The impact of carbon pricing on the credit market: Evidence from securitized car loans

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The impact of carbon prices on household credits

- The transportation sector is a large source of GHG emissions
- Climate policies aim to reduce emissions through higher fossil fuel prices
- But they can also have indirect effects through the financial system
- We focus on the influence of carbon prices on consumer loans
- Based on a formal framework, we derive several loan level transmission channels:
  - Probability of default (PD)
  - Expected collateral value of ICE vehicles
  - Household stranded asset risk may command a brown risk premium

In this paper, we...

- focus on the introduction of the German national CO2 price in 2021, announced in late 2019
- analyze the pricing of 7mio. consumer auto loans in the EU
- match loan data with detailed vehicle information
- employ a DiD design comparing the pricing of German loans vs. neighboring European auto credits
- compare the within variation between similar car models, while also using time, country and bank FE

Results in a nutshell

- **The announcement of carbon prices lead to 0.5 pp. higher interest rates for German loans**
- Higher treatment effects for more fuel-intensive vehicles
- Bank type: captive banks drive majority of the effect
- Loan amount is shrinking, loan duration falling, more linear vs. balloon type loans
- Car values falling for used cars and for fuel intensive cars
- We show empirical support for both a PD channel and a collateral channel

We add to 3 distinct literatures

1. Analyzing the effects of climate policies (Andersson, 2019; Colmer et al., 2024; Dechezleprêtre et al., 2023; Leroutier, 2022)

- Expanding the literature towards indirect effects of carbon pricing through the credit market

2. The pricing of climate transition risk on financial markets (Bolton & Kacperczyk, 2023; Duan et al., 2023; Ilhan et al., 2020; Pástor et al., 2022)

- Pricing of household stranded asset risk in consumer credits

3. Pricing of consumer credits in the automotive sector (Bena et al., 2023; Klee et al., 2024; Kontz, 2025)

- Go beyond focus on EVs and Hybrids to the majority of the global auto fleet, that runs on ICE technology

Contribution

- First to show impact of carbon pricing on consumer credit pricing in a plausibly causal setting
- Highlighting moderating effect of fuel efficiency
- Showing that banks reduce medium term carbon risk by reducing credit duration and changing credit contracts toward linear repayment schedules
- Explaining results by both collateral channel and PD channel
- We also show real effects of the policy announcement

How do we conceptualize car loan pricing?

- Banks provide loans priced at the interest rate r according to the following simple rationale:

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

- The expected loss EL is composed of the probability of default PD and the loss-given-default LGD

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

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

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

How do we conceptualize car loan pricing?

- PTI includes loan payments LP, fuel expenditures FE and other costs OC
$$PTI = \frac{LP + FE + OC}{Income} \tag{4}$$

- The expected loss-given-default at the time of origination is using the car value CV and the recovery rate RR.:
$$LGD = \frac{\text{LoanAmount-CV*RR}}{\text{LoanAmount}} \tag{5}$$

- The transition risk premium TRP is rising with the transition risk of the loan, which in turn is determined by the CO2 intensity of the loan:
$$TRP = I(TR) \tag{6}$$

Loan channel 1: How does a CO2 price change PD and LGD

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

- As g is increasing in PTI, ceteris paribus, this also leads to a higher PD

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

- The CO2 price will decreases the recovery rate, and ultimately increase the LGD:

$$\frac{\partial LGD}{\partial RR} = -\frac{CV}{LoanAmount} < 0, \tag{9}$$

- For ICE cars, the CO2 price leads to an increase in the interest rate
- The positive effect is increasing in the fuel intensity of cars

Loan channel 2: How does a CO2 price impact the transition risk premium?

- If the introduction of the CO2 price increases transition risk for CO2-intensive loans, the effect on the loan interest rates is positive.

$$\frac{\partial h}{\partial TR} > 0. \tag{10}$$

- An increase in the transition risk premium for brown loans would increase the final interest rate

Predictions

- Loan channel:
  - For ICE cars, the CO2 price leads to an increase in the interest rate for loans driven both by higher PD and LGD
  - This effect is increasing in the fuel intensity of cars
  - Higher transition risk induced by the carbon price will increase the transition risk premium per loan.

