. First, we add to a literature on the effectiveness of climate policies by highlighting that the introduction of the German national CO2 price significantly altered loan conditions for ICE vehicles. Previous work assessing the real effects of climate policies focused on the direct impact of climate policies on aggregate emissions. Andersson, 2019 shows that the introduction of the Swedish CO2 tax reduced transport emissions by roughly 11% relative to a synthetic control. Colmer et al., 2024 and Dechezleprêtre et al., 2023 show that the EU ETS led to significant double-digit emission reductions in regulated installations, without detrimental impacts on regulated firms‘ economic performance. Moreover, no carbon leakage could be detected. Using regression discontinuity and synthetic control methods, Gugler et al., 2023 and Leroutier, 2022 show that the introduction of the British CO2 tax for the power sector also led to significant double-digit emission reductions through dirty plant closures, and increased emission efficiency. Finally, two recent papers go beyond case studies of successful climate policies and leverage a comprehensive cross-country climate policy database to show that, on average, more stringent climate policies led to larger emissions reductions (Nachtigall et al., 2024; Stechemesser et al., 2024). We extend this literature toward indirect impacts of climate policies. Most notably, we show an indirect credit channel through higher interest rates for higher risk loans. We thereby show for the first time in a plausibly causal setting, that sufficiently strict climate policies affect banks' lending behavior through interest rates, loan amounts and loan duration. Thus, carbon prices do not only directly influence emissions, but can also trigger emission reductions through financial market mechanisms, i.e., the credit spread – or risk premium compensating for household stranded asset risk. This indirect effect has not been studied before, but can add substantially to the direct effect of climate policies.

Second, we add to a quickly growing literature on the pricing of climate transition risks on financial markets. The focus of this literature has been on equity markets (Bolton and Kacperczyk, 2023; Pástor et al., 2022), corporate loans (Duan et al., 2023; Zerbib, 2019) and the options market (Ilhan et al., 2020). The results of these studies are inconclusive, as some authors find a brown premium, i.e., higher returns for brown assets, while others find a green premium, that is, outperforming green assets. Fliegel, 2025 argues that this is due to differences in measuring climate transition risks. He also shows that common measures of transition risk such as corporate emissions or E-scores do not grasp climate transition risk adequately. This is another advantage of our dataset: we can exactly determine the fuel efficiency and thereby the household stranded asset risk for every vehicle. We are not dependent on third-party environmental ratings. We extend this transition risk pricing literature toward household finances, by showing that policy induced asset stranding risks are also starting to be priced in durable consumer products, that is, browner more fuel-intensive vehicles pay higher interest rates compared to greener cars.

Finally, we contribute to a small literature in household finances investigating how banks price climate risks in household credits. Notably, Bena et al., 2023 show that hybrids are priced at higher interest rates, lower loan-to-value ratios, and shorter durations. They explain their findings with the higher risks of younger unproven technologies. Klee et al., 2024 find contradicting results as they show that EV loans enjoy a 2.2 percentage point lower interest rate compared to other vehicles. This effect is largely driven by captive banks. Kontz, 2025 uses US securitized loans to show that higher emission ABS are priced with lower interest rates but are rated with higher ESG scores. Finally, Ater and Yoseph, 2022 study the VW Dieselgate scandal. They find that both affected cars' resale value and monthly loan transactions fall relative to the control group. We extend the nascent literature on transition risk pricing in car loans beyond the small fraction of hybrid- or electric vehicles to the bulk of the global auto fleet that is still running on ICE technology. We show that owning such cars may be risky for households, as they face the risk of rising interest rates, falling car values as well as reduced credit duration.

The rest of this paper is structured as follows. We first provide a simple theoretical framework to establish interrelations between key variables and derive testable hypotheses. Next, we lay out the data and empirical methodology. We then present key results and conclude with a discussion.

2 Conceptual framework and predictions

We assume that banks provide loans priced at the interest rate r according to the following simple rationale[1]

$$r = f(EL) \tag{1}$$

The function f is increasing in the expected loss. The expected loss EL is composed of the probability of default PD and the loss-given-default LGD

$$EL = PD * LGD, \tag{2}$$

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

$$PD = g(PTI, CR). \tag{3}$$

Clearly, g is increasing in PTI. 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

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

$$PTI = \frac{FE + OC}{Income}. \tag{4}$$

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

$$LGD = \frac{LoanAmount\text{-}CV{*}RR}{LoanAmount}, \tag{5}$$

with the collateral value CV and the recovery rate RR. With this framework, we can assess the effect of the introduction of a CO2 price for the interest rate as follows. First, the CO2 price increases fuel expenses for the borrowers, which leads to an increase in PTI as

$$\frac{\partial PTI}{\partial FE} = \frac{1}{Income} > 0, \tag{6}$$

and as g is increasing in PTI, ceteris paribus this also leads to a higher probability of default

$$\frac{\partial g}{\partial FE} = \frac{\partial g}{\partial PTI}\frac{1}{Income} > 0. \tag{7}$$

We expect this channel to have a relevant effect as German households spend on average 12.3% of monthly income on transportation (Statistisches Bundesamt (Destatis), 2024). Moreover, transportation expenses are relatively inelastic (Bertrand and Morse, 2016). Klee et al., 2024 also find that higher gas prices lead to higher monthly default rates, using data from U.S. auto loans.

Regarding the effect of a CO2 price on the loss-given-default we can assume that it decreases the recovery rate as higher fuel costs might lead to an increase in supply and decrease of demand on the market for used cars, resulting in lower prices. We know that

$$\frac{\partial LGD}{\partial RR} = -\frac{CV}{LoanAmount} < 0, \tag{8}$$

thus, an increase in fuel costs also increases the loss-given-default. We thus have two channels of influence of a higher fuel price on the interest rate r, which both imply a positive effect of the introduction of a CO2 price on the interest rate for ICE loans. We thus formulate

Prediction 1. *For ICE cars, the introduction of a CO2 price leads to an increase in the interest rate for loans.*

As the influence of both channels increases with the fuel intensity of cars, we further predict

Prediction 2. *The positive effect of the introduction of a CO2 price on the interest rate for ICE cars is increasing in the fuel intensity of cars.*

3 Data & methods

3.1 Data

We draw on five large datasets. Two datasets on securitized car loans are prepared by the European Central Bank (ECB), which makes the data available via the European Data Warehouse (EDW). The rationale for the ECB to provide transparent and standardized securitization data rests on EU Regulation 2017/2402: The regulation aims to to guarantee transparency to enable accurate risk assessment for auto ABS, which requires knowledge of the underlying individual loans in terms of obligator' incomes, residual car values and regional distribution (Latino et al., 2024). Observations on car loans are available from 2005 to 2024. Due to changes regarding the characteristics and definitions of car loans, the EDW loan data is split into two separate datasets. We combine both EDW loan datasets by aligning variable definitions. We only retain variables that appear in both datasets.

We gain detailed data on vehicle characteristics from the German Department for Motor Vehicles (KBA). One dataset comprises information on technical car characteristics such as vehicle class, engine size, or the number of powered axles. A second dataset holds information on emission characteristics such as carbon monoxide (CO) or nitric oxides (Nox). A third dataset entails information on fuel consumption and carbon dioxide (CO2) emissions.

We string-match the roughly 30 million individual car loan observations from EDW with 10,000 different vehicle models from KBA, based on both brand and car model information. The final raw dataset comprises 24 million car loan observations that provide detailed car- and loan characteristics for the time from 2005 to 2024. Since we study a policy that was announced in late September 2019 and implemented on January 1st 2021, we restrict the dataset to the time from January 2019 to December 2021. Furthermore, we exclude all commercial buyers, all borrowers without country information, all manufacturer with less than 1,000 loans and all vehicle models with fewer than 100 loan-date observations as well as incomplete monthly availabilities, i.e., at least one loan per model per month for a given country. Due to the low number in our time period of interest, we exclude all electric, hydrogen and CNG powered vehicles from our dataset. These exclusions restrict the final dataset for the main analyzes to 6.75

million loan observations from 2019 to 2022. When we study the policy announcement, we rely on observations from 2019 to 2020. For the policy implementation, we focus on the years 2020 to 2021. Our data covers granular loan information for 11 European countries. Slightly more than 50% of loans (3.85 mio.) originate in Germany, followed by the UK (0.95 mio.) and Spain (0.80 mio.). Other countries in the dataset include Austria, Belgium, Finland, France, Italy, the Netherlands, Poland and Portugal[2].

In order to create the final dataset, we hand-label and align manufacturer definitions in the dataset. Next, we leverage ChatGPT o1 for aligning model categories per manufacturer and power source (EV, ICE, Hybrid). We manually check the accuracy of the results. This substantially reduces excessive and highly granular car categories in the original data to 314 car maker-model-power combinations.

We winsorize all continuous variables at the 1% level to account for database-specific errors and outliers. The descriptive statistics of the dataset are provided in Table 1. We see that the average European car loan carries an interest rate of roughly 5%. The average car value across new or used cars is 25,000€, however, only 5,000€ are provided through a loan. The average credit duration is four years.

Table 1: Summary statistics:

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Interest rate	6,541,756	5.01	2.38	0.06	11.5
Weight	6,741,146	1967.48	371.95	1330	3400
Fuel consumption	6,687,046	5.98	0.98	3.91	8.18
Car value	5,549,798	25075.84	13432.46	5400	73966.48
New car	6,729,848	0.53	0.50	0	1
Car registration year	5,276,719	2018.55	2.28	1917	2023
Bank type	6,741,146	0.75	0.44	0	1
Discount rate	6,726,751	2.86	2.84	0	10.16
Loan amount	6,741,146	15485.46	9125.22	1935.1	46697.68
Loan duration	6,726,751	50.62	18.02	0	160
Yearly income	3,459,150	34036.16	25151.77	5000	158352

Critically, in the automotive sector, many loans are provided by manufacturer-owned captive banks. To differentiate between captive and commercial banks we hand label all unique banks into captive or commercial. Roughly 75% of car loans in our dataset are provided by captive banks[3].

