Wired For Change? Clean Technology Adoption and Labor Market Transitions

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Green technology adoption & the labor market

- Opposition to environmental regulations and carbon taxes is often driven by the fear of massive job destruction
- Green investment programs supporting clean energy technology adoption stand out as an important exception, potentially generating positive employment effects for manual workers.

The Guardian view on a carbon-free economy: no just transition in sight – yet
Editorial

Factory closures highlight the turbulent shift to a green economy, exposing political challenges and the urgent need for a equitable move to net zero

'The only remaining blast furnace at Port Talbot was shut down, as part of a restructuring that will cost 2,800 employees their jobs.' Photograph: Toby Melville/Reuters

Reuters

US clean energy jobs growth rate double that of overall jobs, report says

By Timothy Gardner

August 28, 2024 6:06 PM GMT+2 · Updated August 28, 2024

Solar installers from Baker Electric place solar panels on the roof of a residential home in Scripps Ranch, San Diego, California, U.S. October 14, 2016. Picture taken October 14, 2016. REUTERS/Mike Blake/File Photo Purchase Licensing Rights

Green skills gap challenges the just transition

- The energy transition creates a major skills gap for workers
  - Over 25% of jobs significantly impacted by the net-zero transition
  - Mostly skill upgrades within existing occupation (ILO 2019)
- Strong policy commitment to green workforce training
  - EU European Social Fund (2021-2027) targets retraining of 5 million people in green skills
  - G7 Green Jobs Initiative committed to increase development assistance for green skills (ILO 2023)
- Yet worker transition costs remain poorly understood

$\Rightarrow$ We lack systematic evidence on how workers adjust when their employers adopt clean technologies—a crucial insight to ensure a **just transition**.

Research Question: How do workers adjust when firms adopt clean energy technologies?

In a nutshell

- First ex-post estimates of worker transition costs, using decarbonization of French HVAC installers as a case study
- Adoption yields major within-firm labor reallocation
- Stayers adjust through expanded hours, movers experience only short-run transition costs
- Workers with smaller skill gaps secure wage gains, yet only if they change employers

Technology adoption & environmental regulations

- Environmental regulations
  - imply major **welfare losses** for workers in polluting sectors endowed with occupation-specific skills (Walker 2013, Marin et al. 2021, Rud et al. 2024)
  - **rarely move workers** from pollution-intensive to greener jobs (Bluedorn et al. 2023, Curtis et al. 2024, Garnache et al. 2025)

$\rightarrow$ Little is known on worker adjustment costs when firms adopt clean energy technology (rarely observed).

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- Technical change is **skilled-biased**
  - general purpose technologies: automation (Autor et al. 2003, Acemoglu & Autor 2011, Acemoglu & Restrepo 2022)
  - green technologies (Marin et al. 2018, Saussay et al. 2022)