This study draws on 5 large datasets

- 2 datasets on auto loans from ECB / EDW
  - Detailed loan information (borrower income, interest rate, duration, loan amount, car value, securitized value)
- 3 datasets from the German Department for Motor Vehicles (KBA)
  - Car emissions, fuel consumption, vehicle class
- We combine EDW and KBA datasets through string matching based on both aligned manufacturers and model information
- Next, we group all automodels in the dataset into 314 maker-model-power categories

Descriptive statistics

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

Testing both announcement- and implementation effect

- The German national CO2 price was announced on the 20th of September 2019
- The policy was implemented on the first of January 2021
- The policy imposes a rising price path from €25 per ton of CO2 in 2021 to €55 in 2025
- The policy is specifically targeted at the transportation sector

Employing a unique DiD research design

- Comparing the loan pricing before and after treatment across treatment (Germany) and European control countries
- Since we do not have a loan panel, we use car model FE, country FE, bank FE and time FE
- Controls: Car weight, fuel consumption, used car, registration year, and borrowers income
- Standard errors are clustered at the country and car model level

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

Defending the DiD assumptions

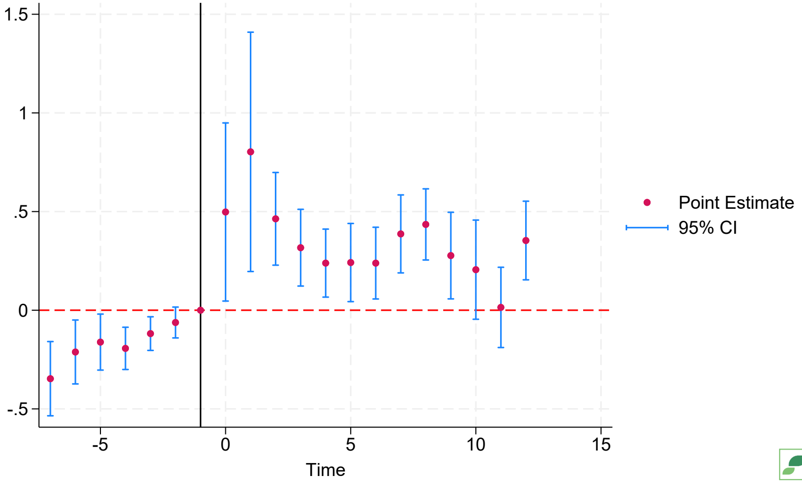
- Parallel trends: Graphical evidence for both the policy announcement and the policy implementation
- Confounding events: No other carbon price implemented in any other European control country
- Policy announcement was a surprise, but the implementation was widely anticipated
- SUTVA: Many banks are operating in many European countries -> bank constraints will thus spill-over (but many banks have strong national focus)
- SUTVA: Lower demand for ICE cars in Germany may affect car loan pricing in other European countries

Effect of the German CO2 price announcement 2019

	(1)	(2)	(3)	(4)	(5)
Dep. variable	Loan interest rate				
Germany*Post	0.46*** (6.86)	0.64*** (7.34)	0.49*** (5.92)	0.43*** (5.00)	0.43*** (5.00)
Controls	No	Yes	Yes	Yes	Yes
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	Yes
Model X Country FE	No	No	No	No	Yes
Captive FE	Yes	No	Yes	No	No
Bank FE	No	No	No	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	4347139	2261232	2261232	2261232	2261224

Table 2 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Event study graph for the policy announcement 2019