[2] For a detailed overview of loan observations per country, we refer to Table 11 of the Appendix

[3] For a detailed overview of loan observations per bank, we refer to Table 12 of the Appendix

3.2 Methodology

In order to identify the causal effect of climate policies on the credit market, we exploit the introduction of the German national CO2 price announced on the 20th of September 2019 and implemented in January 2021. By comparing German car loan pricing against control countries without such a policy shock for similar car models, we can exploit the policy implementation as a quasi-experiment. Most notably, we compare the interest rates of auto loans for ICE vehicles in Germany to the interest rates in 10 neighboring European control countries during the same period, before and after the policy. We rely on a DiD approach applied to our unique loan dataset. Critically, we cannot follow one loan across time and apply loan FE, since all loans in the dataset are unique time-loan recipient-car relations. We therefore use the assigned car maker-model-power categories in order to compare German loan pricing to the credit pricing of similar car models in control countries since most car models exist in both the treatment and control countries. As the policy implementation occurs at the country level, we can exploit a very tight empirical specification, comparing the within-variation before and after treatment across 314 similar car models across treatment and control countries. The baseline specification for our DiD estimation for repeated cross sections is:

$$Y_{ictb} = \beta_0 + \beta_1 \left(\text{Germany}_{ictb} \times \text{Post}_t\right) + \sum_{k=1}^{K} \gamma_k X_{ictb,k} + \mu_i + \mu_c + \mu_b + \mu_t + \varepsilon_{ictb} \tag{9}$$

where Y_{ictb} is the outcome variable for car model i, country c, bank b during month t (the loan interest rate, or other outcomes variables). Germany is a dummy that equals one if a loan originates in Germany and zero if otherwise. Post is a dummy that equals one for the months after the two respective treatment dates, that is, the announcement (September 2019) or the introduction (January 2021) of the German national CO2 price; and zero otherwise. $X_{ictb,k}$ is a rich set of control variables including car weight, fuel consumption, a new car dummy, registration year, and borrowers income. We do not include potential controls for loan characteristics such as car value, loan duration or loan amount as we will later show that these variables in itself change due to the treatment, making them endogenous. In our main specification we thus only control for car characteristics, and borrowers income. We, however, also show that our results are robust to using no controls. We include four sets of fixed effects in our baseline specification: car model fixed effects (μ_i) to control for time-invariant characteristics specific to each car model, country fixed effects (μ_c) to account for unobserved heterogeneity across countries, captive fixed effects (μ_b) to absorb differences among captive/commerical banks, and month-year fixed effects (μ_t) to capture common temporal shocks and seasonal trends. Such time FE are particularly relevant as the Covid-19 pandemic started in early 2020. However, our first event date is substantially before the Covid shock, and the policy implementation is significantly afterwards. In other empirical specifications, we also show that our results are robust to interacting both car model FE and country FE. Moreover, results are robust to using bank-type FE, however, specific bank type FE are just less granular model FE since captive banks predominately finance car models from their owning car manufacturer. We want to emphasize that the unique empirical settings mimics a propensity score matched DiD specification as we find for almost all car models a treatment/control counterpart [4]. As we only have 11 country clusters, in our baseline specification, we double cluster standard errors at the car model- and country level.

Our econometric approach relies on the identifying assumption that the pricing trajectory of treated auto-loans would have continued to follow untreated loans in the absence of the introduction of the German national CO2 price. We argue that this parallel trends assumption is plausible when evaluating the effects of the policy, given the large number of underlying loans in both Germany and neighboring countries, the large number of similar car models across countries and tight FE. The two most likely violations of the parallel trends assumption are, on the one hand: treated and control groups could be on different trajectories already before the introduction of the policy. On the other hand, different shocks in the transportation sector may differentially affect treatment and control group beyond the introduction of the studied policy. Either violation would bias our coefficient estimates. Concerning pre-trends in observable characteristics, we can test the violation in the months before the treatment through event study type graphs. We will show such figures in our result section. Concerns related to other shocks depend on the national context as well as on their timing, i.e., they must coincide with the introduction of the German CO2 price and must affect Germany and control countries differently. Several other European countries that are in our dataset introduced carbon prices for the transportation sector. Finish and Portuguese CO2 prices for the transportation sector remained constant in the critical event months. The French CO2 tax was introduced in 2010 and did not increase further after the Yellow Vest protests in late 2018. Austria and the Netherlands announced carbon pricing regimes after the focal time period. Hence, the German carbon price is not unique in

[4] See the Appendix for a full list of treatment and control car models.

Europe, but for the chosen time period, we are confident that the introduction of the German CO2 price was the only relevant carbon pricing shock to the transportation sector. However, the dynamic climate policy environment in Europe before 2019 makes it difficult to extend the pre-treatment period substantially longer.

Another key assumption for DiD is that the event is not widely anticipated. We argue that this holds particularly for the announcement of the German national CO2 price, which is the result of the political agreement between different political parties in Germany on September 20, 2019. This agreement was not widely anticipated and therefore we do not expect significant pre-treatment effects. The actual policy implementation on the other hand was hardly surprising to anyone familiar with the German policy environment. Finally, we do not expect spillovers or contagion in our empirical setting.

4 Results

We start by presenting the baseline results for the initial policy announcement in September 2019.

4.1 The policy announcement

As depicted in Table 2, we find consistently significant positive treatment effects already for the policy announcement on loan interest rates in Germany. The economic magnitude of 0.5 percentage points is sizable, given that the average German car loan carries an interest rate of 3.9%. Thus, even the lower bound estimate equates to an increase in financing costs of more than 10% for an average German borrower. The treatment effect is stable across empirical specifications. Most notably, adding car and borrower characteristics as controls does not alter the results. Moreover, results are stable when adding more FE such as model FE, country FE,model-country FE, captive FE, bank FE and month-year FE. Thereby, we tightly control for unobserved time-invariant heterogeneity as well as common shocks or trends that affect treatment and control group at one point in time. Given that the trends in financing terms are parallel before treatment, we can interpret any significant difference after treatment as a causal effect stemming from the climate policy in Germany.

As graphically shown in Figure 1, the parallel trends assumption roughly holds for the pre-treatment months. While some monthly coefficient estimates pre-treatment are below zero, no clear upward-sloping trend is recognizable. After treatment, the monthly coefficient estimates sharply increase and are consistently positive and sig-

Table 2: Effect of the German national CO2 price announcement on loan interest rates.

	(1)	(2)	(3)	(4)	(5)
Dep. variable			Loan interest rate		
Germany*Post	0.37***	0.64***	0.50***	0.44***	0.44***
	(5.44)	(7.90)	(6.66)	(5.59)	(5.60)
Weight		-0.00	-0.00	-0.00*	-0.00
		(-1.63)	(-0.56)	(-1.67)	(-1.39)
Fuel consumption		0.06	0.05	0.07*	0.07
		(1.51)	(1.38)	(1.74)	(1.55)
New car		0.11	0.19*	0.19**	0.21**
		(0.90)	(1.91)	(2.01)	(2.26)
Car registration year		-0.04***	-0.06***	-0.05***	-0.05***
		(-2.64)	(-3.55)	(-3.34)	(-2.95)
Income		-0.05***	0.01	0.01***	0.01***
		(-4.94)	(1.36)	(5.84)	(5.91)
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	Yes
Model X Country FE	Yes	No	No	No	Yes
Captive FE	No	No	Yes	No	No
Bank FE	Yes	No	No	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	4385545	2292095	2292095	2292095	2292090

Note: This table shows the results for the DiD estimation for the policy announcement of the German CO2 price in September 2019 based on equation (9). 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 sample period is the full years 2019 and 2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

nificant for 11 months after treatment. Interestingly, the confidence intervals widen sharply after treatment, potentially suggesting heightened uncertainty induced by the policy announcement. The persistent treatment effect shows that the policy shock led to a strong and sustained change in lending behavior by banks.

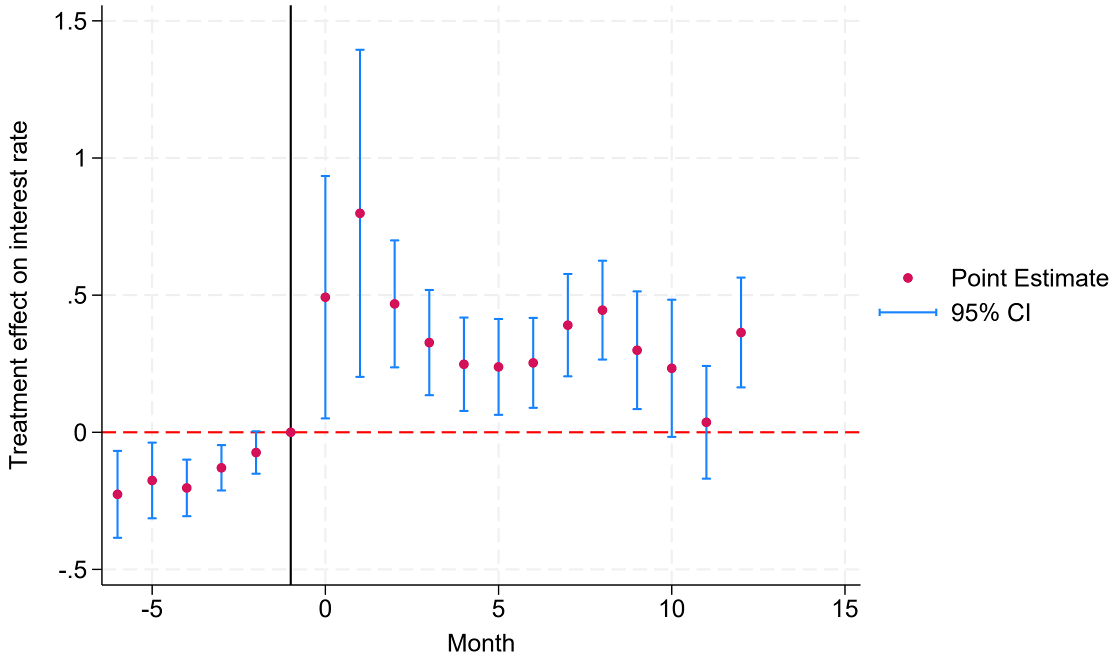

Figure 1: Treatment effect by month for the policy announcement in September 2019.

