The Labor Market Effects of Carbon Pricing

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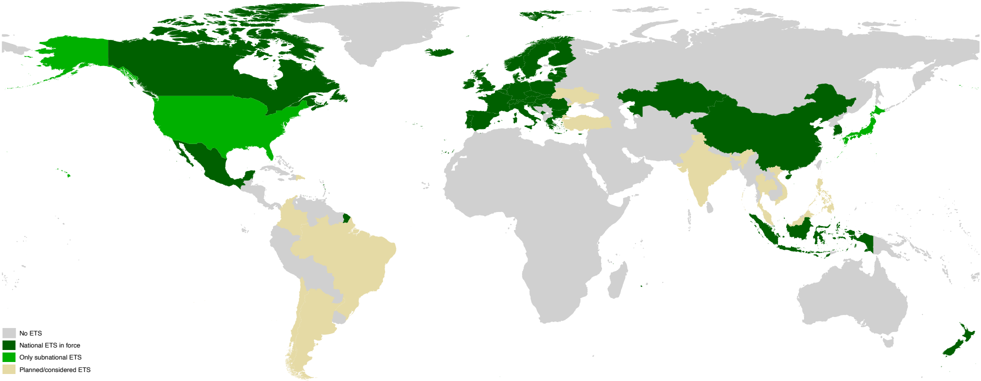
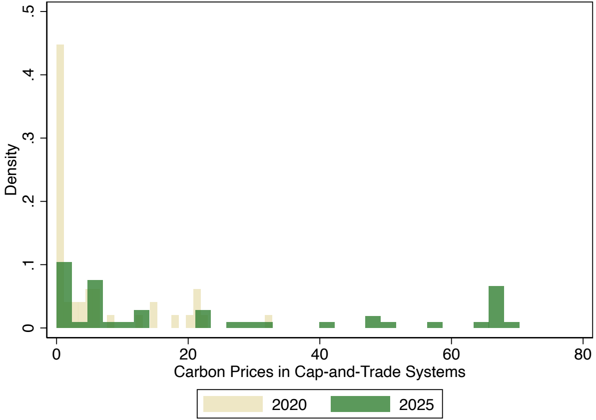
Cap-and-Trade Systems around the World



Cap-and-trade systems are a key carbon mitigation policy instrument

Carbon Prices in Cap-and-Trade Systems



Carbon prices are rising (though not enough to reach net-zero goals)

Carbon Pricing and the Economy

- Carbon prices are likely to further increase in the future
- Debate about the consequences of such increases on the economy overall and on the labor market in particular (UN, ILO, EU)

$\Rightarrow$ Overall employment effects? Winners and losers?

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We study how an increase in **EU ETS carbon prices** affects **workers**

- Exploit 2017 reform in EU ETS that reduced the supply of emission permits
- Rich population-level data sets from the Netherlands
  $\rightarrow$ Employee-employer matched data, worker and plant-level characteristics
- Matched difference-in-differences design

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3. STEM workers enjoy wage increases, potentially reflecting their abatement skills
   $\rightarrow$ 4.3 pp higher wages relative to STEM workers in non-ETS firms
   $\rightarrow$ The STEM wage premium is even larger in firms with permit surpluses, and for workers with better outside options

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   $\rightarrow$ The STEM wage premium is even larger in firms with permit surpluses, and for workers with better outside options
4. ETS plants with more STEM workers before the shock are able to reduce their emissions more

$\Rightarrow$ **Market design and worker skills matter for distributional effects**

Related Literature

- **Climate policies & Labor markets**: Greenstone 2002, Kahn&Mansur 2013, Walker 2013, Gray et al. 2014, Liu et al. 2017, Curtis 2018, Vona et al. 2018, Yip 2018, Sheriff et al. 2019, Saussay et al. 2022, Alexander et al., 2024.
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- **Climate policies & Firm behavior**: Anderson&Sallee 2011, Cullen&Mansur 2017, Meng 2017, Biais&Landier 2022, Seltzer et al. 2022, Bolton&Kacperczyk 2023, Hsu et al. 2023, Bartram et al. 2023, Ivanov et al. 2024, Martinsson et al. 2024, Biais et al. 2025, Doetlling&Rola-Janicka 2025, Acharya et al. 2025, Zhang 2025, Brown et al. 2025
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  → **Complement these studies by focusing on the labor side of the production**
- **Effects of EU ETS**: Martin et al. 2016, Marin et al. 2018, De Jonghe et al. 2020, Verde 2020, Dechezlepretre et al. 2023, Apicella and Fabiani 2023, Akey et al. 2024, Boeckx et al. 2025, Colmer et al. 2025
  → **In line with findings of no adverse effects on economy overall, but document distributional effects**