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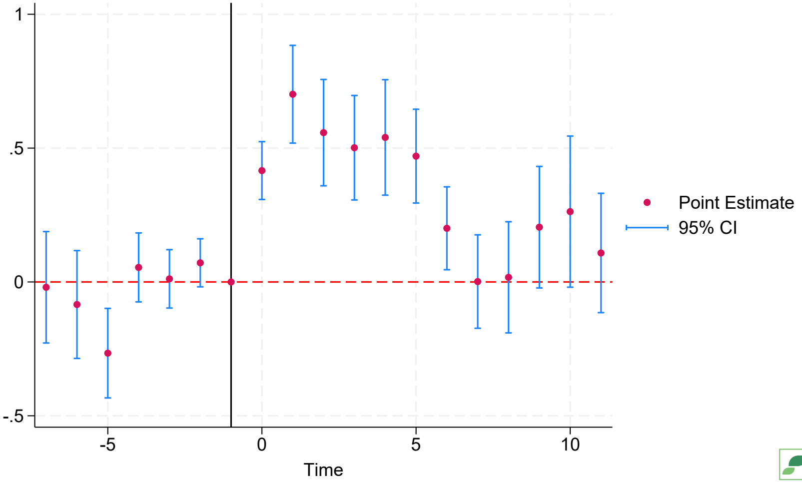
Effect of the German CO2 price implementation 2021

	(1)	(2)	(3)	(4)	(5)
Dep. variable			Loan interest rate		
Germany*Post	0.26***	0.47***	0.40***	0.28***	0.21***
	(5.49)	(6.14)	(8.10)	(4.72)	(3.50)
Controls	No	Yes	Yes	Yes	Yes
Model FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	Yes
Model X Country FE	No	No	No	No	Yes
Captive FE	Yes	No	Yes	No	No
Bank FE	No	No	No	Yes	Yes
Month-year FE	Yes	Yes	Yes	Yes	Yes
# Loans	3987466	1930585	1930585	1930585	1930566

Table 3 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Event study graph for the policy implementation 2021



Effect of the CO2 price announcement - fuel efficiency

	Top 20% fuel consumption	Bottom 20% fuel consumption	DDD with fuel consumption
Germany*Post*Fuel			0.27**
			(2.40)
Germany*Post	0.58***	0.19	0.39***
	(4.25)	(1.32)	(4.47)
Controls	Yes	Yes	Yes
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

Table 4 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Effect of the CO_2 price announcement - fin. institutions

	Captive banks interest rate	Comm. banks interest rate	DDD with bank type
GER*Post*Capt.			0.25**
			(2.14)
GER*Post	0.36***	0.12***	0.09***
	(3.24)	(5.39)	(3.14)
Controls	Yes	Yes	Yes
Model FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes
# Loans	1741692	519535	2261232

Table 5 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

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Effect of the CO2 price announcement - other outcomes

	Loan duration	Car value	Loan amount	Linear credits	Balloon credits	Income
Germany*Post	-1.79***	-138.41	-1835.84***	0.13***	-0.12***	0.02
	(-5.67)	(-0.50)	(-6.59)	(9.39)	(-7.34)	(0.99)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
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	2343575	2173712	2343573	2343575	2343575	2343575

Table 6 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

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Effect of the CO2 price implementation - other outcomes

	Loan duration	Car value	Loan amount	Linear credits	Balloon credits	Income
Germany*Post	-1.41***	-500.85**	-869.61***	0.11***	-0.20***	-0.01
	(-2.64)	(-2.35)	(-3.41)	(7.14)	(-14.33)	(-0.32)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
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	1998915	1918937	1998909	1998915	1998915	1998915

Table 7 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Results are robust to:

- Using fewer/more controls
- All possible combinations of FE
- Adding country specific time trends
- Different clusters for standard errors
- Bootstrapping for small standard error clusters
- Both event dates
- Using balanced/unbalanced panel

3 possible explanations for results

- Increasing PD through higher fuel expenses
  - Overall yearly impact low (average €100), no effect for income
  - But we see a higher treatment effect for higher LTV loans!
- Shrinking expected collateral value - increasing LGD
  - Negative effect on car value for used and fuel intensive cars
  - Negative effect on overall car value for the policy implementation
- An increasing transition risk premium for CO2 intensive loans
  - Banks may fear future more stringent climate policies that restrict driving ICE cars.