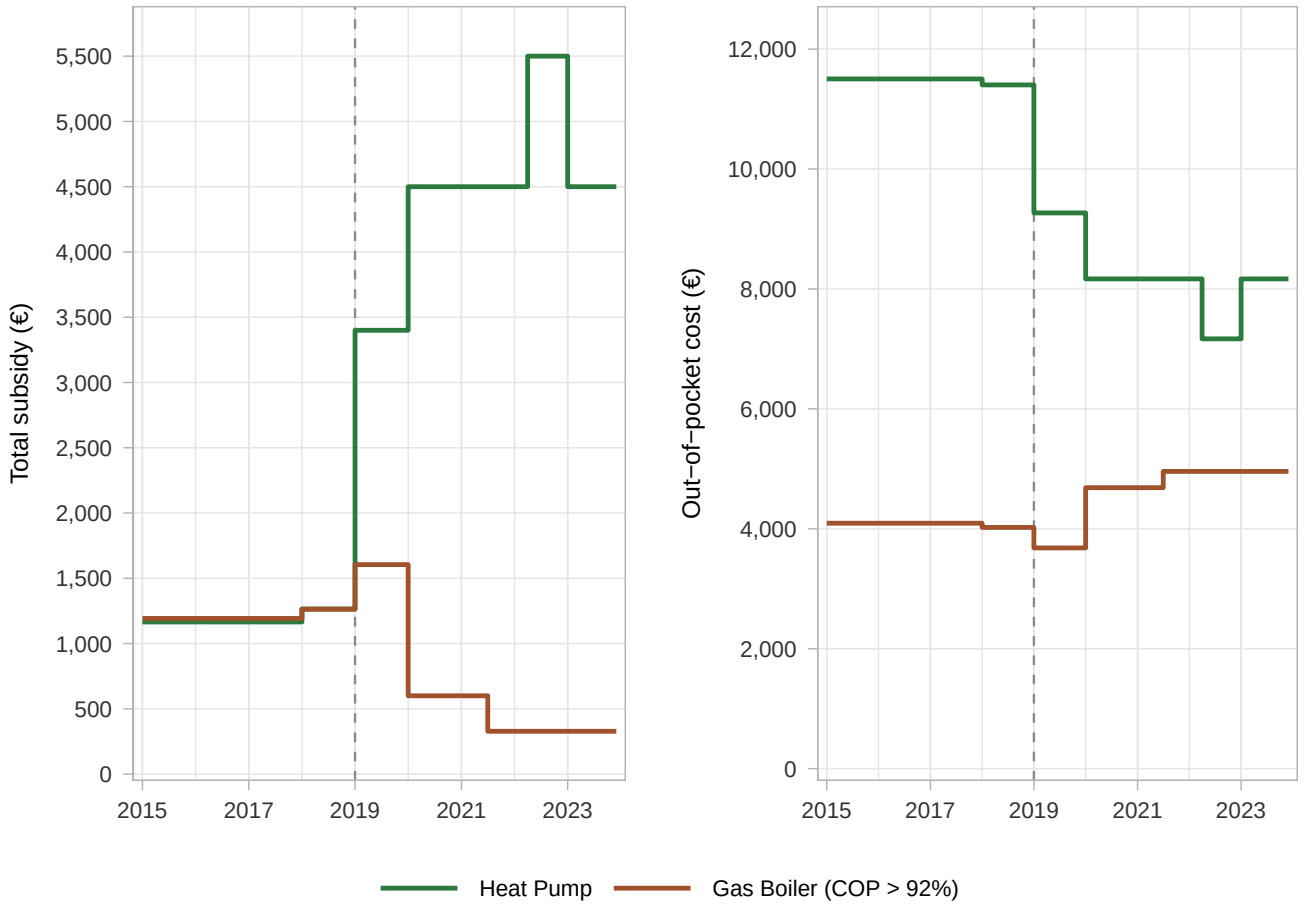
→ Technology adoption may have positive & negative outcomes for workers with different skill endowments

My case study: Decarbonization of French HVAC installation

- Buildings account for 25% of GHG emission and 40% of energy consumption, mostly through heating
- 60K+ heating service SMEs and 375K+ employees (2019)
- From fossil boilers to heat pump installation: an emblematic SME-level clean technology adoption

Massive incentive shift favors heat pump installation

- Mix of public subsidies (€3B/y) and energy obligations (€6B/y)
- Jan. 2019 reform: +€2,500 granted for heat pump installation



(a) Financial support (b) Out-of-pocket cost

Installers shift from fossil boilers to heat pump

- Energy efficiency investments are credence goods

⇒ Only works performed by "Recognized Environmental Guarantor" certified firms qualify for subsidies & supplier grants.

(a) Certificates by work-type

(b) Cumulative Adoption Rate

Certification content

Data sources

- Residential heating services industry
  - "Recognized Environmental Guarantor" certificates (ADEME) for each month over 2017-2023
  - National comprehensive directory for the identification of French companies and their establishments (SIRENE from INSEE)

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  - Daily entries & exits from any position in each business (Mouvement de Main d'Œuvre, 2017-2021)
  - Yearly hours worked and labor earnings for each wage earner, derived from employer tax declarations (Base Tous Salariés, 2015-2023)

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$\Rightarrow \approx$ 100K heating service businesses & 800K workers.

▸ Sample selection

Estimation strategy: Industry-specific dynamics vs. spillovers

- **Treated**: Get heat pump certification in 2019
- **Control**: Never certified through 2023
- **Excluded**: Late adopters triggered by spillover effects (SUTVA).