European Union Emissions Trading System

The EU ETS is a cap-and-trade program

- The EU sets an annual emission amount and issues allowances accordingly
  $\rightarrow$ Covering 35-40% of GHG emissions in the EU
  $\rightarrow$ Phase 1 (2005-07), Phase 2 (2008-12), Phase 3 (2013-20), Phase 4 (2021-30)
- Phase 3: Single, EU-wide cap on emissions replaced previous system of national caps; major reduction in free allowances (so allocation mostly by auction)
- Participation is at the installation (not firm) level
- Based on capacity thresholds: e.g. combustion >20 MW total rated thermal input; 2.5t of production per hour for iron and steel manufacturing, etc.
- Firms submit their allowances by April 30 for the previous year
  $\rightarrow$ Participants can keep or sell their unused permits
  $\rightarrow$ Not submitting leads to a fine of 100 euros per tonne + allowance

European Union Emissions Trading System

Permits are distributed freely or via an auction

- In Phase 3, 43% of allowances are allocated for free. The rest is auctioned.
- Free allocation = Historical activity × Benchmark × Carbon leakage × Linear reduction
- Historical activity: Median activity level of the installation in earlier phases.

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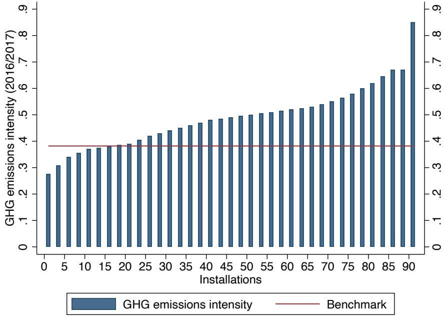

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- Historical activity: Median activity level of the installation in earlier phases.
- Benchmark: Average emission of the best 10 percent installations in that product.
- Carbon leakage: Sectors exposed to carbon leakage receive higher free allowances.

Carbon leakage factor	2013	2014	2015	2016	2017	2018	2019	2020
Electricity producers	0%	0%	0%	0%	0%	0%	0%	0%
Sectors exposed to carbon leakage	100%	100%	100%	100%	100%	100%	100%	100%
Others	80.0%	72.9%	65.7%	58.6%	51.4%	44.2%	37.1%	30.0%

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- Historical activity: Median activity level of the installation in earlier phases.
- Benchmark: Average emission of the best 10 percent installations in that product.
- Carbon leakage: Sectors exposed to carbon leakage receive higher free allowances.
- Linear reduction reduces total allowances every year

	2013	2014	2015	2016	2017	2018	2019	2020
Linear reduction factor	94.3%	92.5%	90.8%	89.1%	87.3%	85.6%	83.8%	82.1%

Reform in 2017

- The carbon price until 2017 was deemed to be too low to incentivize the firms (€5)
  → Weak economic activity & structural oversupply
- In 2015, the Market Stability Reserve (MSR) is announced to start operations in 2019
  → MSR's main purpose is to absorb the oversupply of allowances
- In Feb 2017, the EU increases the MSR's absorption capacity significantly
  → Absorption of 24% of unused allowances instead of 12% if unused is above a threshold
  → Permanent cancellation of allowances
  → Legally introduced in Nov 2017
- These changes increased the carbon prices in ETS substantially!
  (De Jonghe et al. 2020, Apicella&Fabiani 2023, Boeckx et al. 2025)