Investigating the PD channel

	High LTV interest rate	Low LTV interest rate	DDD with with LTV
Germany*Post*LTV			0.38***
			(7.40)
Germany*Post	0.65***	0.25***	0.28***
	(8.13)	(3.64)	(3.97)
Controls	Yes	Yes	Yes
Model FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Captive FE	Yes	Yes	Yes
Month-year FE	Yes	Yes	Yes
# Loans	974699	1206411	2184870

Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Investigating car values

	Top 20% fuel car value	Bottom 20% fuel car value	New car car value	Used cars car value
Germany*Post	-723.36* (-1.82)	-245.55 (-1.07)	819.43*** (2.82)	-800.66*** (-2.80)
Controls	Yes	Yes	Yes	Yes
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	364312	1815557	1098068	1075636

Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Real effects of the policy announcement: 2% more fuel efficiency leading to a 0.43% CO2 reduction

	(1)	(2)
Dep. variable	Average fuel consumption	
Germany*Post	-0.12**	-0.14**
	(-1.98)	(-2.12)
Controls	Yes	Yes
Model FE	Yes	No
Country FE	Yes	Yes
Captive FE	Yes	Yes
Month-year FE	Yes	Yes
# Loans	2311527	2311536

Table 3 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Take home summary

- Sizable impact on interest rate, particularly for the policy announcement
- Impact is mediated through fuel efficiency
- Special role of captive banks
- PD and collateral channel most likely explanations

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Loan observations by 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

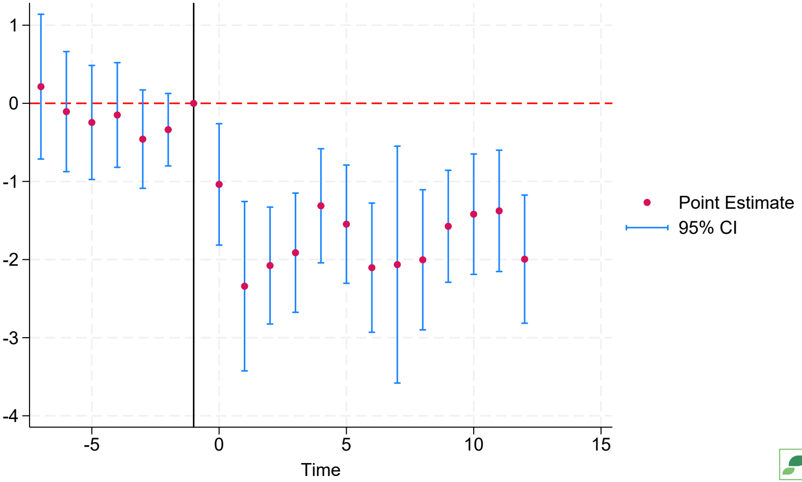
Note: Observations split by country for the time period from 2019 until the end of 2021.

Loan observations by bank

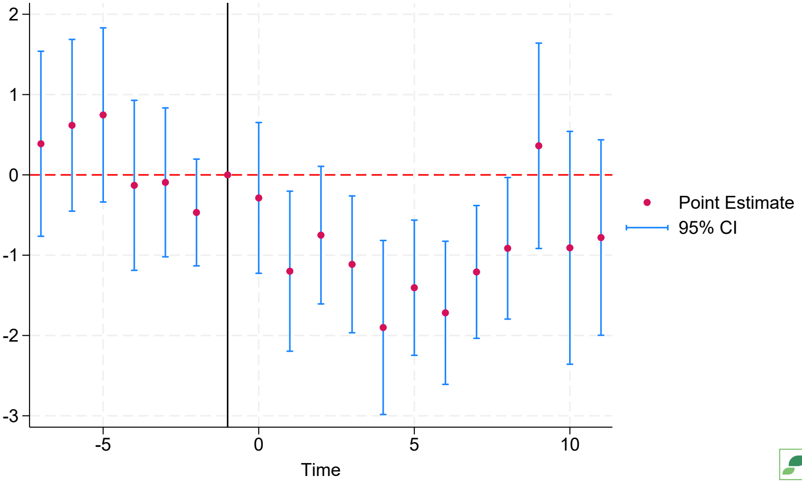
Category	Frequency	Percent
Captive-BMW	247,132	3.67
Captive-FCA	291,725	4.33
Captive-Ford	162,161	2.41
Captive-PSA	416,305	6.18
Captive-RCI	365,817	5.43
Captive-TOYOTA	148,169	2.20
Captive-VW	3,329,489	49.39
Captive-other	63,539	0.94
Commercial-BNP	16,251	0.24
Commercial-Kraftfahrzeuggewerbe	188,312	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.

