Financing constraints, climate policies and carbon emissions

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Introduction

Motivation

The effects of climate policies crucially depend on how firms react, for example by changing their energy mix or investing in carbon-saving technologies.

However, as well known, firms are not all equal and their reactions to the same policy can be very heterogeneous.

The macro literature suggests that financing constraints can be a relevant source of heterogeneity (Bernanke et al., 1999; Durante et al., 2022).

Financial constraints and heterogeneity

- Constrained firms might find it more difficult to adapt and reduce their carbon content.
- Especially so, when also the climate regulation bites.
- Quite surprisingly, this issue has been unexplored in the environmental economics literature.

Potential effects of financial constraints on emissions

The overall effect of *relaxing financial constraints* on emissions of CO_2 is ex-ante ambiguous.

- Size effect (positive): relaxing financial constraints accelerates firm growth and thus, for a given level of technology, increases emissions (Bakhtiari et al., 2020).
- Technology effect (negative): relaxing financial constraints allows firms to adopt more efficient technologies and free resources for long-term investments also in green innovation, which reduce emissions (Cloyne et al., 2023; Durante et al., 2022; Jeenas, 2023).

This paper

Research questions

1. Do financial constraints affect CO_2 emissions for a large sample of small and large firms in the manufacturing sectors?
2. Is the ATT effect equivalent for all firms? Or does heterogeneity matter?
3. Which are the channels through which financially constrained firms reduce their emissions after a credit shock?
4. Is the role of relaxing financial constraints different for firms regulated under the EU ETS?

Data and Methods

Data sources

We use a set of French administrative and survey data covering the 2000-2019 period.

Database	Period	Coverage	Variables of interest
FICUS-FARE	2000-2019	Universe of french firms	Sales, earnings, debt, assets, equity, capital, ...
EACEI	2000-2019	Survey $\approx$ 10k french establishments per year	Energy use by source, energy related investments
EUTL	2005-2019	Universe of EU ETS regulated establishments	Dummy for ETS regulated firms
DADS	2000-2019	Universe of french establishments	Employment

Detailed information available from the data provider (see https://www.casd.eu/)

The aggregation, merge, and cleaning process led to a sample of 69 248 observations and 10 536 unique firms operating in the manufacturing sectors.

Measuring financial fragility

Measuring financial constraints can be a daunting task, since many factors affect the access to external finance for firms (Farre-Mensa and Ljungqvist, 2016).

Measures of financial exposure

We start from three widely adopted measures of financial fragility (DtA, DtE and GOP), also smoothing out their short-term variability taking pre-shock average:

$$DtA_i = (\tau_1 - \tau_0)^{-1} \sum_{t=\tau_0}^{\tau_1} \left(\frac{Debt}{Assets} \right)_{it}$$

These variables are endogenous:

- **Measurement error**: high DtA might also imply that a firm was able to gather credit.
- **Unobserved heterogeneity**: large and capital intensive firms are less constrained. Also, "brown" and "green" firms could have different preferences for the financial structure.

Tackling the endogeneity problem

We use a quasi-natural experiment in which an exogenous shock hits the firms' ability to access external finance.

We employ the monetary policy of the ECB. A dummy equals one after the main refinancing rate suddenly hit the Zero Lower Bound (ZLB) in late 2011.

Exogeneity of the ZLB:

- It has not been implemented with the aim of reducing emissions of CO_2 by companies.
- Hits all French firms at the same time.
- But financially fragile (more leveraged) firms are expected to benefit the most from looser credit

As a robustness check we also use a dummy for the implementation of the Asset Purchase Programme, started in 2015.

Baseline regression exercises

To estimate the causal effect of financial constraints we use a diff-in-diff approach by means of a two-way fixed-effect (TWFE) regression.

Baseline specification

$$Y_{it} = \beta(DtA_i \times ZLB_t) + X'\gamma + \mu_i + \lambda_{ts} + \varepsilon_{it}$$

- The regressor of interest is the interaction between exposure to the shock pre-sample (DtA_i) and a post ZLB dummy (ZLB_t)
- We control for unobserved heterogeneity using both firm and sector-year FE.
- In the favourite specification, we always control for:
  - dummies for the ETS phases, interacted with year FE;
  - dummies for the electricity intensity deciles at 2000, interacted with year FE.
- Robustness checks control also for productivity, capital-intensity and size.

To limit NAs, we applied the inverse hyperbolic sine (ihs) transformation to the dependent variables.