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Table: Pre-Treatment Balance (2017–2018)

	Treated		Control		Difference
	Mean	(SD)	Mean	(SD)	
N Establishments	2,859		92,559		
Headcount (avg)	6.07	(12.05)	5.80	(19.37)	0.27
Age (years)	6.71	(9.81)	6.92	(9.27)	−0.22
Population (CZ)	20,518	(48,050)	33,911	(60,698)	−13, 393
% Fuel Oil (CZ)	11.6	(8.4)	8.9	(7.4)	2.6

→ Same size/age; Treated more rural—Control more urban.

Employment dynamics at the establishment-level

Technology adoption

Identifying variation: Heat pump certification for establishment i in month m.

Empirical Challenges:

- Staggered adoption for 2,859/95,418 establishments
- Local labor markets affect employment dynamics

Callaway & Sant'Anna (2021):

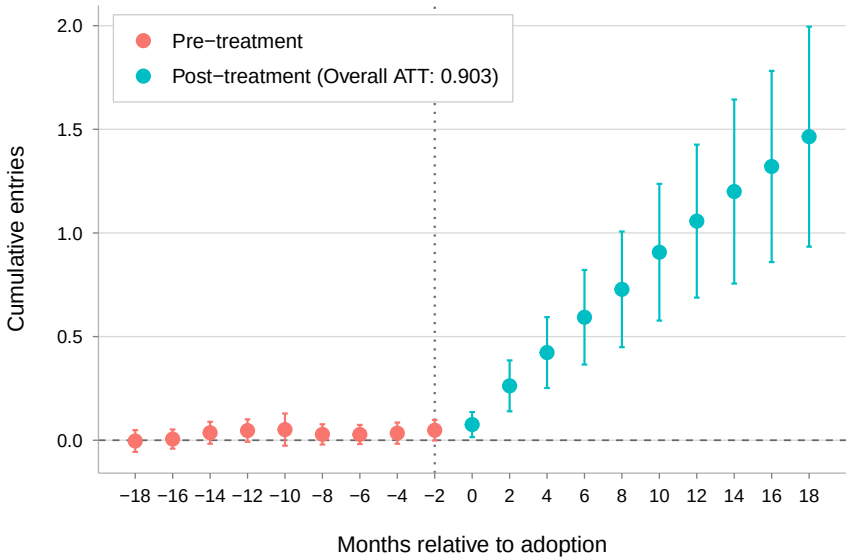
- Group-time specific effects: $ATT(g, t)$
- Inverse probability weighting on local heating sector headcount and establishment age.

Staggered Difference in Difference

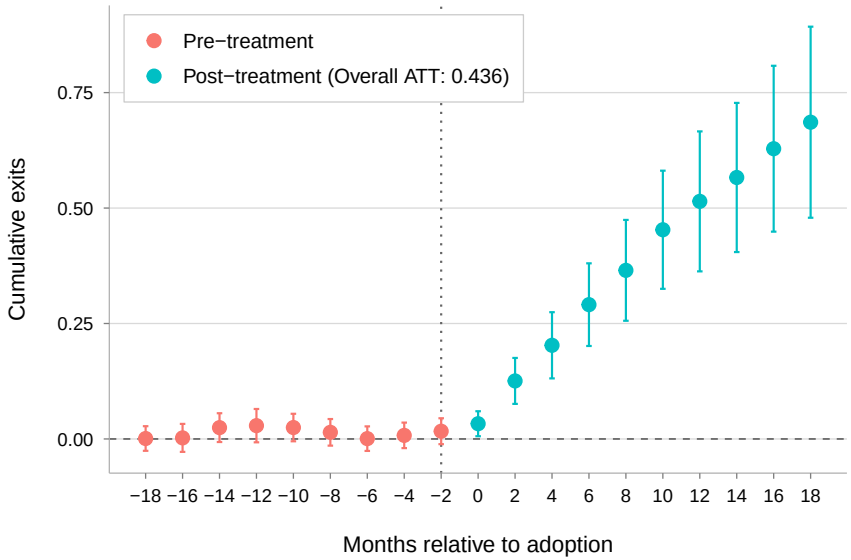
For each cohort g (treatment timing) and period t:

$$ATT(g, t) = \mathbb{E}[Y_{it}(g) - Y_{it}(\infty) \mid G_i = g]$$

Job creation and destruction



Entries



Exits

- **Within-firm labor reallocation**:
  +1.5 jobs created and **+0.75 jobs destroyed** within 18 months

⇒ **Winners and losers** of clean technology adoption?