4.2 The policy implementation

We perform a similar analysis for the policy implementation in January 2021. One could expect no effect, given that the announcement already induced a significant positive treatment effect and banks are forward-looking. However, even the unsurprising policy implementation induced another smaller but significantly positive treatment effect. As depicted in Table 3, the estimates range from 0.20% to 0.38% when adding control variables. Again, results are robust to empirical specifications.

Table 3: Effect of the German national CO2 price implementation on loan interest rates.

	(1)	(2)	(3)	(4)	(5)
Dep. variable	Loan interest rate				
Germany*Post	0.09**	0.38***	0.36***	0.26***	0.20***
	(2.09)	(5.37)	(7.44)	(4.84)	(3.67)
Weight		-0.00	0.00	-0.00	-0.00
		(-1.25)	(1.06)	(-1.03)	(-1.13)
Fuel consumption		-0.01	-0.02	0.01	0.00
		(-0.21)	(-0.76)	(0.50)	(0.08)
New car		0.29**	0.50***	0.48***	0.49***
		(1.97)	(5.29)	(5.46)	(5.52)
Registration year		-0.03	-0.05*	-0.04	-0.04
		(-1.27)	(-1.73)	(-1.50)	(-1.28)
Income		-0.06***	0.00	0.01**	0.01*
		(-5.40)	(0.04)	(1.97)	(1.93)
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	Yes
Model X Country FE	Yes	No	No	No	Yes
Captive FE	No	No	Yes	No	No
Bank FE	Yes	No	No	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	3953117	1952319	1952319	1952319	1952303

Note: This table shows the DiD estimation for the implementation of the German CO2 price in January 2021 based on equation (9). 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 sample period is the full years 2020 and 2021. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

The event study in Figure 2 highlights parallel trends before January 2021 and a very clear jump in financing costs after the treatment. The positive treatment effect persists for 7 month after the policy implementation to then approach 0. Thus the treatment effect for the policy implementation is overall less strong in magnitude and shorter in duration compared to the policy announcement, however, it is highly significant.

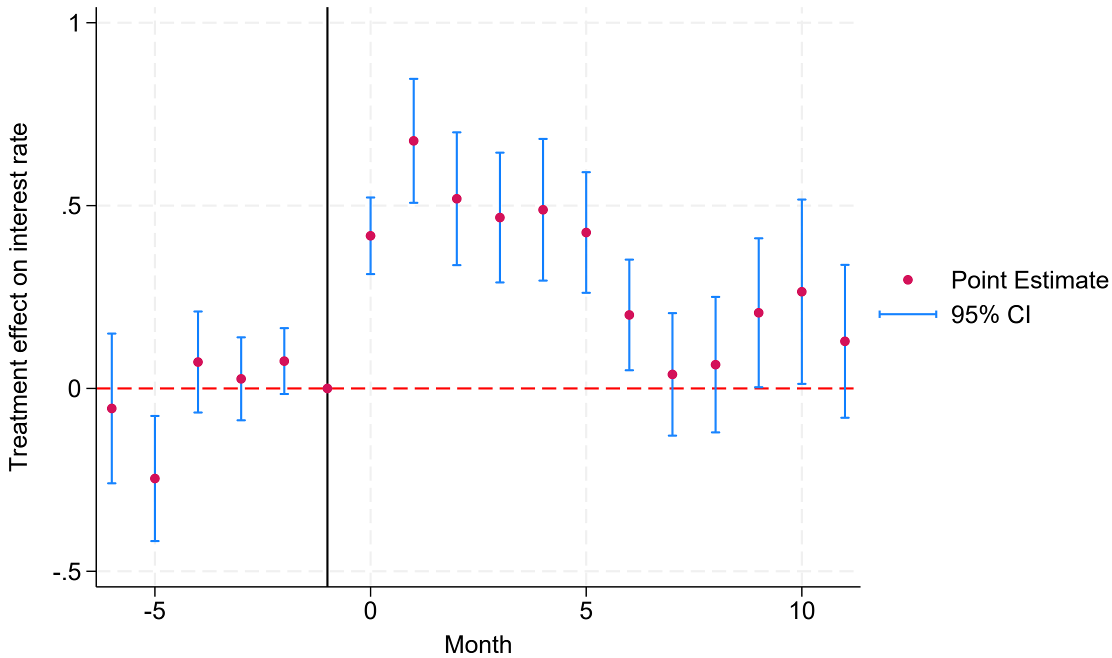

Figure 2: Treatment effect by month for the policy implementation in January 2021.

4.3 Triple DiD with fuel-efficiency

The German CO2 price aims to reduce CO2 emissions from the transportation sector by penalizing CO2 emitting energy technologies (ICE). However, very fuel-inefficient vehicles are more affected compared to more efficient vehicles. A given households total cost of ownership increases more, when it owns a very fuel-intensive car. We thus expect a stronger positive treatment effect for more fuel-intensive cars. Table 4 supports this hypothesis as we only find a significant positive treatment effect for the policy announcement for the top 20% in terms of fuel consumption. For the most fuel-efficient cars, we find no significant treatment effect. To further demonstrate the robustness of this finding, we also execute a triple DiD specification for the policy announcement. Therefore, we interact the Post and Treatment dummy with another dummy indicating if fuel-efficiency is above or below the median. The estimator is significantly positive and indicates that driving a very fuel-intensive car adds another 0.27 percentage point increase in interest rate to the average treatment effect of roughly 0.4%.

Table 4: Effect of the CO2 price on loans with respect to fuel efficiency.

	(1) Top 20% fuel consumption	(2) Bottom 20% fuel consumption	(3) DDD with fuel efficiency
Germany*Post*Fuel			0.27**
			(2.40)
Germany*Post	0.58***	0.19	0.39***
	(4.25)	(1.32)	(4.47)
Weight	-0.00	-0.00	-0.00
	(-0.60)	(-1.40)	(-0.72)
Fuel consumption	0.10	0.01	
	(1.63)	(0.06)	
New car	0.09	0.26	0.20*
	(0.68)	(1.48)	(1.93)
Registration year	-0.05	-0.04	-0.06***
	(-1.27)	(-1.41)	(-3.71)
Income	-0.01	-0.01	0.01
	(-1.13)	(-0.84)	(1.37)
Model FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes
# Loans	373283	555273	2297981

Note: This table shows the results for the DiD estimation for the announcement of the German CO2 price in September 2019. Columns 1 and 2 are based on equation (9). Column 3 features a triple DiD design where the dummies Post, Germany and fuel-efficiency are interacted. 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 sample period is the full years 2019 and 2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

4.4 Captive vs. commercial banks

Next, we investigate result heterogeneity with respect to the financial institution providing the loan contract to the household. A special feature of the automotive industry is that manufacturer-owned captive banks play a large role in providing households with vehicle financing options. In our dataset, roughly 75% of loans are provided by captive banks. In Table 5, we therefore separately estimate results for captive and commercial banks in our dataset. We find a statistically very significant treatment effect for both commercial and captive banks for interest rates, however, the treatment effect is higher for captive banks. To further corroborate this finding, we again perform a triple DiD estimation using a captive/commercial dummy. Results show that captive banks charge a significantly higher interest rate premium compared to commercial banks. Next, we also analyze the discount rate provided by banks to investors, who buy the securitized auto loans. We find substantially increased discount rates for captive banks. Commercial banks on the other hand reduce discount rates to investors after the event.

Table 5: Effect of the CO2 price on loans with respect to financial institutions.

	(1) Captive banks interest rate	(2) Captive banks discount rate	(3) Commercial banks interest rate	(4) Commercial banks discount rate	(5) DDD with captive bank
GER*Post *Capt.					0.23**
					(2.14)
GER*Post	0.38***	1.80***	0.14***	-0.12***	0.12***
	(3.62)	(4.06)	(5.93)	(-3.93)	(4.72)
Weight	-0.00*	-0.00*	-0.00	0.00**	-0.00
	(-1.70)	(-1.77)	(-1.00)	(2.24)	(-1.31)
Fuel consump.	0.06	0.04	0.01	0.00	0.05
	(1.21)	(0.98)	(0.46)	(0.05)	(1.43)
New car	0.20*	0.21**	0.02	0.24*	0.20**
	(1.79)	(2.49)	(0.52)	(1.92)	(2.09)
Reg. year	0.01	0.09***	-0.14***	0.04***	-0.05***
	(0.55)	(4.91)	(-20.24)	(4.03)	(-3.03)
Income	0.01***	-0.00	0.02***	0.02***	0.01***
	(2.61)	(-1.38)	(2.72)	(2.82)	(2.70)
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	1759299	1849768	532790	527815	2292095

Note: This table shows the results for the DiD estimation for the announcement of the German CO2 price in September 2019 based on equation (9) split by commercial/captive bank for different outcome variables. 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 sample period is the full years 2019 and 2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

4.5 Treatment effect for other outcome variables

Table 6 shows the treatment effect of the policy announcement on other relevant loan outcomes as well as the borrowers income. We find a negative effect on average loan duration, indicating that banks reduce long-term exposure to mounting carbon risks. We find no effect for borrowers income and car value. Interestingly, and very significant we find a strong negative effect on loan amount. Moreover, banks significantly change the credit type as a result of the policy announcement, that is, after treatment banks use significantly more linear type credit structure, while reducing balloon type credits. This shows risk-averse behavior from banks with respect to German borrowers as balloon type credits are riskier since borrowers must pay a large sum at the end of the credit term, while linear credits offer banks a more predictable repayment schedule. In line with the observations that banks limit loan duration, this indicates that bank try to limit medium to long-term repayment risks of ICE loans. A concern that might arise is that the increase in interest rate can solely be explained by the shift toward linear repayment contracts since banks earn less interest income in absolute terms on linear credits. Banks therefore potentially increase interest rates on linear credits to compensate for this lower income. We also separately run the regression for balloon/linear credits and apply credit contract FE, results remain highly positively significant (Table 10 of the Appendix). For all significant variables, we also show the monthly event study plots in the Appendix. Most notably, parallel trends are very robust for for loan duration, loan amount, linear type credits and balloon type credits. For car value we see one monthly estimate post event being negative and significant, however, all other estimates are insignificant.