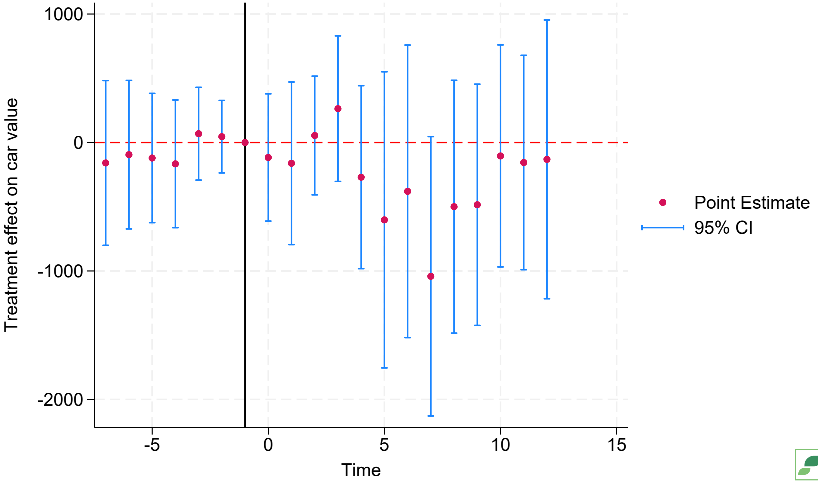
Event study - policy announcement 2019: Loan duration



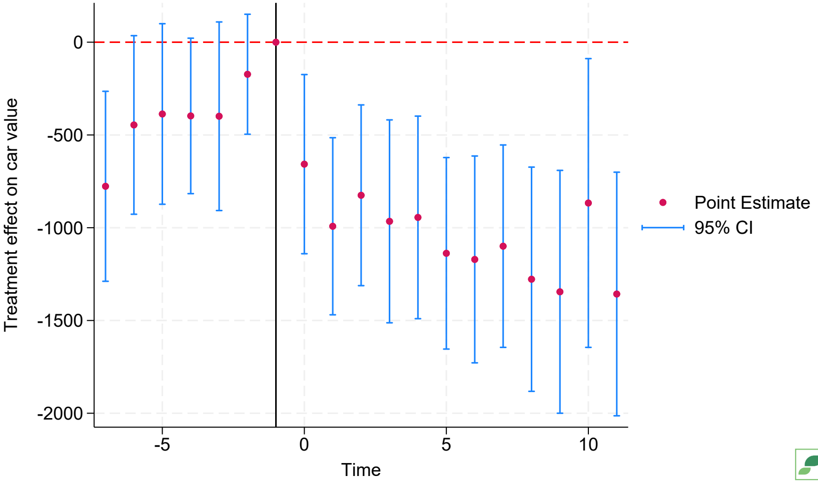
Event study - policy implementation 2021: Loan duration



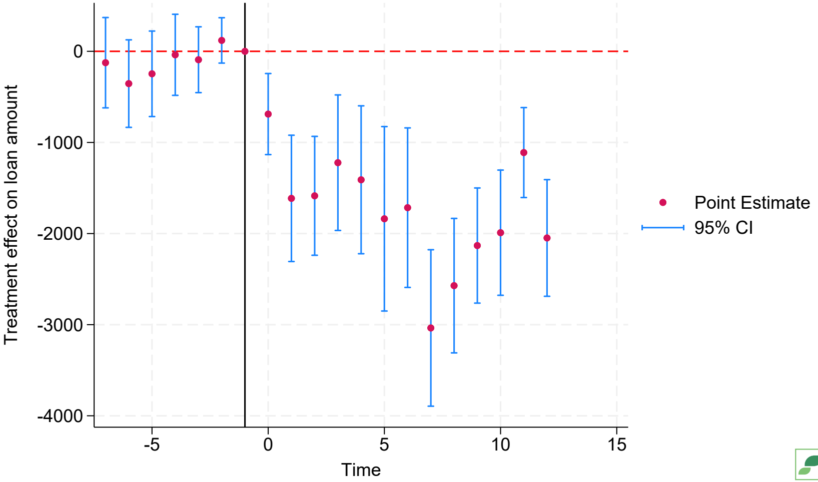
Event study - policy announcement 2019: Car value