Notes: Event-study estimates using Callaway & Sant'Anna (2021).
Sample: 95,418 establishments across 42 odd-months.

Labor market outcomes for incumbent workers

Worker exposure to technology adoption

Sample: All workers present at same establishments in both 2018 & 2019
Identifying variation: Employed in establishment adopting heat pump in 2019.

Workers may differ systematically across treated vs. control establishments

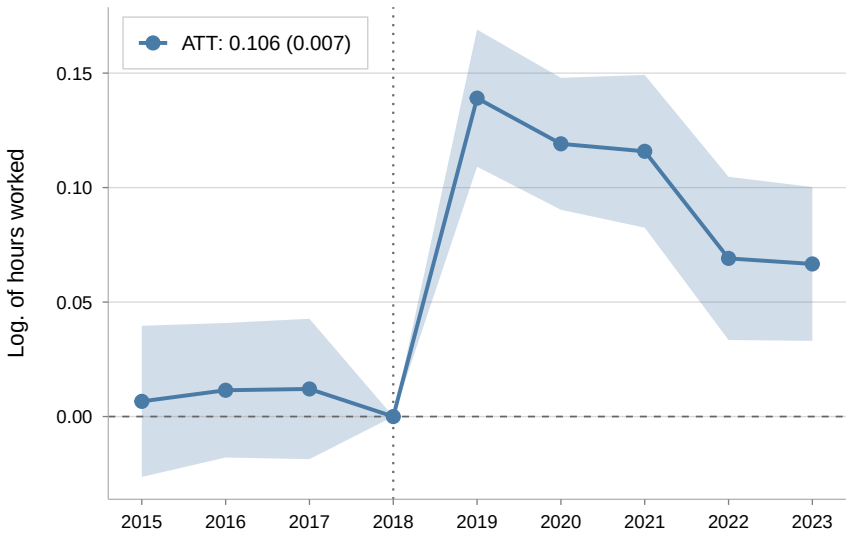
- 1:20 nearest-neighbor matching on workers age
- Exact matching on: main activity code, occupation code, gender

Event Study design

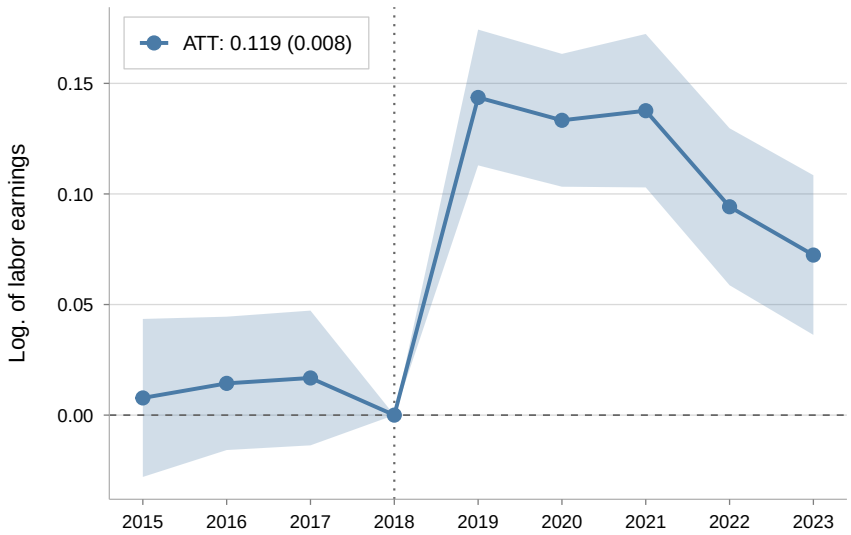
$$\log(y_{ist}) = \sum_{k \neq -1} \beta_k \cdot \mathbb{1}\{t = k\} \cdot \text{Treat}_{st} + \alpha_i + \gamma_s + \delta_t + \varepsilon_{ist}$$

where y_{ist} is hours/earnings/wages for worker i in establishment s in year t; k measures years relative to 2019. Standard errors clustered at establishment level.