Interestingly, results are roughly similar for the policy announcement and the policy implementation (depicted in Table 7 of the Appendix). One notable difference is the highly significant effect for car value. The event study plot for car value in the Appendix exhibits parallel trends before treatment and persistently falling monthly coefficient estimates afterwards. The average estimate approaches values of below €1000.

Table 6: Effect of the CO2 price announcement on other outcome variables.

	(1) Loan duration	(2) Car value	(3) Loan amount	(4) Linear credits	(5) Balloon Credits	(6) Income
Germany*Post	-1.70***	-340.15	-1877.48***	0.13***	-0.11***	0.00
	(-5.94)	(-1.28)	(-7.57)	(10.37)	(-8.00)	(0.20)
Weight	0.00***	7.77***	5.61***	-0.00	0.00	0.00***
	(6.29)	(7.30)	(7.24)	(-1.58)	(0.99)	(3.02)
Fuel consumption	-0.64***	464.44	-152.14	0.02***	-0.02**	0.03*
	(-3.65)	(1.45)	(-0.92)	(2.61)	(-2.47)	(1.66)
New car	-3.36***	5848.24***	-379.36	0.03	0.01	0.29***
	(-6.66)	(9.69)	(-1.25)	(1.03)	(0.50)	(7.79)
Registration year	0.94***	1716.07***	798.95***	-0.00	0.01***	0.14***
	(5.58)	(18.68)	(12.37)	(-1.63)	(3.10)	(22.44)
Income	-0.65***	214.01***	35.17	-0.00**	0.00	
	(-17.01)	(8.77)	(1.61)	(-2.07)	(0.59)	
Model FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes	Yes
# Loans	2382993	2197630	2382993	2382993	2382993	2382993

Note: This table shows the results for the DiD estimation for the announcement of the German CO2 price in September 2019 based on equation (9) for a range of other outcome variables. 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 sample period is the full years 2019 and 2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

5 Discussion & conclusion

Summing up, we find substantial treatment effects for both policy announcement and implementation. The economic magnitude amounts to more than a 10% increase in financing costs for the average German car purchase relative to the before treatment period. We further show that the treatment effect is driven by the most fuel-inefficient vehicles, indicating that banks reward more fuel-efficient vehicles in light of upcoming carbon pricing. We also demonstrate interesting bank heterogeneity; that is, captive banks increase financing costs more than commercial banks. Finally, we show that banks reduce lending amounts and loan duration to German households as a result of both policy announcement and implementation. Banks are changing their preferred credit type strongly post event, that is, balloon type credits with a large one-time payment at the end of the credit term are reduced, while linear repayment credit schedules increase in usage post event in Germany. In terms of collateral value, we only find shrinking collateral values after the policy implementation, but not the announcement. We find evidence for Prediction 1, as financing costs increase sharply as a result of the carbon price policy in Germany. We find an even stronger effect for captive banks compared to commercial banks. Interestingly, captive banks increase discounting post event, indicating that they face difficulties selling the now riskier assets to investors. In line with Prediction 2, we show that the treatment effect is mediated by fuel efficiency, suggesting that banks pay close attention to the increasing total costs of ownership for ICE vehicles, as they only increase financing costs for more fuel-intensive vehicles.

Our results are robust to a whole battery of robustness tests and alternative specifications. Most notably, they are robust to using fewer control variables, a wide range of FE, relying on different clustering methods for the standard error (Table 9 of the Appendix), both event dates, and to including/excluding car models without full credit availability (Table 8 of the Appendix). We further demonstrate parallel trends for all key outcome variables. Lastly, we make sure that control countries did not impose comparable climate policies directed at the transportation sector.

We see a surprisingly strong reaction to the introduction of the Germany national CO2 price, given that initial carbon prices are low. We also see higher volatility in estimates post event, indicating heightened uncertainty in lending. In line with our theoretical model, the sharp reaction to the carbon price announcement may be explained by either increased total costs of ownership for ICE vehicles leading to rising probabilities of default as well as a shrinking collateral value for a given ICE vehicle, since ICE vehicles suddenly became less competitive relative to more fuel-efficient vehicles. Another explanation for the strong reaction of banks to carbon prices are green preferences. We will now briefly investigate each potential channel.

Increasing probability of default

The average probability of default of individual consumers in Germany for auto loans is substantial, at roughly 3.3% (Fenner and Vollmar, 2023). Ceteris Paribus, owning an ICE vehicle after the introduction of the Germany CO2 price, becomes more expensive, which increases this probability of default for borrowers. However, the initial CO2 prices are too small to matter economically and we already find a treatment effect for the policy announcement in 2019, years before the pricing scheme even started. Another argument against a probability of default channel is the non significant result for income, indicating that banks do not shift to wealthier individuals past event, which would reduce the probability of default. If a probability of default channel is at work, we do not expect it to be key to explaining our results.

Shrinking collateral values

For the policy implementation, we find a small but significant effect on car value, indicating that German collateral (car) values are decreasing compared to similar models in untreated countries. However, the small magnitude of €400 does not justify such a steep increase in financing costs. We offer another explanation: climate policy adoption is often staggered, that is, initial less stringent climate policies are followed by more ambitious policies. Indeed, the German national CO2 price is rising over time and was designed with the objective to later merge with the EU ETS, which would substantially increase the carbon price beyond 55€, given current EU ETS prices. Banks may price the risk that the collateral value of the car will decrease further and the car may potentially even become stranded when carbon prices rise, or driving bans limit the value of ICE vehicles. Thus, the carbon price introduction might function as a salience shock for banks, inducing larger effects on interest rates than would be justified by the small decrease in collateral value. We find evidence for such medium to long term bank risk aversion with respect to ICE financing in both the reduced loan duration and the shift away from balloon type credits to linear repayments with less long-term repayment risk. Critically, this explanation implies that banks are either more risk averse or more forward looking compared to other market participants because they change lending strongly while car prices do not react substantially. We argue that this is possible, given that consumer car prices are determined by consumer demand and consumers are plausibly less forward-looking in decision making compared to banks.

Banks green preferences

Finally, banks might develop green preferences after the German policy shock. Thus banks may enjoy holding greener assets and may see greener assets as a hedge against more regulation in the future. This argumentation is in line with a similar explanation for a brown risk premium for companies in the equity market (Pástor et al., 2021). Critically, individuals are not a business with inherent climate transition risk, however, households face stranding asset risks too, when regulation prohibits using the emitting durable consumer product, thus similarly to companies, banks may want to charge a premium for financing such risky brown assets.

Conclusion

We contribute to the nascent literature on the impact of carbon pricing on the consumer credit market by providing, for the first time, plausibly causal evidence that salient climate policies not only affect fossil-fuel prices, but also have indirect effects through consumer credit markets. Future research could expand the analysis to other continents. Another avenue for future research is comparing the effects for carbon pricing with results for non market-based policies such as driving bans or efficiency standards.

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6 Appendix

6.1 Event study graphs for loan duration

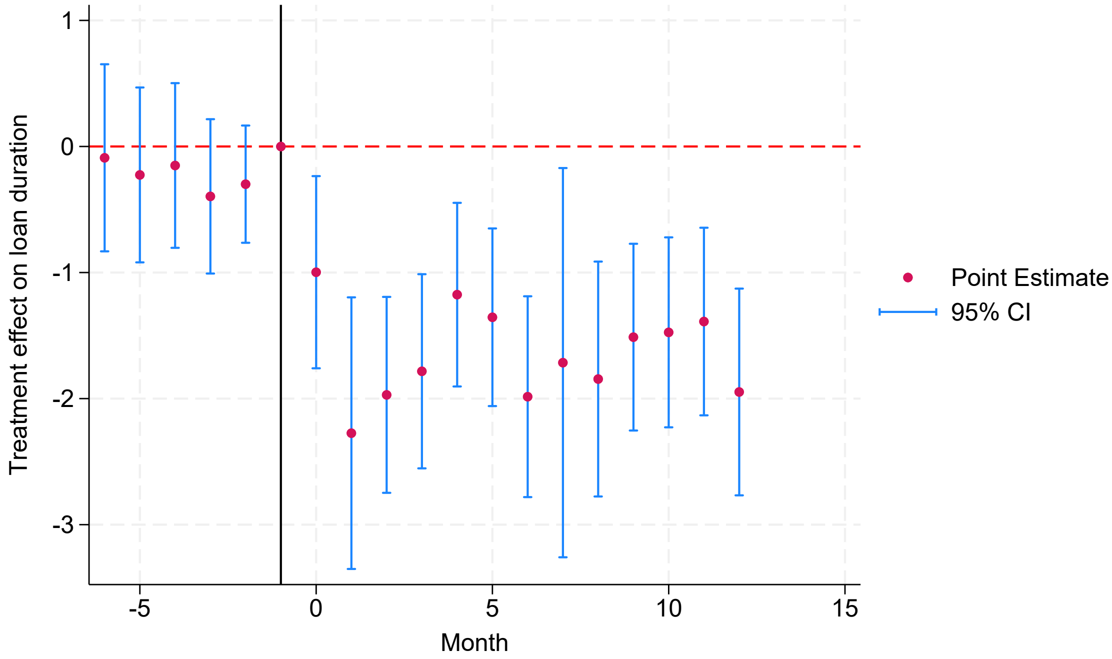

Figure 3: Treatment effect by month for the policy announcement in September 2019 for the loan duration.