Dependent variables: decomposing carbon emissions

Emissions are observed at the establishment level and we aggregate them at the firm level:

$$CO_{2\,it} = \sum_{j=1}^{J_i} (CO_2)_{jt}$$

We exclude from our sample firms for which the total observed employment in all surveyed establishments is below 90% of the total employment of the firm.

Dependent variables

To examine the channels through which firms adjust to the credit shock, we exploit the rich information of the data and conduct the following Kaya-type decomposition:

$$CO2_{it} \equiv \underbrace{\frac{CO2_{it}}{E_{it}}}_{\text{carbon content}} \times \underbrace{\frac{E_{it}}{VA_{it}}}_{\text{energy intensity}} \times \underbrace{VA_{it}}_{\text{size}}$$

Baseline results and heterogeneity

Results on the decomposition

	Dep. Variable				
	$ihs(CO2)$	$ihs(CO2/VA)$	$ihs(CO2/E)$	$ihs(E/VA)$	$ihs(VA)$
$DtA \times ZLB$	-0.455***	-0.529***	-0.310**	-0.219***	0.074**
	(0.149)	(0.151)	(0.127)	(0.053)	(0.037)
Mean in 2000	1012.94 t	0.16 t/Mln	36.83 t/KW	0.004 KW/Mln	6473.26 Mln
ΔIQ effect	-11.97%	-13.93%	-8.16%	-5,76%	1,95%
N. Obs.	69248	69248	69248	69248	69248
N. Firms	10536	10536	10536	10536	10536
R^2 Adj.	0.685	0.614	0.564	0.791	0.920

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1: Estimates of the baseline regression model when financial exposure is measured by the debt-to-assets ratio.

Event Study (I)

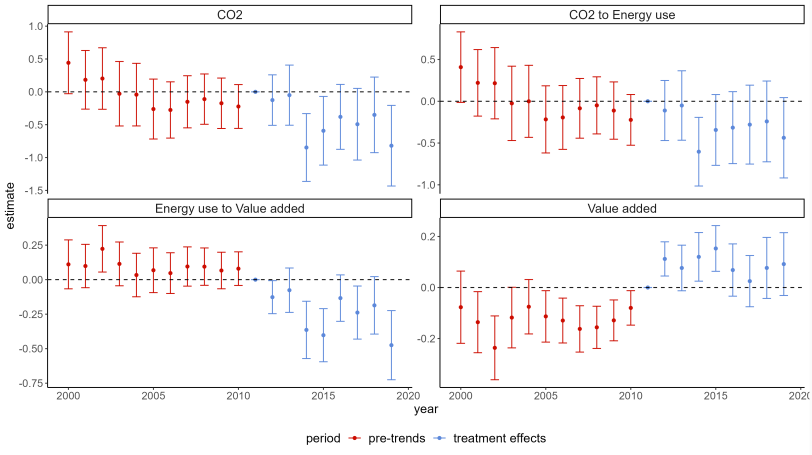


Figure 1: Event study estimates. All estimates are normalized at 0 for 2011.

Event Study (II)

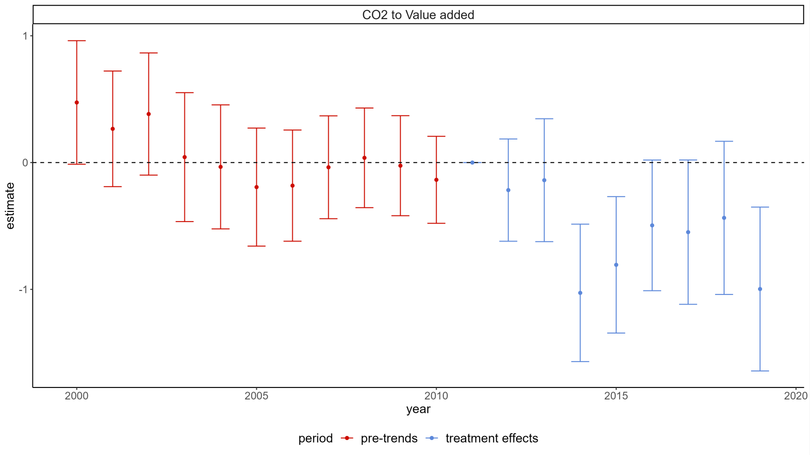


Figure 2: Event study estimates on the ratio of CO_2 to value added. All estimates are normalized at 0 for 2011.