Phase III starts
1 Jan 2013

6 Oct 2015
MSR is announced

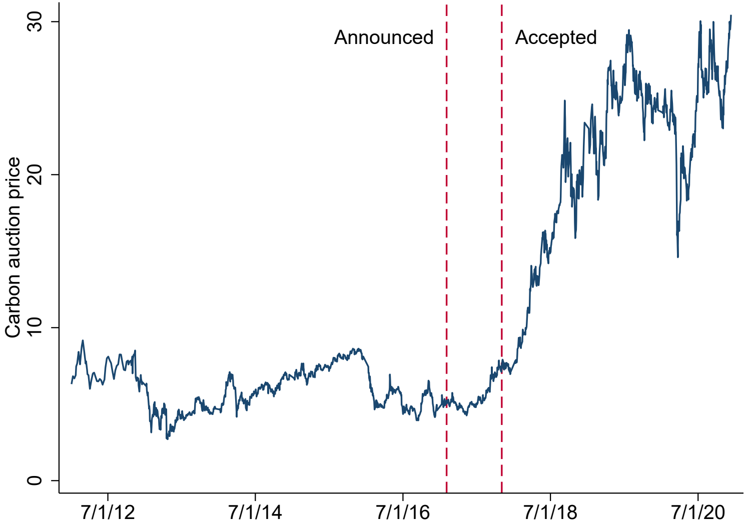
ETS reform is proposed
28 Feb 2017

9 Nov 2017
Reform is adopted

MSR starts its operations
1 Jan 2019

31 Dec 2020
Phase III ends

Carbon Prices



Simple Conceptual Framework

- Match surplus between worker i and firm j, given carbon price p_c: $V_j(p_c) + V_i(p_c)$
- Worker outside option: $\omega_i(p_c)$
- Solve for wage w_i via Nash bargaining:

$$\max_{w_i} (w_i - \omega_i)^{\beta} (V_j(p_c) + V_i(p_c) - w_i)^{(1-\beta)}.$$

$$\Rightarrow w_i^*(p_c) = \beta(V_j(p_c) + V_i(p_c)) + (1-\beta)\omega_i(p_c).$$

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Hence, the effect of a small carbon price increase is given by:

$$\frac{\partial w_i^*(p_c)}{\partial p_c} = \beta\left(\frac{\partial V_j(p_c)}{\partial p_c} + \frac{\partial V_i(p_c)}{\partial p_c}\right) + (1-\beta)\frac{\partial \omega_i(p_c)}{\partial p_c}.$$

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$\Rightarrow$ **Wage of worker i in firm j will tend to increase if:**

1. Firm j has a permit surplus it can monetize: $\partial V_j / \partial p_c > 0$
2. Worker i becomes more valuable to the firm because can reduce emissions: $\partial V_i / \partial p_c > 0$
3. Worker i's outside option improves: $\partial \omega_i / \partial p_c > 0$

Data

- ETS, labor market, firm characteristics, individual characteristics
    1. ETS transactions log: Carbon emissions, free allowances (EUTL)
    2. Labor market: Wage components, hours obtained from employee-employer matched data (CBS)
    3. Firm characteristics: Balance sheet, income statement, sector (CBS)
    4. Individual characteristics: Education, age (CBS)
    5. Plant-level production statistics (CBS)
    6. We manually match EUTL variables with CBS variables
- 2014-2020 (Phase 3), annual

Empirical Strategy – Matching

- 212 ETS installations/plants belonging to 181 firms
    - Note: we remove non-ETS plants of firms that have at least one ETS plant
- ETS firms are larger and more profitable, workers are older and earn more

⇒ Use matching to make workers in ETS and non-ETS firms more comparable

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Matching is done at the worker and firm levels. Specifically:

- Start with workers aged 25 to 60 and employed at same company in 2015 and 2016
- Match exactly on industry, gender, high-tenure dummy, all in 2016
- Within each cell, estimate propensity score of being at ETS firm, as function of: age_{t-1}, $\log(\text{wage}_{t-1})$, $\log(\text{wage}_{t-2})$, $\log(\text{firm size})_{t-1}$, and firm $\text{profit/employee}_{t-1}$
- For every treated worker, select non-ETS worker with closest score, with caliper 0.01