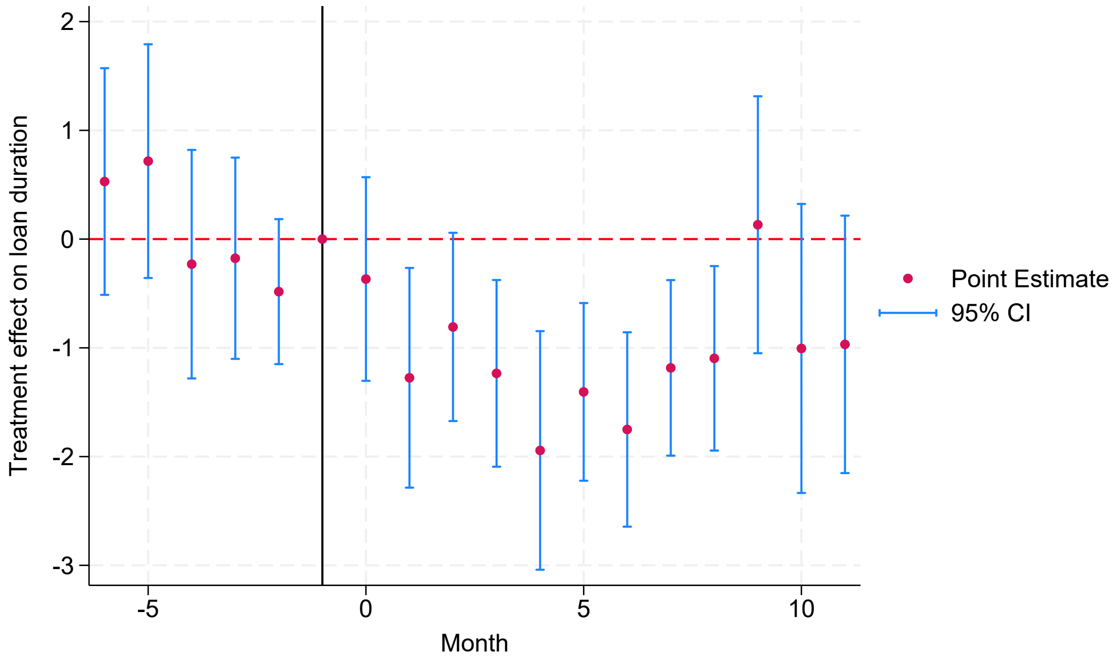

Figure 4: Treatment effect by month for the policy implementation in January 2021 for the loan duration.

6.2 Event study graphs for car value

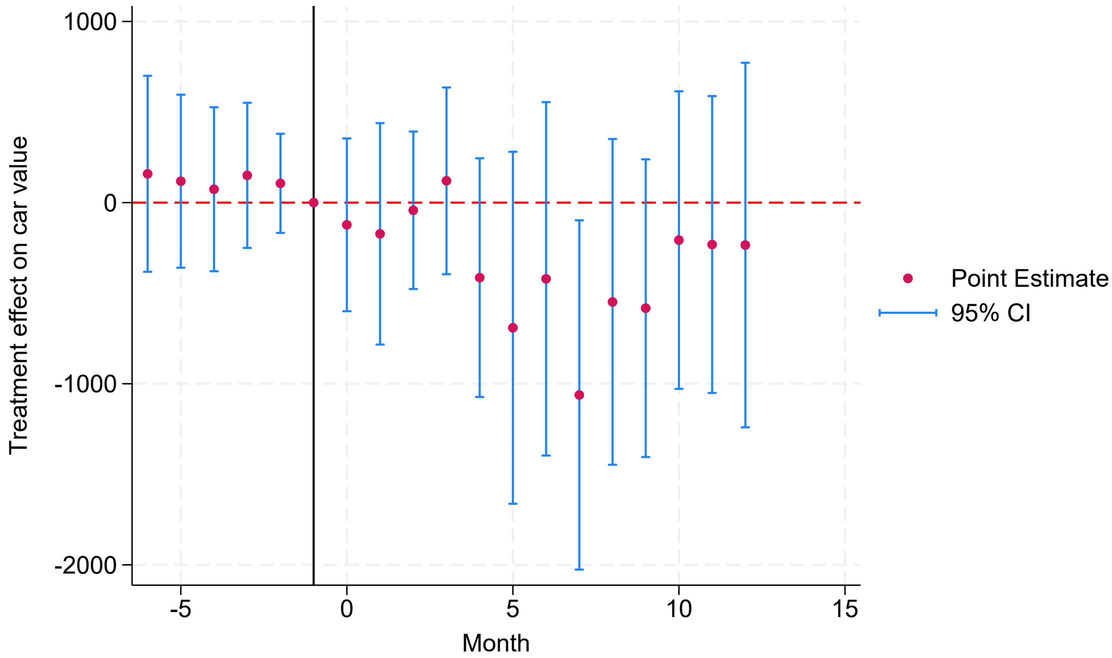

Figure 5: Treatment effect by month for the policy announcement in September 2019 for car value.

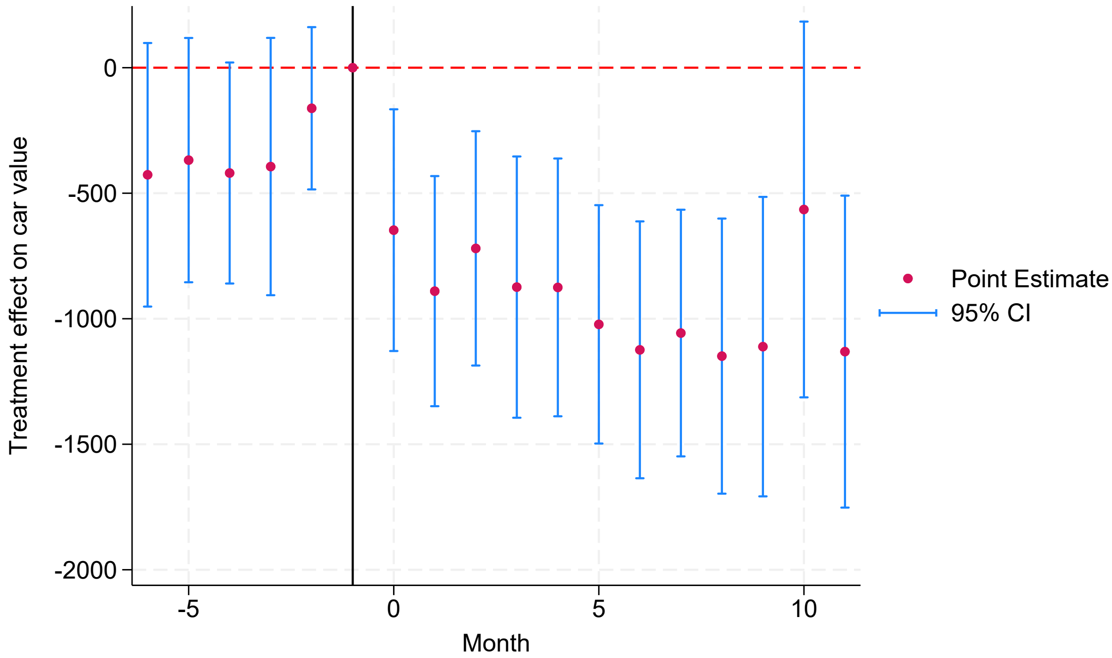

Figure 6: Treatment effect by month for the policy implementation in January 2021 for car value.

6.3 Event study graphs for loan amount

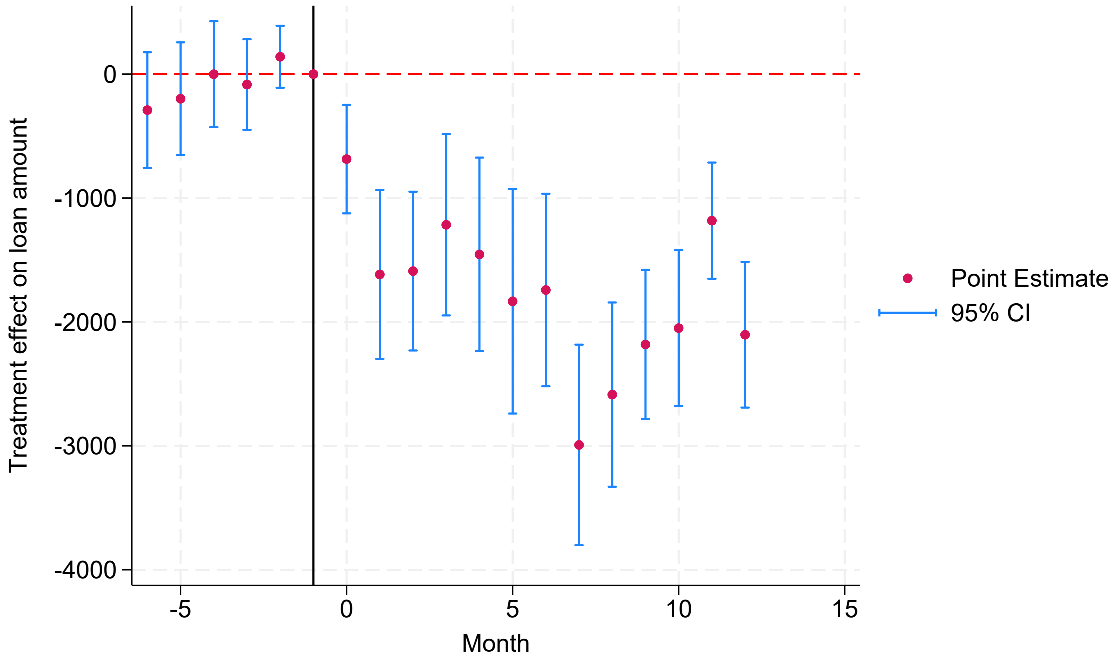

Figure 7: Treatment effect by month for the policy announcement in September 2019 for the loan amount.

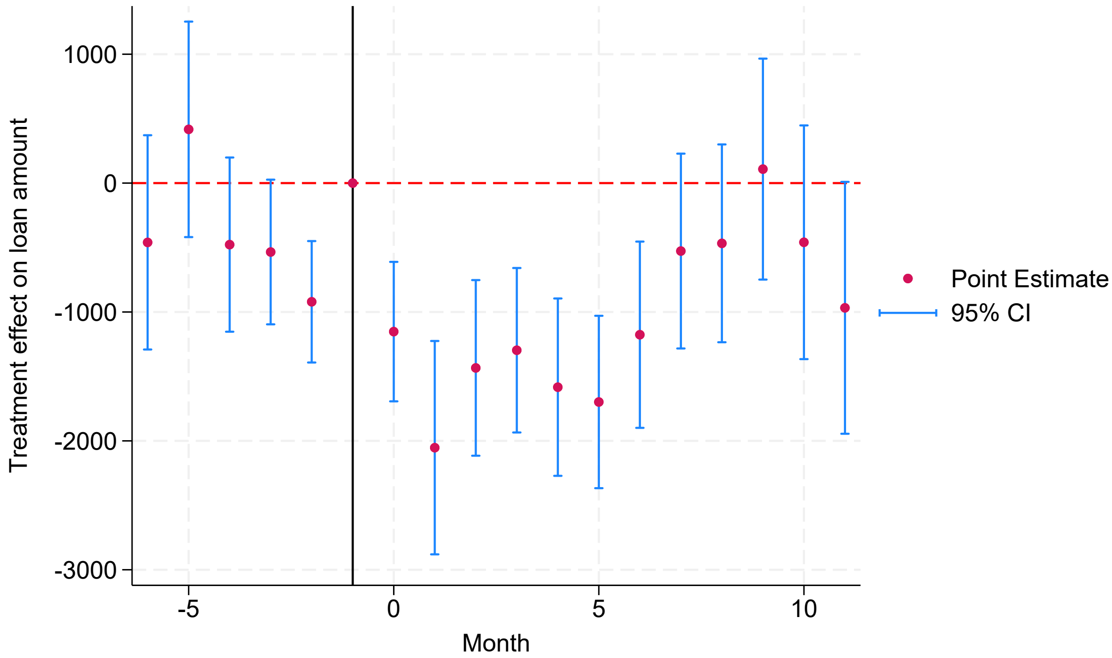

Figure 8: Treatment effect by month for the policy implementation in January 2021 for the loan amount.