Heterogeneity analysis by size class

	Dep. Variable				
	ihs($CO2$)	*ihs*($CO2/VA$)	*ihs*($CO2/E$)	*ihs*(E/VA)	*ihs*(VA)
$Size_1 \times DtA \times ZLB$	−0.902***	−1.097***	−0.750***	−0.361***	0.195***
	(0.191)	(0.193)	(0.162)	(0.070)	(0.041)
$Size_2 \times DtA \times ZLB$	−0.561***	−0.697***	−0.336*	−0.369***	0.135***
	(0.201)	(0.202)	(0.172)	(0.067)	(0.039)
$Size_3 \times DtA \times ZLB$	−0.419**	−0.477**	−0.304*	−0.173**	0.059
	(0.200)	(0.202)	(0.174)	(0.067)	(0.045)
$Size_4 \times DtA \times ZLB$	−0.161	−0.230	−0.073	−0.149**	0.068
	(0.176)	(0.177)	(0.153)	(0.061)	(0.044)
$Size_5 \times DtA \times ZLB$	0.048	0.158	0.159	0.009	−0.110**
	(0.171)	(0.172)	(0.147)	(0.065)	(0.050)
N. Obs.	69248	69248	69248	69248	69248
N. Firms	10536	10536	10536	10536	10536
R^2 Adj.	0.687	0.616	0.565	0.792	0.920

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: Estimates of the baseline regression model when accounting for firm heterogeneity as measured by the quintiles of the size distributions. All the dependent variables have been transformed with the *ihs* function.

Transmission mechanisms

	$\%Ele.$	$Self.Prod.$	$ihs(K/L)$	$ihs(alp)$	$ihs(tfp)$
$DtA \times ZLB$	-0.014	0.041**	0.370***	0.188***	-0.002
	(0.012)	(0.018)	(0.068)	(0.030)	(0.004)
Mean in 2000	0.57	0.04	12.09	42.22	10.69
ΔIQ effect	-0.36%	1.08%	9.73%	4.95%	-0.05%
N. Obs.	68 203	69 248	69 248	69 248	69 248
R2 Adj.	0.745	0.813	0.799	0.707	0.849

Std. Errors are clustered at the firm level. Fixed effects by time-sector are included.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Estimates of the transmission mechanisms. $\%Ele.$: share of electricity; $Self.Prod.$: dummy variable if the company uses some kind of energy self-generation techniques (solar panels and co-generation); K/L: capital-to-labour ratio; *alp*: apparent labor productivity; *tfp*: total factor productivity.

Heterogeneity in the transmission mechanisms

	$\%Ele.$	$Self.Prod.$	$ihs(K/L)$	$ihs(alp)$	$ihs(tfp)$
$Size_1 \times DtA \times ZLB$	0.013	0.055***	0.504***	0.225***	0.010*
	(0.017)	(0.019)	(0.088)	(0.035)	(0.005)
$Size_2 \times DtA \times ZLB$	−0.016	0.049***	0.366***	0.246***	0.005
	(0.015)	(0.018)	(0.079)	(0.032)	(0.005)
$Size_3 \times DtA \times ZLB$	−0.012	0.018	0.365***	0.138***	−0.006
	(0.015)	(0.019)	(0.078)	(0.036)	(0.005)
$Size_4 \times DtA \times ZLB$	−0.011	0.039*	0.420***	0.201***	−0.004
	(0.014)	(0.022)	(0.084)	(0.037)	(0.005)
$Size_5 \times DtA \times ZLB$	−0.049***	0.011	0.194**	0.117***	−0.018***
	(0.014)	(0.026)	(0.092)	(0.044)	(0.006)
N. Obs.	68 203	69 248	69 248	69 248	69 248
R2 Adj.	0.746	0.815	0.800	0.707	0.849

Std. Errors are clustered at the firm level. Fixed effects by time-sector are included.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Estimates of the transmission mechanisms when accounting for firm heterogeneity as measured by the quintiles of the size distributions.

Interaction with climate policies

Interaction with the EU ETS

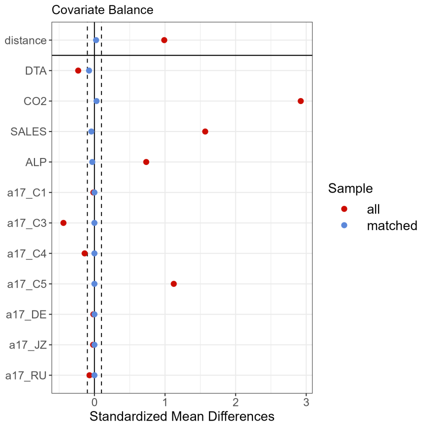
We consider the EU ETS as a pre-existing climate policy. As well-known, ETS regulated companies are larger, less financially fragile, and more energy intensive (Marin and Vona, 2021; Dechezleprêtre et al., 2023).

