Carbon pricing and credit reallocation

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May, 11th 2023

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Introduction

- Important tool to reduce CO2 emissions: Cap-and-Trade system
  - Set a cap on emissions
  - Companies must hold/trade permits to cover emissions (Emission Trading System (ETS))
    - ✓ Incentives to invest in abatement (Porter & van der Linde, 1995)

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- Climate change affects supply of external finance
  - Investor preferences (Pastor et al., 2021; Baker et al., 2022; Yoo, 2022)
  - Pricing of climate/transition risk (Correa et al., 2020; Starks et al., 2020; Ilhan et al., 2021)
  - Regulation (Dombrovskis, 2017; Oehmke & Opp, 2022)

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  - Regulation (Dombrovskis, 2017; Oehmke & Opp, 2022)

- Our paper: How does introduction of ETS shape firm credit demand and bank lending?

Our paper

- To examine this:
  - Theoretical model linking permit price to credit demand & profitability
    - Investment in (1) innovation and/or (2) hedge of permit price
  - Empirical analysis using German data and exploiting shock to bank funding
    - Lending to ETS firms higher,
    - Lending to ETS firms safer

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- Our work relates to:
  - Bank lending & environmental risks (Benincasa et al., 2022; Correa et al., 2020; Green, Valle, 2022; Laeven & Popov, 2022)
  - Bank regulation to foster transition to cleaner environment (Oehmke & Opp, 2022)
  - Transmission of monetary policy shock (Altavilla et al., 2022; Bittner et al. 2022)

Institutional background & conceptual framework

EU Emission Trading Scheme (ETS)

- Cap-and-trade system for CO_2 emissions in Europe (EU ETS)
  - Launched in 2005, currently covers 30 countries across Europe
    - Firms need to submit permits/allowances for CO_2 emissions
    - Firms receive freely allocated permits (in declining share)
    - Permits fully tradeable
  - Abatement innovation ↑ (Calel, 2020; Calel & Dechezelpretre, 2016)
  - CO_2 permit price ↑ emission efficiency ↑ (De Jonghe et al., 2020)

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- Whether a firm is subject to EU ETS depends on (a) activity and (b) emissions of *plant(s)*
  - Power & heat plants
  - Manufacturing plants if
    - specialize in certain industrial activities and
    - *plant/installation* exceeds specific capacity threshold
      e.g. steel plants if production capacity $>$ 2.5 t per hour;
      glass and glass fiber if melting capacity $>$ 20 t per day

Model

- Firms:
  - Produce a good, earn revenue R and face costs of production per emission $c \cdot e$ over period
  - Have no funds of their own

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    - Need to surrender CO_2 permit per emission e at the end of the period
    - Receive free allowance $\bar{e}$ (where $\bar{e} < e$)
    - Price of permit now: 1; Expected price at the end of the period: $E(p)$

ETS firms	Non-ETS firms
$E(\pi) = R - c \cdot e - E(p) \cdot (e - \bar{e})$	$E(\pi) = R - c \cdot e$

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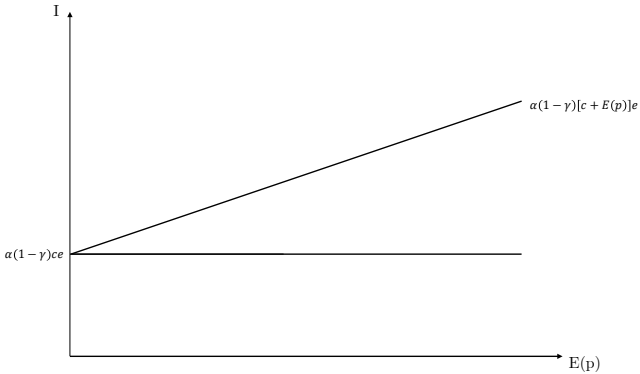
- Innovation technology:
  - Requires set-up costs of I ($\rightarrow$ firms need external finance to start)
  - Success with probability α: reduces firm emissions to $\gamma \cdot e$, with $\gamma < 1$