6.4 Event study graphs for linear credits

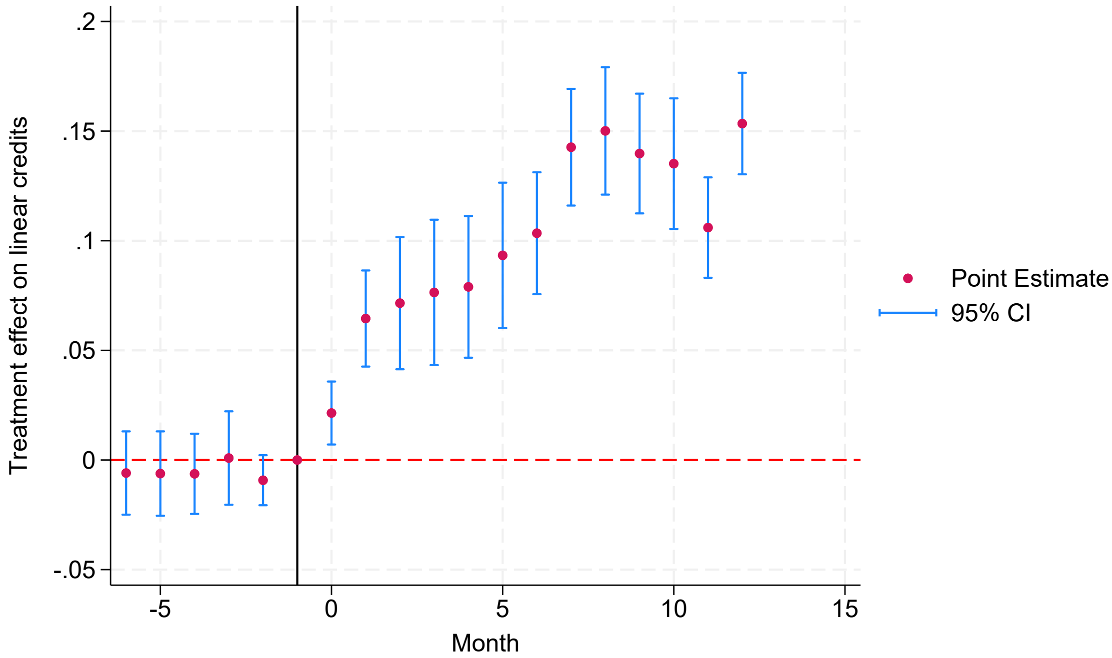

Figure 9: Treatment effect by month for the policy announcement in September 2019 for linear credits.

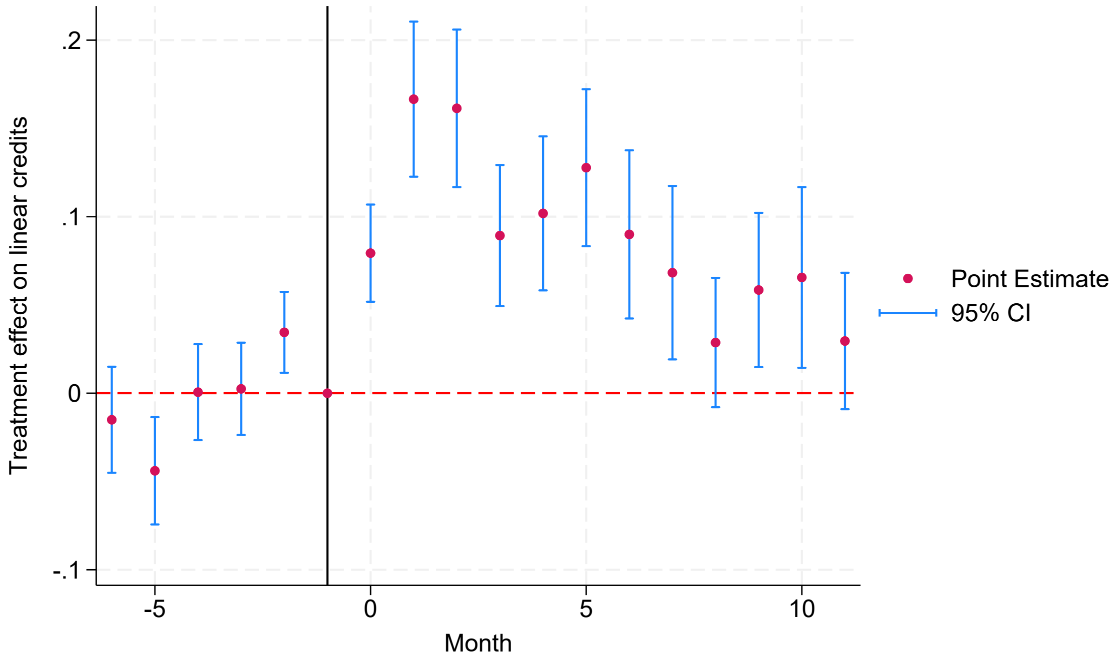

Figure 10: Treatment effect by month for the policy implementation in January 2021 for linear credits.

6.5 Event study graphs for balloon credits

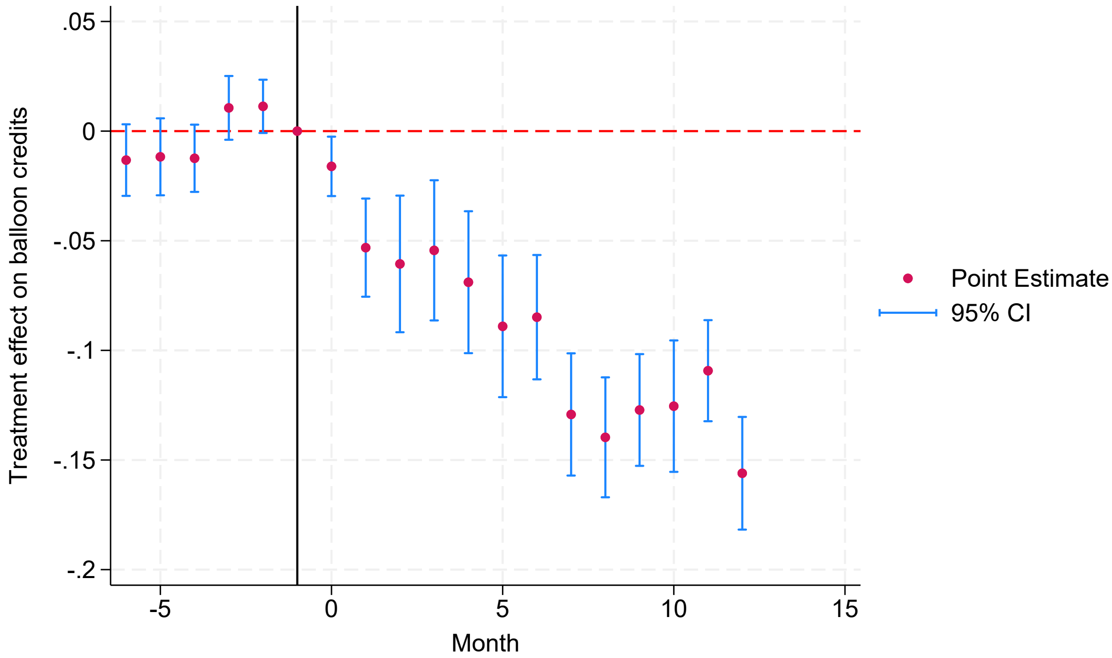

Figure 11: Treatment effect by month for the policy announcement in September 2019 for balloon credits.

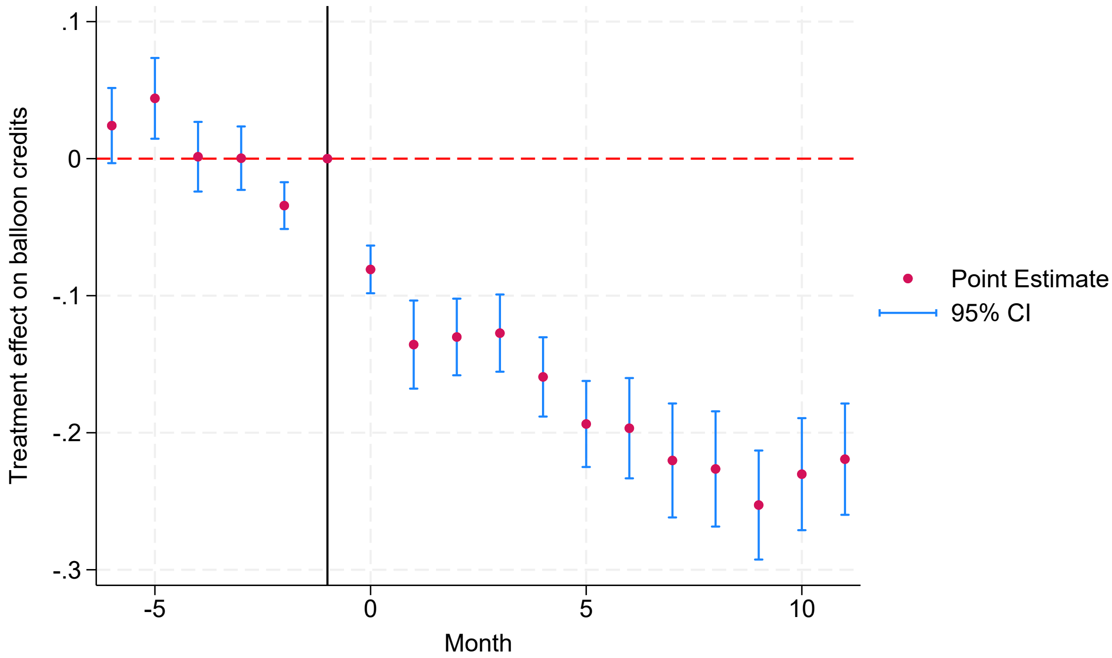

Figure 12: Treatment effect by month for the policy implementation in January 2021 for balloon credits.