Balance Test

- Matching removes the differences between the ETS and non-ETS groups

	Full Sample			*Matched Sample*		
Variable	**Control**	**Treated**	**Diff**	**Control**	**Treated**	**Diff**
Age_{t-1}	40.260	41.196	0.935	42.565	42.481	-0.084
	(0.105)	(0.317)	(0.334)	(0.348)	(0.250)	(0.428)
$\text{Log(Hourly Wage}_{t-1})$	3.019	3.354	0.335	3.364	3.374	0.010
	(0.009)	(0.016)	(0.018)	(0.045)	(0.031)	(0.054)
$\text{Log(Hourly Wage}_{t-2})$	2.965	3.293	0.328	3.320	3.329	0.009
	(0.009)	(0.015)	(0.018)	(0.044)	(0.030)	(0.053)
$\text{Log(Size}_{t-1})$	5.496	8.375	2.879	6.445	6.450	0.005
	(0.138)	(0.274)	(0.306)	(0.180)	(0.126)	(0.220)
$\text{Profits}_{t-1}/\text{Workers}_{t-1}$	20.168	45.403	25.235	90.485	86.049	-4.436
	(1.284)	(13.294)	(13.319)	(14.341)	(14.174)	(20.134)
Observations	1,671,261	95,441	1,766,702	16,082	16,082	32,164

Note: all continuous variables are winsorized at 1st and 99th percentile throughout.

Sample Composition

Number of Workers by Industry and Firm Size Class After Matching

Industry	**[1, 49]**	**[50, 249]**	**250+**	**Total**
Crop and animal production, hunting and related service activities	200	154	232	586
Electricity, gas, steam and air conditioning supply	250	720	3,406	4,376
Manufacture of basic metals	46	324	210	580
Manufacture of basic pharmaceutical products and preparations	44	432	832	1,308
Manufacture of chemicals and chemical products	452	2,014	5,626	8,092
Manufacture of food products	296	1,826	6,286	8,408
Manufacture of other non-metallic mineral products	268	768	614	1,650
Manufacture of paper and paper products	62	614	506	1,182
Warehousing, storage and support activities for transportation	16	282	1,556	1,854
Wholesale trade	66	292	1,394	1,752
Other (pooling non-top-10 industries)	354	754	1,268	2,376
Total	2,054	8,180	21,930	32,164

- Note: air transport industry not included because no control workers

Before

Empirical Strategy – Estimation

Exploit the increase in carbon prices in a matched difference-in-differences setting:

$$y_{it} = \boldsymbol{\beta}\ ETS_i \times Post_t + \gamma_i + \delta_t + \epsilon_{it}$$

Event-study version:

$$y_{it} = \sum_{\tau=-3}^{3} \boldsymbol{\beta_\tau}\ ETS_i \times \mathbb{1}(t = t^* + \tau) + \gamma_i + \delta_t + \epsilon_{it}$$

- $ETS_i = 1$ for workers in ETS firms as of 2016, $ETS_i = 0$ for matched units
- $Post_t = 1$ if year ≥ 2018
- y_{it}: log(hourly wages) (but also log(wages), earnings, and employment)
- Throughout, cluster standard errors at 2016-firm level

Baseline Results

- No adverse effects on workers – if anything, workers in ETS firms have better outcomes (in line with Dechezlepretre et al. 2023, Colmer et al. 2025, Gallé et al. 2025)
- Significant yet small positive effect on employment

Dep. Var.:	Log(Hr. Wage)	Earnings	Log(Wage)	Employed
	(1)	(2)	(3)	(4)
ETS × Post	0.018	2,010.812	0.021	0.007**
	(0.014)	(1,389.491)	(0.016)	(0.003)
R^2	0.916	0.844	0.834	0.371
Obs.	220,186	225,148	220,186	225,148
Worker FE	X	X	X	X
Year FE	X	X	X	X

Permit Shortfall

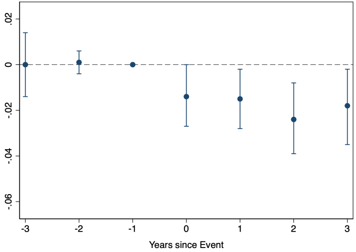
- Free permit allocation may lead to distributional effects (Coase 1960, Montgomery 1972)
- Workers in ETS firms with permit shortfalls experience a relative reduction in their wages
  $\rightarrow$ 1 std dev higher permit shortfall $\Rightarrow$ 1.6 pp differential decline in hourly wages

Dep. Var.:	Log(Hr. Wage)	Earnings	Log(Wage)	Employed
	(1)	(2)	(3)	(4)
ETS $\times$ Post	0.018	2,010.812	0.021	0.007**
	(0.014)	(1,378.972)	(0.015)	(0.003)
Post $\times$ Shortfall (standardized)	0.002	245.317	0.003	0.000
	(0.005)	(460.537)	(0.005)	(0.002)
ETS $\times$ Post $\times$ Shortfall	-0.016***	-1,325.647**	-0.029***	-0.003
	(0.005)	(545.372)	(0.010)	(0.002)
R^2	0.916	0.844	0.834	0.371
Observations	220,186	225,148	220,186	225,148
Worker FE	X	X	X	X
Year FE	X	X	X	X