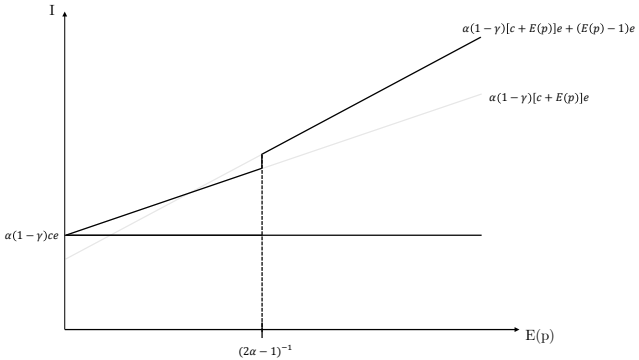
Decision to invest in technology $(I - E(p))$

- Non-ETS firms will invest if $\bar{I}^{Non-ETS} \leq \alpha(1-\gamma)ec$
- ETS firms will invest if $\bar{I}^{ETS} \leq \alpha(1-\gamma)e(c+E(p))$



ETS firms may want to "hedge"

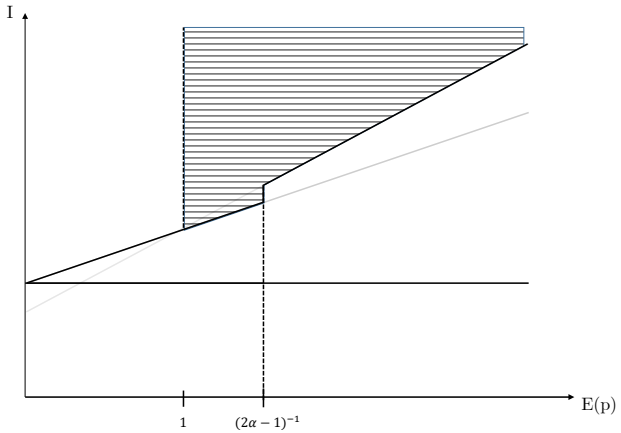
- Additionally, ETS firms:
  - Can acquire $e - \bar{e}$ permits at the beginning at price$= 1$ ("hedge")
  - Prefer to hedge...
    - ... if expected permit price above 1 even if I very large
    - ... and innovate if price large/innovation success probability small i.e. $p \geq (2\alpha - 1)^{-1}$



Credit demand (1) Hedging

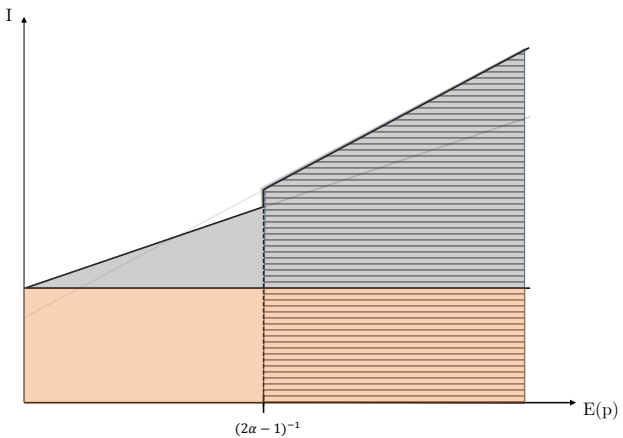
- If cost of innovation I high: firms will not innovate
- If expected permit price larger than 1:

  ETS firms prefer to hedge



Credit demand (2) Innovation

- If cost of innovation I low:
  $\Rightarrow$ both firms innovate



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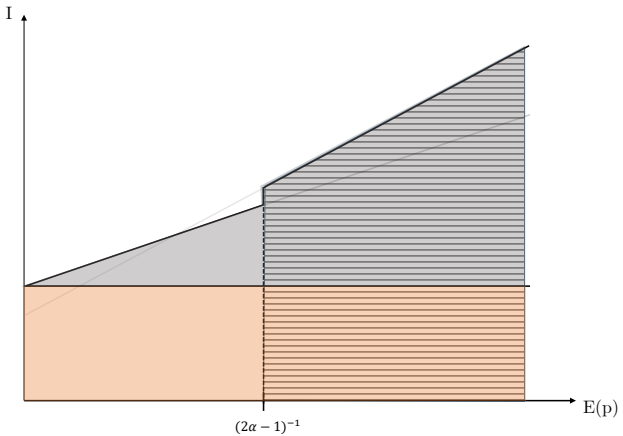
  - ... are willing to pay higher I, and also
  - ... hedge CO_2 exposure.