Balancing the estimation sample

- We employ a Propensity Score Matching approach to create a sample of “twin firms” to ETS companies.
- We use a standard 1-to-1 nearest neighbour method, minimizing the Mahalanobis distance (see Rosenbaum and Rubin, 1983).
- The matching controls are the pre-ETS (before 2005) averages of: (i) DtA, (ii) sales, and (iii) labour productivity. We match exactly the 2-digit sector of each treated firm.

Caveat: our goal is not to evaluate the effect of the ETS.

Quality of the Matching



As a robustness check, we also used the CEM by Iacus et al. (2012). Results remain qualitatively unchanged.

Augmented regression exercises

On the matched subsample, we run the following augmented regression.

ETS augmented specification

$$ihs(Y_{it}) = \beta_1(ETS_i \times ZLB_t) + \beta_2(DtA_i \times ZLB_t) + \beta_3(DtA_i \times ZLB_t \times ETS_i) + X'\gamma + \mu_i + \lambda_{ts} + \varepsilon_{it}$$

where ETS_i is a dummy variable equal to one for firms belonging to the treatment in 2005 (i.e., ETS firms).

- As a robustness check, we also regress the baseline model on the three separate samples (treated, matched, and other).
- Importantly, this allows to examine small firms (i.e. "unmatched") which are more likely to be financially constrained and less studied in previous work.

The joint effect of credit and climate policies

	Dep. Variable				
	$ihs(CO2)$	$ihs(CO2/VA)$	$ihs(CO2/E)$	$ihs(E/VA)$	$ihs(VA)$
$ETS \times ZLB$	1.576*	1.293*	1.265	0.029	0.282
	(0.934)	(0.756)	(0.780)	(0.291)	(0.374)
$DtA \times ZLB$	1.940	1.744	1.869	−0.125	0.196
	(1.431)	(1.184)	(1.225)	(0.571)	(0.606)
$DtA \times ZLB \times ETS$	−2.349	−2.427*	−2.190	−0.238	0.079
	(1.635)	(1.344)	(1.374)	(0.682)	(0.676)
N. Obs.	2195	2195	2195	2195	2195
N. Firms	206	206	206	206	206
R^2 Adj.	0.705	0.719	0.541	0.890	0.912

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Estimates of the augmented regression model when financial fragility is measured by debt-to-assets. All the dependent variables have been transformed with the *ihs* function.

The effect on non-ETS unmatched companies

	Dep. Variable				
	$ihs(CO2)$	$ihs(CO2/VA)$	$ihs(CO2/E)$	$ihs(E/VA)$	$ihs(VA)$
$DtA \times ZLB$	-0.461***	-0.519***	-0.321**	-0.198***	0.059
	(0.152)	(0.155)	(0.130)	(0.054)	(0.037)
Mean in 2000	935.68 t	0.17 t/Mln	42.90 t/KW	0.004 KW/Mln	5369.03 Mln
ΔIQ effect	-12.06%	-13.59%	-8.41%	-5.19%	1.53%
N. Obs.	66985	66985	66985	66985	66985
N. Firms	10340	10340	10340	10340	10340
R^2 Adj.	0.658	0.594	0.561	0.764	0.916

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Estimates of the baseline regression model for different sub-samples. Top table: treated firms. Bottom tables: matched firms.

Conclusions

Wrapping up

Main Results

1. When financing constraints are relaxed, the more financially fragile firms are those that react the most by reducing their emission levels notwithstanding an increase in their value added (Goetz, 2018).
2. The main mechanisms through which the reduction takes place are efficiency gains and self-production (photovoltaic, co-generation, . . .) of energy.
3. Small firms takes most of the benefit arising from the credit loosening policy
4. There are only mild benefits from a fine tuning between credit and climate policies since large companies that are subject to the EU ETS scheme slightly reduce the carbon content of production vis-à-vis similar untreated firms (Marin et al., 2018; Muûls et al., 2022).

Thanks for the attention

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Related literature on financial constraints and the green transition

Few studies focused on the effects of **financing constraints** on the **green transition**.