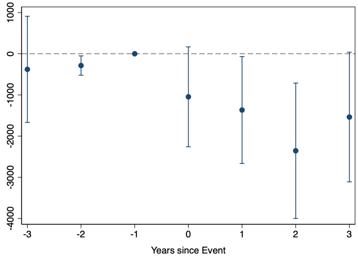
Note: for control group workers, the Shortfall of the matched treatment group worker is used.

Permit Shortfall: Event-Study Evidence

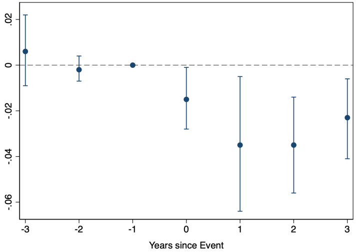
A. log(Hourly Wage)



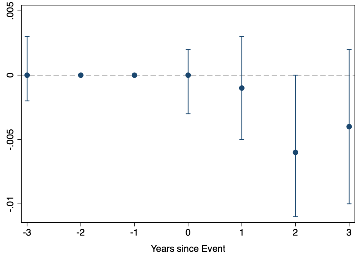
B. Earnings



C. log(Wage)



D. Employed



Heterogeneity in Worker Skills/Education

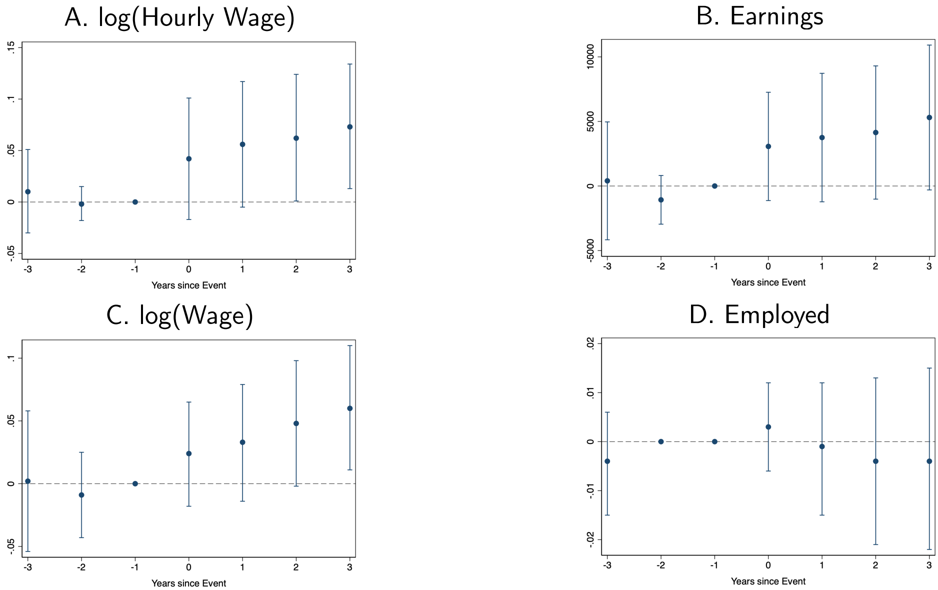
- STEM workers are the most valuable to cut emissions (Vona et al. 2018, Saussay et al. 2022)
- The carbon price shock may increase the value of their emission reduction skills, increasing their value for their employers

STEM and Non-STEM Workers

- In line with idea that their skills become more valuable, STEM workers in ETS firms enjoy a wage increase
  $\rightarrow$ 4.3 percent higher wages compared to STEM workers in non-ETS firms

Dep. Var.:	Log(Hr. Wage)		Earnings		Log(Wage)		Employed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ETS × Post	0.015	0.051**	1,850.694	3,801.727**	0.019	0.043**	0.008**	-0.003
	(0.015)	(0.023)	(1,383.103)	(1,852.996)	(0.016)	(0.020)	(0.003)	(0.006)
R^2	0.913	0.892	0.838	0.826	0.830	0.788	0.371	0.368
Observations	203,473	16,713	208,033	17,115	203,473	16,713	208,033	17,115
$\beta_{STEM} - \beta_{NO\ STEM}$	0.036*		1,951.032		0.024		-0.010	
S.E.	(0.021)		(1,343.754)		(0.017)		(0.007)	
Worker FE	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X
STEM	No	Yes	No	Yes	No	Yes	No	Yes