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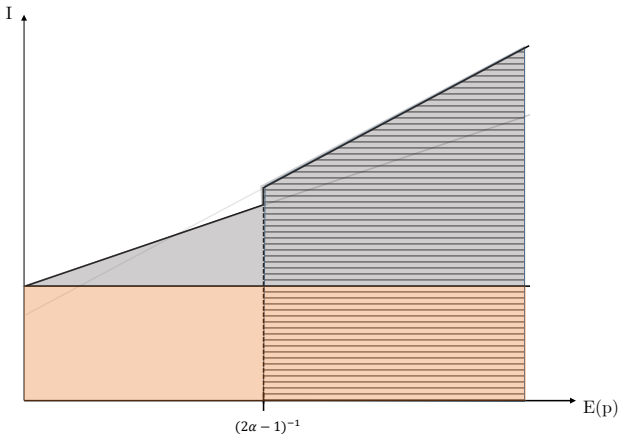
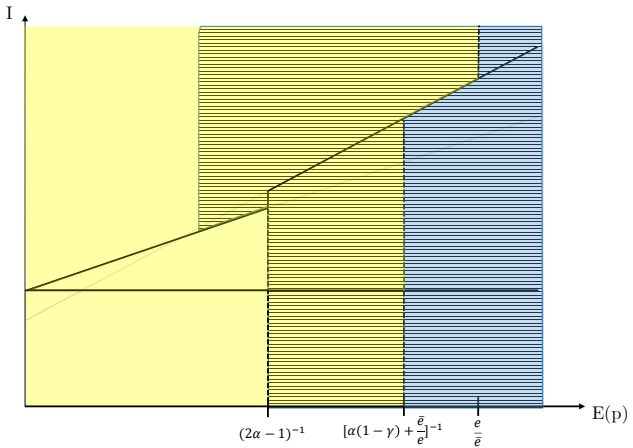
$\Rightarrow$ ETS firms' demand for external funds larger



Firm profits

- If both firms innovate:
  - Non-ETS firms in general more profitable
  - ETS firms more profitable if
    - expected permit price high (and hedge)



Firm profits

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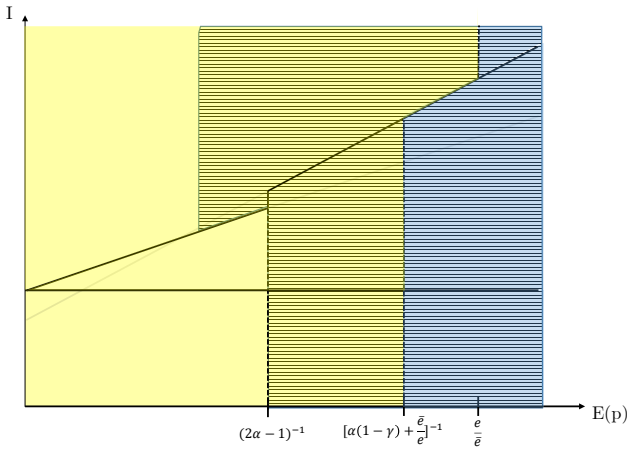
- If both firms do not innovate:
  - Non-ETS firms generally more profitable
  - ETS firms more profitable if
    - expected permit price much larger (and hedge)



Take-away from model

Interpreting these results through a financier's point of view:

1. ETS firms have greater demand for financing...
   - ... to invest in innovation
   - ... and/or invest in hedging

2. Lending to ETS firms can be safer if
   - ETS firms more profitable

Empirical Analysis

Empirical Strategy

- Challenge: Identify exogenous link between firm's participation in ETS and bank lending
  - Non-random selection of firms into ETS
  - Self-selection of firms to banks

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- Approach: Difference-in-differences methodology & matched sample
  - (Exogenous) Shock to bank funding (introduction of negative interest rate policy)
  - Utilize micro-level data on bank lending to firms before/after shock
  - Selection into ETS based on *plant* emissions
    - Matched sample: Identify control firms based on (pre-shock) balance sheet characteristics