6.6 Other outcome variables for the policy implementation

Table 7: Effect of the CO2 price implementation on other outcome variables.

	(1) Loan duration	(2) Car value	(3) Loan amount	(4) Linear credits	(5) Balloon Credits	(6) Income
Germany*Post	-1.50***	-404.75**	-834.03***	0.11***	-0.20***	-0.01
	(-2.87)	(-2.01)	(-3.34)	(7.49)	(-14.72)	(-0.26)
Weight	0.00*	8.51***	4.76***	-0.00	-0.00	0.00***
	(1.81)	(7.04)	(4.61)	(-0.22)	(-0.90)	(2.90)
Fuel consumption	0.07	1018.37**	366.63***	0.01	-0.01*	0.10***
	(0.29)	(2.39)	(2.64)	(0.82)	(-1.91)	(2.96)
New car	-3.93***	7107.22***	-955.27**	0.04	0.03**	0.27***
	(-6.39)	(9.14)	(-2.24)	(1.54)	(2.07)	(7.18)
Registration year	0.86***	1665.03***	692.09***	-0.00	0.00**	0.13***
	(4.78)	(17.33)	(6.12)	(-0.65)	(2.10)	(20.17)
Income	-0.64***	225.47***	29.83	-0.00***	0.00	
	(-13.22)	(8.81)	(1.42)	(-2.65)	(0.97)	
Model FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes	Yes
# Loans	2020772	1939321	2020772	2020772	2020772	2020772

Note: This table shows the results for the DiD estimation for the implementation of the German CO2 price in January 2021 based on equation (9) for a range of other outcome variables. 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 sample period is the full years 2020 and 2021. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

6.7 Results when including incomplete observations

Table 8: Effect of the German national CO2 price announcement on loan interest rates.

	(1)	(2)	(3)	(4)	(5)
Dep. variable			Loan interest rate		
Germany*Post	0.37***	0.65***	0.51***	0.44***	0.44***
	(5.58)	(8.39)	(6.96)	(5.88)	(5.74)
Weight		-0.00	-0.00	-0.00	-0.00
		(-1.58)	(-0.51)	(-1.64)	(-1.39)
Fuel consumption		0.07	0.06	0.07*	0.07
		(1.63)	(1.40)	(1.77)	(1.58)
New car		0.09	0.19*	0.19**	0.22**
		(0.78)	(1.95)	(2.10)	(2.38)
Car registration year		-0.05***	-0.06***	-0.06***	-0.05***
		(-3.15)	(-4.10)	(-3.87)	(-3.29)
Income		-0.06***	0.01	0.01***	0.01***
		(-5.41)	(1.59)	(6.17)	(6.16)
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	Yes
Model X Country FE	Yes	No	No	No	Yes
Captive FE	No	No	Yes	No	No
Bank FE	Yes	No	No	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	4622962	2419381	2419381	2419381	2419257

Note: This table shows the results for the DiD estimation for the policy announcement of the German CO2 price in September 2019 based on equation (9). The unit of observation is the monthly loan level. The sample is not restricted to car models, which have complete observations for all month within a country. The sample period is the full years 2019 and 2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

6.8 Results for different standard error clusters

Table 9: Effect of the German national CO2 price announcement on loan interest rates.

	(1)	(2)	(3)	(4)
Dep. variable	Loan interest rate			
Germany*Post	0.50***	0.50***	0.50***	0.50***
	(6.66)	(9.43)	(5.44)	(6.46)
Weight	-0.00	-0.00	-0.00	-0.00
	(-0.56)	(-0.49)	(-0.51)	(-0.54)
Fuel consumption	0.05	0.05**	0.05**	0.05
	(1.38)	(2.63)	(2.41)	(1.41)
New car	0.19*	0.19**	0.19**	0.19*
	(1.91)	(2.96)	(2.95)	(1.74)
Car registration year	-0.06***	-0.06	-0.06	-0.06***
	(-3.55)	(-1.42)	(-1.46)	(-3.84)
Income	0.01	0.01	0.01	0.01
	(1.36)	(1.22)	(1.21)	(1.38)
Model FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes
# Loans	2292095	2292095	2292095	2292095

Note: This table shows the results for the DiD estimation for the policy announcement of the German CO2 price in September 2019 based on equation (9). 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 sample period is the full years 2019 and 2020. Standard errors are clustered at the country-car model level (1), the country level (2), the country-month level (3), and the car model level (4). $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

6.9 Applying credit contract term fixed effects

Table 10: Effect of the German national CO2 price announcement on loan interest rates.

	(1)	(2)	(3)
Dep. variable	Loan interest rate		
Germany*Post	0.31***	0.13**	0.22***
	(5.44)	(2.08)	(2.62)
Weight	-0.00	-0.00	-0.00
	(-0.14)	(-0.45)	(-0.93)
Fuel consumption	0.03	0.00	0.08**
	(0.95)	(0.01)	(2.42)
New car	0.15*	0.30***	0.10
	(1.80)	(3.35)	(1.01)
Car registration year	-0.05***	-0.04**	-0.08***
	(-3.74)	(-2.24)	(-9.43)
Income	0.01**	0.01***	0.01*
	(2.53)	(2.84)	(1.85)
Credit contract FE	Yes	No	No
Model FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes
Observations	2292095	1488037	701775

Note: This table shows the results for the DiD estimation for the policy announcement of the German CO2 price in September 2019 with special emphasis on the type of credit contract. The first column shows baseline results, but includes credit contract FE, the second and third column are separate estimations for linear and balloon type credits only. 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 sample period is the 2019-2020. Standard errors are double clustered at the country-car model level. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

6.10 Observations per country

Table 11: Observations per country.

Country	Frequency	Percent
Austria	34,402	0.51
Belgium	71,826	1.07
Finland	77,167	1.14
France	284,038	4.21
Germany	3,846,353	57.06
Italy	497,232	7.38
Netherlands	58,555	0.87
Poland	26,121	0.39
Portugal	105,758	1.57
Spain	792,203	11.75
United Kingdom	947,491	14.06
Total	6,741,146	100.00

Note: Observations split by country for the time period from 2019 until the end of 2021.

6.11 Observations per bank

Table 12: Observations per bank.

Category	Freq.	Percent
Captive-BMW	247,132	3.67
Captive-FCA	291,725	4.33
Captive-Ford	162,161	2.41
Captive-PSA	416,305	6.18
Captive-RCI	365,817	5.43
Captive-TOYOTA	148,169	2.20
Captive-VW	3,329,489	49.39
Captive-other	63,539	0.94
Commercial-BNP	16,251	0.24
Commercial-Kraftfahrzeuggewerbe	188,312	2.79
Commercial-Santander	993,481	14.74
Commercial-smaller	518,765	7.70
Total	6,741,146	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.

6.12 List of car models

For our baseline specification we have a total of 636 car models, separated by treatment and control models. There are only 8 models with very little observations that do not have a treatment control counterpart. All other car models appear in both treatment and control countries. The following Table 13 lists all car models used for the baseline analysis separated for treatment and control countries.

Table 13: List of car models split for control and treatment country

Control Countries	**Germany**
bmw 1 Series	bmw 1 Series
peugeot 107	peugeot 107
peugeot 108	peugeot 108
bmw 2 Series	bmw 2 Series
peugeot 2008	peugeot 2008
peugeot 206	peugeot 206
peugeot 207	peugeot 207
peugeot 208	peugeot 208
bmw 3 Series	bmw 3 Series
peugeot 3008	peugeot 3008
peugeot 307	peugeot 307
peugeot 308	peugeot 308
nissan 370Z	nissan 370Z
peugeot 4008	peugeot 4008
peugeot 407	peugeot 407
bmw 5 Series	bmw 5 Series
fiat 500 Series	fiat 500 Series
peugeot 5008	peugeot 5008
peugeot 508	peugeot 508
bmw 7 Series	bmw 7 Series
peugeot 807	peugeot 807
porsche 911 Carrera	porsche 911 Carrera
mercedes A-Class	mercedes A-Class
audi A1	audi A1
audi A3	audi A3
audi A4	audi A4
audi A5	audi A5

Control Countries	**Germany**
audi A6	audi A6
audi A7	audi A7
audi A8	audi A8
mercedes AMG	mercedes AMG
mitsubishi ASX	mitsubishi ASX
honda Accord	honda Accord
opel Adam	opel Adam
opel Agila	opel Agila
seat Alhambra	seat Alhambra
seat Altea	seat Altea
opel Antara	opel Antara
seat Arona	seat Arona
volkswagen Arteon	volkswagen Arteon
opel Astra	opel Astra
seat Ateca	seat Ateca
toyota Auris	toyota Auris
toyota Avensis	toyota Avensis
toyota Aygo	toyota Aygo
mercedes B-Class	mercedes B-Class
ford B-Max	ford B-Max
subaru BRZ	subaru BRZ
hyundai Bayon	hyundai Bayon
volkswagen Beetle	volkswagen Beetle
bentley Bentayga	bentley Bentayga
citroen Berlingo	citroen Berlingo
peugeot Bipper	peugeot Bipper
peugeot Boxer	peugeot Boxer
porsche Boxster	porsche Boxster
fiat Bravo	fiat Bravo
mercedes C-Class	mercedes C-Class
citroen C-Elysee	citroen C-Elysee
toyota C-HR	toyota C-HR
ford C-Max	ford C-Max
citroen C1	citroen C1
citroen C2	citroen C2