STEM Workers: Event-Study Evidence



STEM Workers and Permit Shortfall

- STEM workers who are employed by ETS firms with the lowest permit shortfalls (bottom third of distribution) experience an even higher increase
- Also goes against concern that previous result reflected higher number of STEM workers in efficient firms

Dep. Var.:	Log(Hr. Wage)		Earnings		Log(Wage)		Employed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ETS × Post	0.026	0.092***	3,214.137*	8,538.462***	0.042*	0.081**	0.010**	0.011
	(0.023)	(0.029)	(1,931.109)	(2,550.140)	(0.022)	(0.032)	(0.005)	(0.011)
R^2	0.904	0.888	0.834	0.821	0.831	0.788	0.381	0.358
Obs.	68,196	6,310	69,650	6,454	68,196	6,310	69,650	6,454
$\beta_{STEM} - \beta_{NO\ STEM}$	0.066**		5,324.325***		0.039		0.001	
S.E.	(0.027)		(1,850.357)		(0.027)		(0.010)	
Worker FE	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X
STEM	No	Yes	No	Yes	No	Yes	No	Yes

Other Degrees

- Other education levels or degrees do not lead to systematic wage premiums
- Business graduates earn higher wages (similar to STEM) but earnings do not increase due to lower employment prob.

Dep. Var.Sample	Business	Other Uni.	Applied Uni.	Vocational	Other
Log(Hr. Wage)	0.057*	0.020	0.017	0.011	0.009
	(0.029)	(0.023)	(0.018)	(0.012)	(0.012)
Earnings	1,526.756	3,430.825	1,376.268	1,981.900**	1,688.808
	(3,205.928)	(2,773.616)	(1,769.106)	(971.750)	(1,035.221)
Log(Wage)	0.060**	0.022	0.012	0.020	0.014
	(0.030)	(0.029)	(0.020)	(0.014)	(0.014)
Employed	-0.015	0.009	0.005	0.006*	0.014**
	(0.010)	(0.009)	(0.005)	(0.004)	(0.007)
Observations	12,775	14,595	62,097	78,155	40,411

STEM Workers & Outside Options

- STEM workers who have better outside options may capture a larger fraction of the value they created
  $\rightarrow$ Proxy the outside options with ex-ante and ex-post job switches
- Larger effects for STEM workers with better outside options

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- Larger effects for STEM workers with better outside options
- **Ex-ante definition** – moved in the past:

Dep. Var.:	Log(Hr. Wage)		Earnings		Log(Wage)		Employed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Ex Ante Definition				
ETS × Post	0.030	0.074**	3,273.119	4,746.570***	0.035	0.061***	-0.006	0.000
	(0.019)	(0.035)	(2,879.051)	(1,676.600)	(0.028)	(0.023)	(0.011)	(0.008)
R^2	0.888	0.893	0.824	0.822	0.800	0.777	0.381	0.359
Obs.	7,302	9,411	7,469	9,646	7,302	9,411	7,469	9,646
$\beta_{STEM} - \beta_{NO\ STEM}$	0.044		1,473.451		0.026		0.005	
S.E.	(0.033)		(2,794.605)		(0.031)		(0.014)	
Worker FE	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X
STEM	No	Yes	No	Yes	No	Yes	No	Yes

STEM Workers & Outside Options

- STEM workers who have better outside options may capture a larger fraction of the value they created
  $\rightarrow$ Proxy the outside options with ex-ante and ex-post job switches
- Larger effects for STEM workers with better outside options
- **Ex-post definition** – moved after carbon price increase:

Dep. Var.:	Log(Hr. Wage)		Earnings		Log(Wage)		Employed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Ex Post Definition				
ETS $\times$ Post	0.035	0.090**	1,628.375	9,813.407*	0.019	0.110**	0.003	-0.001
	(0.021)	(0.039)	(2,879.051)	(5,507.653)	(0.020)	(0.053)	(0.002)	(0.023)
R^2	0.922	0.841	0.913	0.709	0.871	0.685	0.149	0.401
Obs.	11,093	5,620	11,130	5,985	11,093	5,620	11,130	5,985
$\beta_{STEM} - \beta_{NO\ STEM}$	0.066**		5,324.325***		0.039		0.001	
S.E.	(0.027)		(1,850.357)		(0.027)		(0.010)	
Worker FE	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X
STEM	No	Yes	No	Yes	No	Yes	No	Yes

STEM Workers and Emissions

- Are the higher wage premiums for STEM workers "justified"?
- Plant-level emissions statistics. Within-ETS and industry-year comparison (no matching)

$$\log(\mathit{Emissions}_{jt}) = \beta \mathit{Post}_t \times \mathit{Frac.\,STEM\ Workers}_j + \alpha_j + \delta_{ts} + \varepsilon_{jt}$$

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Dep. Var.:	Log(Emissions)					
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Frac. STEM	-1.447**	-1.669*				
	(0.731)	(0.886)				
Post × Frac. Bus.			-0.841	-0.676		
			(0.822)	(0.852)		
Post × Frac. Other					-1.353	-1.211
					(1.081)	(1.107)
Post × Log(Size)		-0.004		-0.017		-0.014
		(0.026)		(0.027)		(0.025)
Post × Profits/Workers		0.000		0.000		0.000
		(0.000)		(0.000)		(0.001)
R^2	0.985	0.985	0.985	0.985	0.985	0.985
Observations	721	721	721	721	721	721
Firm FE	X	X	X	X	X	X
Year-Ind. FE	X	X	X	X	X	X

STEM Workers and Emissions

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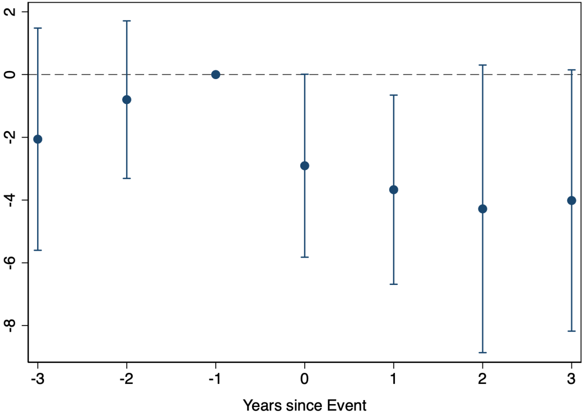


Workforce Composition

- No differential change in firms' STEM worker composition – suggesting rigid labor supply

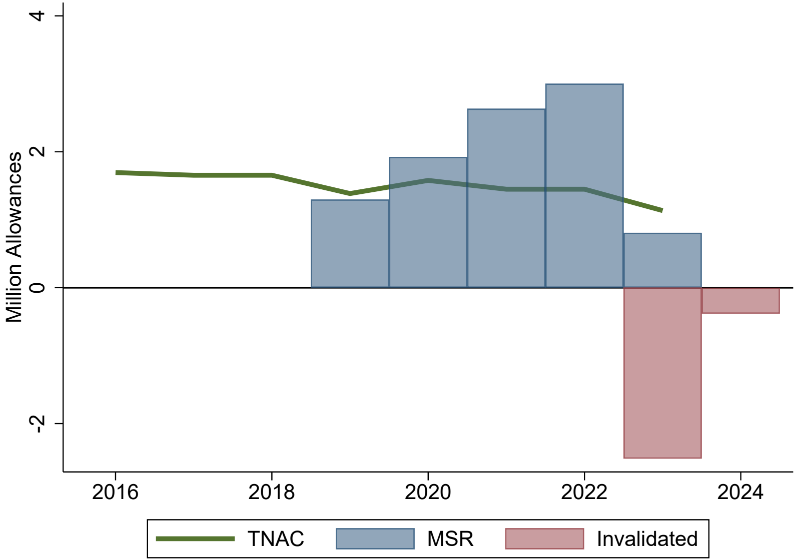
Dep. Var.:	Fraction STEM	STEM Hire	STEM Separated
	(1)	(2)	(3)
ETS × Post	-0.002	0.008	0.002
	(0.002)	(0.007)	(0.006)
R^2	0.962	0.214	0.133
Obs.	1,288	236,083	247,456
Firm FE	X	X	X
Year FE	X	X	X

Conclusion

- No average losses: The 2017 EU ETS reform caused no overall wage or employment declines
- Distributional effects: Wage impacts vary—permit shortfalls hurt workers; STEM skills yield gains
- Skills matter: STEM-intensive plants reduce energy costs more after the reform
- Rising carbon prices and new ETS systems make skill development and allocation rules central for a fair transition
- In progress: various robustness checks
- Potential future work: complementarity between worker skills and firms' green investments

Thank You!