Negative Interest Rate Policy and Data Sources

- June 5th 2014: Introduction of negative interest rate policy by ECB
  - Interest rate on the deposit facility $\downarrow$ to -0.1%
  - Shock to bank funding costs (esp. for banks with greater deposit funding)
  - Affected banks increased lending more (Heider et al., 2019; Altvilla et al., 2022, Bittner et al., 2022)

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- Data Sources:
  - German Credit registry (BAKIS-M)
  - Balance sheet information for banks (BISTA) and firms (JANIS)
  - European Union Transaction Log (EUTL)

Sample construction and variable definitions

- Sample
  - Quarterly bank-firm panel on outstanding credit (Q1/2013 to Q2/2015)
  - Matched sample of ETS/non-ETS firms
    - Variables (pre-2014): sector, assets, sales/assets, profit/sales, equity/assets, collateral/assets
    - Control firms: Nearest 1(3/5) neighbors
  - Results hold if analyzing companies in manufacturing and electricity supply sectors

T-tests

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T-tests

- Characteristics:
  - 571 banks and lending to 496 ETS and 366 non-ETS firms
    - Avg credit exposure per bank: $\approx$ 8.8 million €
    - Avg number of bank relationship: $\approx$ 3.5
    - Avg firm size: $\approx$ 315 million €

Panel regression model

$$ln(credit_{bft}) = \beta_1 \frac{D}{A}_b \cdot ETS_f + \beta_2 ETS_f \cdot Post_t + \beta_3 ETS_f \cdot \frac{D}{A}_b \cdot Post_t + FEs + \varepsilon_b$$

β_3 Differential credit effect within bank-firm for ETS firms after NIRP-shock

- Fixed effects (FEs) account for time-varying effects at firm and bank-level
- Main Variables:
  - log of credit from bank b to firm f in quarter t
  - Deposit / asset ratio for bank b (averaged over 6 month period prior to June 2014)
  - Post $= 1$ if after Q2/2014
- Standard errors clustered at bank level

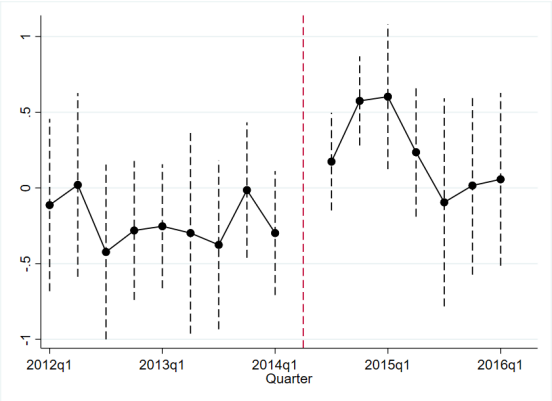
Results

Dependent variable:	Ln(Credit)			
Post	-0.015			
	(0.059)			
Post x ETS	-0.226	-0.226		
	(0.236)	(0.236)		
Post x D/A	-0.100	-0.098	-0.055	
	(0.116)	(0.116)	(0.104)	
ETS x D/A	-0.120*	-0.120*	-0.128**	
	(0.070)	(0.070)	(0.059)	
ETS x D/A x Post	0.260**	0.259**	0.216**	0.420**
	(0.125)	(0.125)	(0.112)	(0.168)
N	27,010	27,010	26,449	22,114
Bank	Yes	Yes	Yes	
Firm	Yes	Yes	Yes	
Time		Yes	Yes	
Bank-Firm			Yes	Yes
Bank-Date				Yes
Firm-Date				Yes

Full sample

Dynamic effect

$$ln(credit_{bft}) = \sum_{j=Q1/2012}^{Q1/2016} \alpha_j \cdot T_j \cdot \frac{D}{A}_b \cdot ETS_f + \alpha_{bt} + \alpha_{ft} + \alpha_{bf} + \epsilon_{bft},$$



Interpretation

- Lending increases more to ETS firms

  Consistent with theoretical framework

- Does exposure risk also change?

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- Does exposure risk also change?