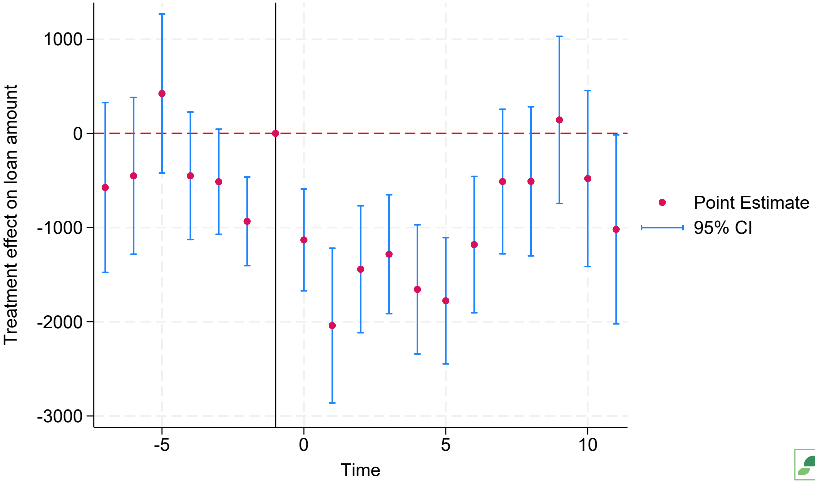
Event study - policy implementation 2021: Car value



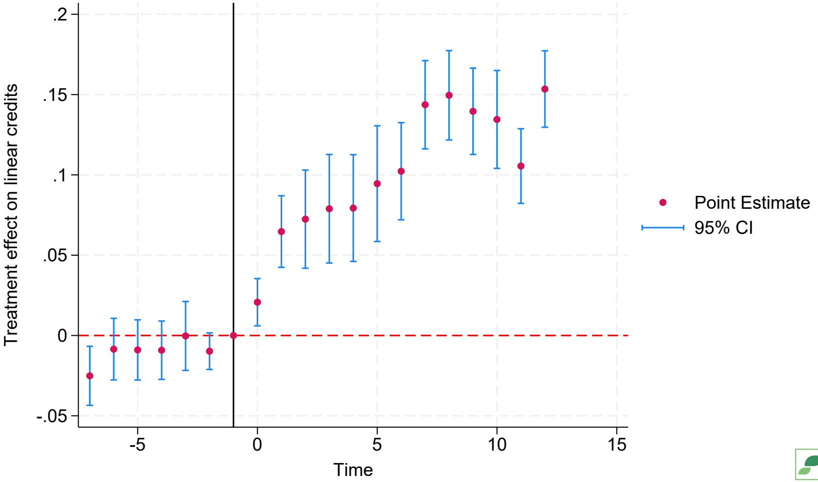
Event study - policy announcement 2019: Loan amount



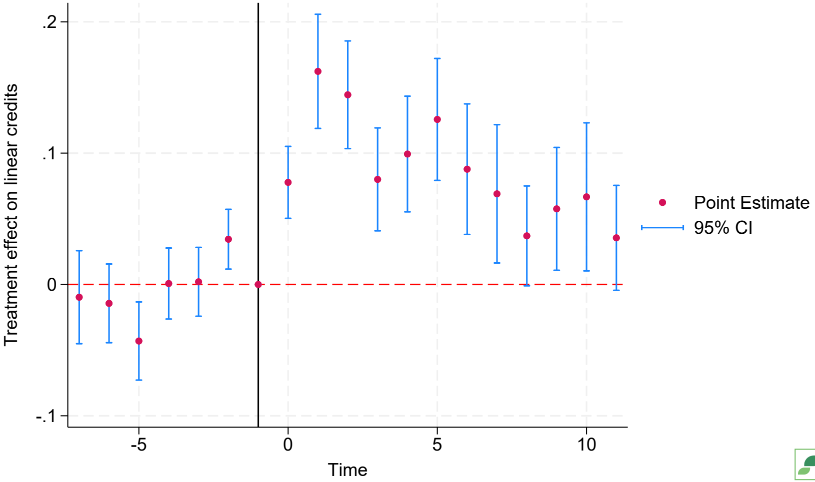
Event study - policy implementation 2021: Loan amount