MSR



Million Allowances
4
2
0
-2
2016
2018
2020
2022
2024
TNAC
MSR
Invalidated

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Empirical Strategy – Matching

Top 10 industries with largest number of workers in ETS firms:

Number of Workers by Industry and Size Class Before Matching

Industry	**[1, 49]**	**[50, 249]**	**250+**	**Total**
Air transport	103	133	12,414	12,650
Education	5,647	3,694	60,517	69,858
Electricity, gas, steam and air conditioning supply	488	1,229	9,948	11,665
Human health activities	16,686	6,458	109,364	132,508
Manufacture of basic metals	808	2,004	5,164	7,976
Manufacture of chemicals and chemical products	2,145	5,574	10,913	18,632
Manufacture of food products	4,934	13,366	21,367	39,667
Manufacture of motor vehicles, trailers and semi-trailers	1,107	1,945	6,032	9,084
Manufacture of other non-metallic mineral products	1,733	2,184	2,200	6,117
Manufacture of paper and paper products	804	2,829	1,875	5,508
Other	408,802	333,289	710,946	1,453,037
Total	443,257	372,705	950,740	1,766,702

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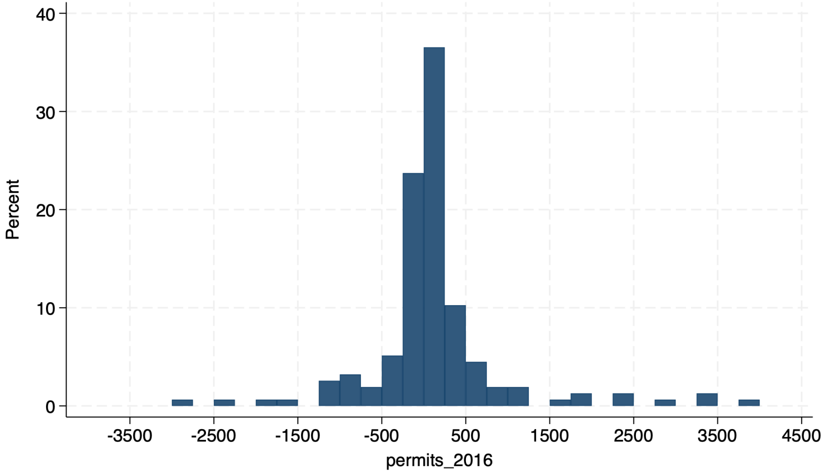
Permit Shortfall – Distribution in 2016



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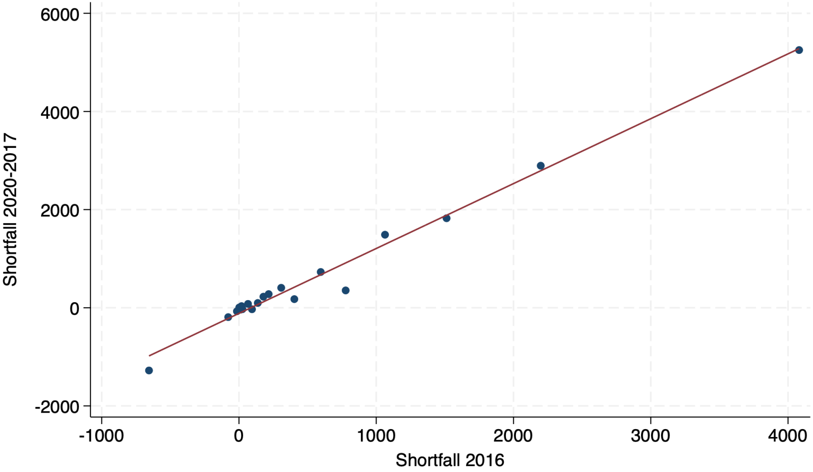
Permit Shortfall – 2016 vs 2020



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