Control Countries	**Germany**
citroen C3	citroen C3
volvo C30	volvo C30
citroen C4	citroen C4
citroen C5	citroen C5
volkswagen CC	volkswagen CC
mercedes CLA	mercedes CLA
mercedes CLA-Class	mercedes CLA-Class
mercedes CLS-Class	mercedes CLS-Class
honda CR-V	honda CR-V
volkswagen Caddy	volkswagen Caddy
toyota Camry	toyota Camry
renault Captur	renault Captur
volkswagen Caravelle	volkswagen Caravelle
opel Cascada	opel Cascada
porsche Cayman	porsche Cayman
kia Ceed	kia Ceed
suzuki Celerio	suzuki Celerio
skoda Citigo	skoda Citigo
honda Civic	honda Civic
renault Clio	renault Clio
mitsubishi Colt	mitsubishi Colt
opel Combo	opel Combo
jeep Compass	jeep Compass
bentley Continental	bentley Continental
toyota Corolla	toyota Corolla
opel Corsa	opel Corsa
hyundai Coupe	hyundai Coupe
volkswagen Crafter	volkswagen Crafter
opel Crossland	opel Crossland
citroen DS3	citroen DS3
citroen DS4	citroen DS4
citroen DS5	citroen DS5
fiat Doblo	fiat Doblo
dacia Dokker	dacia Dokker
fiat Ducato	fiat Ducato

Control Countries	**Germany**
dacia Duster	dacia Duster
mercedes E-Class	mercedes E-Class
mitsubishi Eclipse Cross	mitsubishi Eclipse Cross
ford EcoSport	ford EcoSport
ford Edge	ford Edge
volkswagen Eos	volkswagen Eos
renault Espace	renault Espace
seat Exeo	seat Exeo
peugeot Expert	peugeot Expert
ford Explorer	ford Explorer
skoda Fabia	skoda Fabia
ford Fiesta	ford Fiesta
fiat Fiorino	fiat Fiorino
ford Focus	ford Focus
subaru Forester	subaru Forester
volkswagen Fox	volkswagen Fox
ford Fusion	ford Fusion
mercedes GLA-Class	mercedes GLA-Class
mercedes GLC-Class	mercedes GLC-Class
mercedes GLE-Class	mercedes GLE-Class
toyota GT86	toyota GT86
ford Galaxy	ford Galaxy
hyundai Getz	hyundai Getz
maserati Ghibli	maserati Ghibli
alfa romeo Giulia	alfa romeo Giulia
alfa romeo Giulietta	alfa romeo Giulietta
volkswagen Golf	volkswagen Golf
opel Grandland	opel Grandland
honda HR-V	honda HR-V
toyota Hiace	toyota Hiace
seat Ibiza	seat Ibiza
suzuki Ignis	suzuki Ignis
subaru Impreza	subaru Impreza
nissan Infiniti Q-Series	nissan Infiniti Q-Series
opel Insignia	opel Insignia

Control Countries	**Germany**
honda Jazz	honda Jazz
volkswagen Jetta	volkswagen Jetta
suzuki Jimny	suzuki Jimny
nissan Juke	nissan Juke
citroen Jumper	citroen Jumper
ford Ka	ford Ka
renault Kadjar	renault Kadjar
skoda Kamiq	skoda Kamiq
renault Kangoo	renault Kangoo
opel Karl	opel Karl
skoda Karoq	skoda Karoq
skoda Kodiaq	skoda Kodiaq
renault Koleos	renault Koleos
hyundai Kona	hyundai Kona
ssangyong Korando	ssangyong Korando
ford Kuga	ford Kuga
renault Laguna	renault Laguna
mitsubishi Lancer	mitsubishi Lancer
seat Leon	seat Leon
maserati Levante	maserati Levante
subaru Levorg	subaru Levorg
dacia Lodgy	dacia Lodgy
dacia Logan	dacia Logan
bmw M Series	bmw M Series
porsche Macan	porsche Macan
renault Master	renault Master
mazda Mazda 2	mazda Mazda 2
mazda Mazda 3	mazda Mazda 3
mazda Mazda 5	mazda Mazda 5
mazda Mazda 6	mazda Mazda 6
mazda Mazda CX-3	mazda Mazda CX-3
mazda Mazda CX-30	mazda Mazda CX-30
mazda Mazda CX-5	mazda Mazda CX-5
mazda Mazda CX-7	mazda Mazda CX-7
mazda Mazda MX-5	mazda Mazda MX-5

Control Countries	**Germany**
renault Megane	renault Megane
opel Meriva	opel Meriva
nissan Micra	nissan Micra
seat Mii	seat Mii
bmw Mini	bmw Mini
fiat Mito	fiat Mito
renault Modus	renault Modus
opel Mokka	opel Mokka
ford Mondeo	ford Mondeo
opel Movano	opel Movano
volkswagen Multivan	volkswagen Multivan
nissan Murano	nissan Murano
ford Mustang	ford Mustang
nissan NV-Series	nissan NV-Series
citroen Nemo	citroen Nemo
nissan Note	nissan Note
skoda Octavia	skoda Octavia
kia Optima	kia Optima
fiat Other Fiat	fiat Other Fiat
subaru Outback	subaru Outback
mitsubishi Outlander	mitsubishi Outlander
porsche Panamera	porsche Panamera
fiat Panda	fiat Panda
volkswagen Passat	volkswagen Passat
nissan Pathfinder	nissan Pathfinder
volkswagen Phaeton	volkswagen Phaeton
kia Picanto	kia Picanto
volkswagen Polo	volkswagen Polo
nissan Primastar	nissan Primastar
toyota Prius	toyota Prius
kia ProCeed	kia ProCeed
toyota Proace	toyota Proace
nissan Pulsar	nissan Pulsar
ford Puma	ford Puma
fiat Punto	fiat Punto

Control Countries	**Germany**
audi Q2	audi Q2
audi Q3	audi Q3
audi Q5	audi Q5
audi Q7	audi Q7
audi Q8	audi Q8
nissan Qashqai	nissan Qashqai
toyota RAV4	toyota RAV4
peugeot RCZ	peugeot RCZ
audi RS Q3	audi RS Q3
land rover Range rover evoque	land rover Range rover evoque
skoda Rapid	skoda Rapid
ssangyong Rexton	ssangyong Rexton
kia Rio	kia Rio
ssangyong Rodius	ssangyong Rodius
skoda Roomster	skoda Roomster
mercedes S-Class	mercedes S-Class
suzuki S-Cross	suzuki S-Cross
ford S-Max	ford S-Max
jaguar S-Type	jaguar S-Type
audi S3	audi S3
audi S4	audi S4
volvo S40	volvo S40
audi S5	audi S5
audi S6	audi S6
volvo S60	volvo S60
volvo S80	volvo S80
volvo S90	volvo S90
audi SQ2	audi SQ2
audi SQ5	audi SQ5
suzuki SX4	suzuki SX4
dacia Sandero	dacia Sandero
hyundai Santa Fe	hyundai Santa Fe
skoda Scala	skoda Scala
renault Scenic	renault Scenic
volkswagen Scirocco	volkswagen Scirocco

Control Countries	**Germany**
volkswagen Sharan	volkswagen Sharan
kia Sorento	kia Sorento
mitsubishi Space Star	mitsubishi Space Star
suzuki Splash	suzuki Splash
fiat Sport	fiat Sport
kia Sportage	kia Sportage
mercedes Sprinter	mercedes Sprinter
alfa romeo Stelvio	alfa romeo Stelvio
kia Stinger	kia Stinger
kia Stonic	kia Stonic
skoda Superb	skoda Superb
toyota Supra	toyota Supra
suzuki Swift	suzuki Swift
volkswagen T-Cross	volkswagen T-Cross
volkswagen T-Roc	volkswagen T-Roc
audi TT	audi TT
renault Talisman	renault Talisman
seat Tarraco	seat Tarraco
opel Tigra	opel Tigra
volkswagen Tiguan	volkswagen Tiguan
ssangyong Tivoli	ssangyong Tivoli
seat Toledo	seat Toledo
volkswagen Touran	volkswagen Touran
ford Tourneo	ford Tourneo
renault Trafic	renault Trafic
ford Transit	ford Transit
volkswagen Transporter	volkswagen Transporter
hyundai Tucson	hyundai Tucson
fiat Twin	fiat Twin
renault Twingo	renault Twingo
volkswagen Up!	volkswagen Up!
toyota Urban Cruiser	toyota Urban Cruiser
mercedes V-Class	mercedes V-Class
volvo V40	volvo V40
volvo V50	volvo V50

Control Countries	**Germany**
volvo V60	volvo V60
volvo V70	volvo V70
volvo V90	volvo V90
opel Vectra	opel Vectra
hyundai Veloster	hyundai Veloster
hyundai Venga	hyundai Venga
toyota Verso	toyota Verso
suzuki Vitara	suzuki Vitara
mercedes Vito	mercedes Vito
opel Vivaro	opel Vivaro
nissan X-Trail	nissan X-Trail
bmw X1	bmw X1
bmw X2	bmw X2
bmw X3	bmw X3
bmw X4	bmw X4
bmw X6	bmw X6
volvo XC40	volvo XC40
volvo XC60	volvo XC60
volvo XC70	volvo XC70
volvo XC90	volvo XC90
kia XCeed	kia XCeed
jaguar XF	jaguar XF
jaguar XJ	jaguar XJ
ssangyong XLV	ssangyong XLV
subaru XV	subaru XV
toyota Yaris	toyota Yaris
toyota Yaris	toyota Yaris
skoda Yeti	skoda Yeti
bmw Z Series	bmw Z Series
opel Zafira	opel Zafira
hyundai i10	hyundai i10
hyundai i20	hyundai i20
hyundai i30	hyundai i30
hyundai i40	hyundai i40
hyundai ix20	hyundai ix20

Control Countries	**Germany**
	bmw 8 Series
	chrysler Freemont
	mercedes GLK-Class
	mercedes SLK-Class
	mercedes Viano
hyundai Elantra	
volvo v60	
bentley Mulsanne	