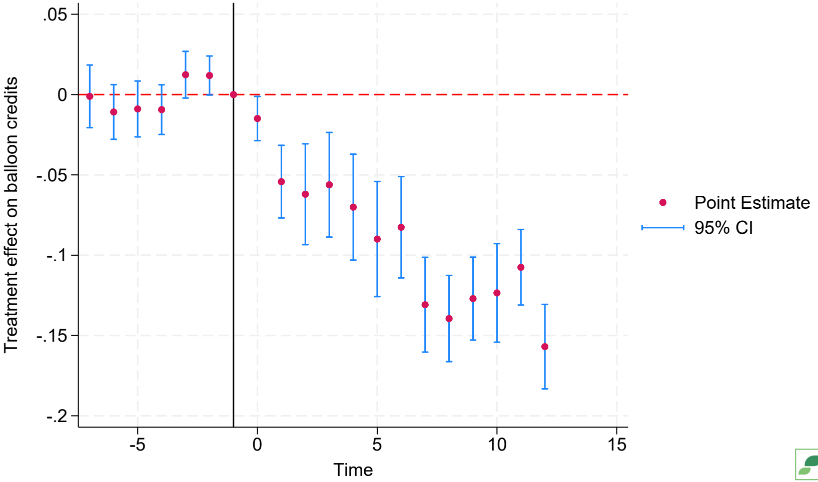
Event study - policy announcement 2019: Linear credits



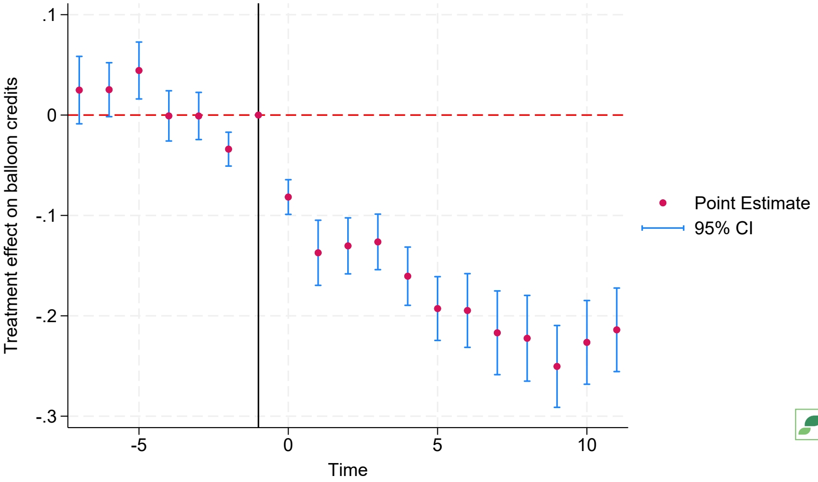
Event study - policy implementation 2021: Linear credits



Event study - policy announcement 2019: Balloon credits



Event study - policy implementation 2021: Balloon credits



Excluding Covid

	Loan interest rate
Germany*Post	0.55***
	(4.54)
Controls	Yes
Model FE	Yes
Country FE	Yes
Captive FE	Yes
Month-year FE	Yes
# Loans	1509712

Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Different effects for new or used cars?

	New car interest rate	Used cars interest rate
Germany*Post	0.44***	0.57***
	(4.35)	(4.56)
Controls	Yes	Yes
Model FE	Yes	Yes
Country FE	Yes	Yes
Captive FE	Yes	Yes
Month-year FE	Yes	Yes
# Loans	1134921	1126305

Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.

Baseline 2019 results with different s.e. clusters

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable	Loan interest rate					
Germany*Post	0.49***	0.49***	0.49***	0.49***	0.49***	0.49***
	(5.92)	(8.57)	(8.34)	(5.85)	(8.34)	(5.16)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
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	2261232	2261232	2261232	2261232	2261232	2261232

Table 2 - Note: $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. t statistics in parentheses.