- Two risk measures: Collateral share and probability of default
  1. Collateral/ Credit exposure
     - Higher collateral associated with lower borrower risk (Jimenez et al., 2006)
  2. Probability of default (PD)
     - Banks need to estimate borrower's likelihood of default
     - Only available for banks with internal risk rating models (large banks)

Results

Dependent variable:	Collateral share			Probability of default (PD)		
ETS x D/A	-0.074			-0.012		
	(0.058)			(0.020)		
ETS x Post	0.013	0.025*		0.019**	0.015*	
	(0.012)	(0.013)		(0.008)	(0.008)	
Post x D/A	0.049	0.062**		-0.011	-0.007	
	(0.039)	(0.029)		(0.016)	(0.017)	
ETS x D/A x Post	-0.019	-0.051*	-0.073*	-0.054**	-0.042	-0.051*
	(0.027)	(0.027)	(0.038)	(0.025)	(0.026)	(0.027)
Bank	Yes	Yes		Yes	Yes	
Firm	Yes	Yes		Yes	Yes	
Time	Yes	Yes		Yes	Yes	
Bank-Firm		Yes	Yes		Yes	Yes
Bank-Date			Yes			Yes
Firm-Date			Yes			Yes
Observations	26,917	26,355	22,024	13,873	13,670	11,051

Conclusion

- Theoretical framework:
  - Cost of surrendering CO_2 permits shapes ETS firms' credit demand:
    - Willingness to incur larger set-up costs when permit price increases
    - "Hedging" if permit price increases

Conclusion

- Theoretical framework:
  - Cost of surrendering CO_2 permits shapes ETS firms' credit demand:
    - Willingness to incur larger set-up costs when permit price increases
    - "Hedging" if permit price increases
  - ETS firms can be more profitable (and safer) than non-ETS firms
- Empirical evidence:
  - Panel data set of lending at bank-firm-quarter level
  - Shock to bank funding: Introduction of NIRP
    - Credit exposure to ETS firms larger when banks increase overall lending
    - Marginal exposure to ETS firms less risk (less collateral, lower PD)

Thank you

Differences between ETS and non-ETS firms

	ETS	*Non-ETS*		
	Mean	Mean	Diff	p-value
Number of banks	5.71	1.45	4.26	0.00
Credit (thsd €)	6,050	2,420	3,630	0.00
Collateral / Credit	0.43	0.29	0.14	0.00
PD	3.09	6.09	-3.00	0.00
Total Assets (MM €)	543.80	67.09	476.71	0.00
Profit / Sales	0.44	0.65	-0.21	0.39
Sales / Assets	1.46	1.82	-0.36	0.00
Age	49	33	16	0.00
Equity / Assets	0.31	0.35	-0.04	0.00

return

Descriptive statistics and differences

- Even after matching: ETS firms...
  - ... larger (total assets and # of banks), and
  - ... less risky (lower PD)

	Non-ETS Mean	ETS Mean	Diff	p-value
Number of banks with credit relationship	3.23	3.94	0.70	0.09
Average ln(Credit brutto)	7.15	7.13	-0.02	0.91
Average Credit brutto	5.77	6.36	0.60	0.37
Average (PD)	5.35	3.17	-2.18	0.07
Total Assets (MM EUR)	276	434	158	0.00
Sales /Assets	1.42	1.4921	0.08	0.35
Profit /Sales	0.42	0.46	0.03	0.21
Age	50.86	49.55	-1.32	0.72

return

Results: full sample

Post	-0.074***			
	(0.013)			
ETS x D/A	-1.522***	-1.521***		
	(0.322)	(0.322)		
Post x D/A	-0.013	-0.014	0.026	
	(0.023)	(0.023)	(0.023)	
ETS x Post	-0.046	-0.047	-0.049	
	(0.044)	(0.044)	(0.031)	
ETS x Post x D/A	0.149**	0.152**	0.199***	0.105*
	(0.068)	(0.068)	(0.046)	(0.062)
Observations	411,431	411,431	405,375	215,998
Bank	Yes	Yes	Yes	
Firm	Yes	Yes	Yes	
Time		Yes	Yes	
Bank-Firm			Yes	Yes
Bank-Date				Yes
Firm-Date				Yes

return