- Rehman et al. (2023) find that financially constrained firms display, ceteris paribus, higher levels of CO_2 emissions .
- Following a credit availability shock favouring long-term investments, Goetz (2018) finds that financially constrained companies reduce the carbon content of their production relatively more.
- However, both papers only look at US listed firms that are less likely to be financially constrained.
- Bijnens et al. (2021) look at a broader sample of French manufacturing companies, but focus on the extent to financial constraints mediate the impacts of energy price shocks on employment (-).
- Following the adoption of California cap-and-trade, Bartram et al. (2022) show that financially constrained, multi-establishment firms escape the regulation by relocating production in other states, thus increasing overall CO_2 emissions.

Distributions of financial constrains

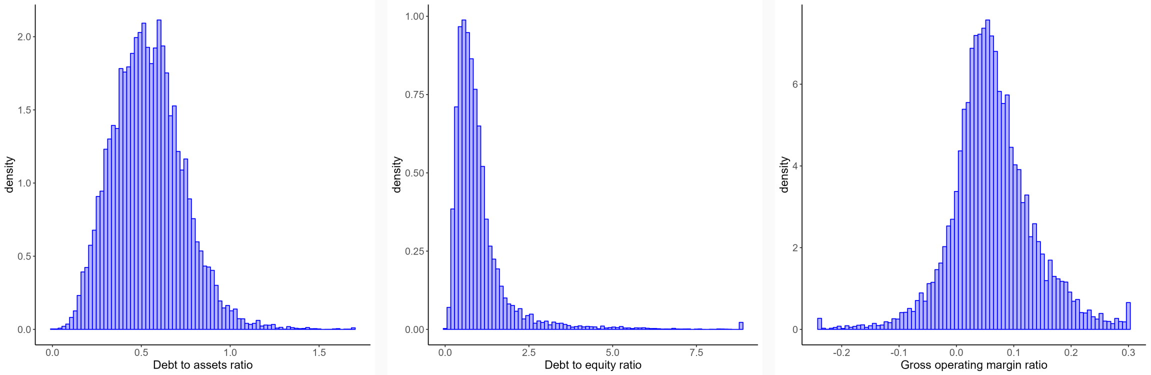

Figure 3: Histograms of Debt-to-Assets (left), Debt-to-equity (center) and Gross Operating Profits ratio (right).

Baseline results with Debt-to-Equity

	Dep. Variable				
	ihs(*CO2*)	*ihs*(*CO2*/*VA*)	*ihs*(*CO2*/*E*)	*ihs*(*E*/*VA*)	*ihs*(*VA*)
$DtE \times ZLB$	-0.085**	-0.100***	-0.068**	-0.032**	0.014
	(0.035)	(0.037)	(0.030)	(0.013)	(0.009)
Mean in 2000	1012.94 t	0.16 t/Mln	36.83 t/KW	0.004 KW/Mln	6473.26 Mln
ΔIQ effect	-5.33%	-6.22%	-4.23%	-2.00%	0.90%
N. Obs.	69248	69248	69248	69248	69248
N. Firms	10536	10536	10536	10536	10536
R^2 Adj.	0.685	0.614	0.563	0.791	0.920

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Estimates of the baseline regression model when financial fragility is measured by debt-to-equity. All the dependent variables have been transformed with the *ihs* function.

Baseline results with Gross Operating Profits ratio

	Dep. Variable				
	ihs(*CO2*)	*ihs*(*CO2*/*VA*)	*ihs*(*CO2*/*E*)	*ihs*(*E*/*VA*)	*ihs*(*VA*)
$GOP \times ZLB$	1.289***	1.100***	0.205	0.895***	0.189
	(0.420)	(0.372)	(0.339)	(0.137)	(0.136)
Mean in 2000	1012.94 t	0.16 t/Mln	36.83 t/KW	0.004 KW/Mln	6473.26 Mln
ΔIQ effect	9.86%	8.42%	1.57%	6.85%	1.45%
N. Obs.	73699	73699	73699	73699	73699
N. Firms	13755	13755	13755	13755	13755
R^2 Adj.	0.656	0.579	0.514	0.788	0.916

Std. Errors are clustered at the firm level. Fixed effects by firm and by time-sector are included.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Estimates of the baseline regression model when financial robustness is measured by the gross operating profits ratio. All the dependent variables have been transformed with the *ihs* function.

Quality of the Matching