Incumbents Workers: Hours and Earnings



Log Total Hours Worked



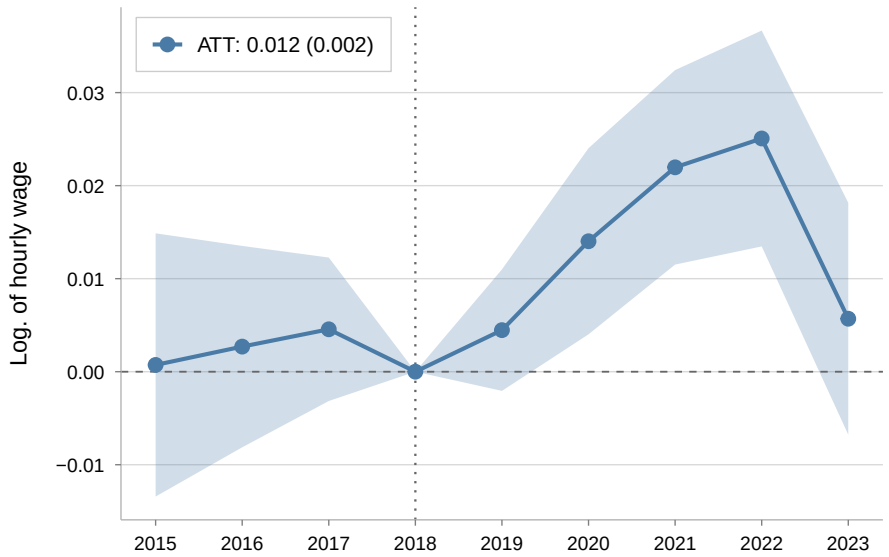
Log Annual Earnings

- Substantial increase in 2019, moderate over time

→ Labor supply is the primary adjustment margin, consistent with **on-the-job reskilling**.

Sample: 11,229 treated workers, 117,748 matched controls (2015-2023)

Incumbent Workers: Hourly Wages



Log Hourly Wage

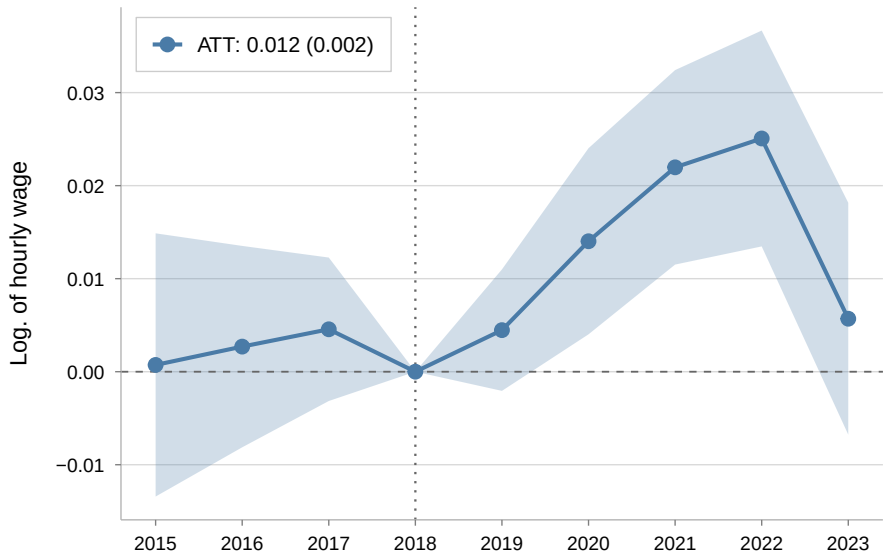
- No wage effect in 2019 despite large rise in hours

→ **Retraining costs** passed-through wages

- Only modest wage gains emerge (+2% average ATT)

→ **Monopsony power** of employers.

Incumbent Workers: Hourly Wages



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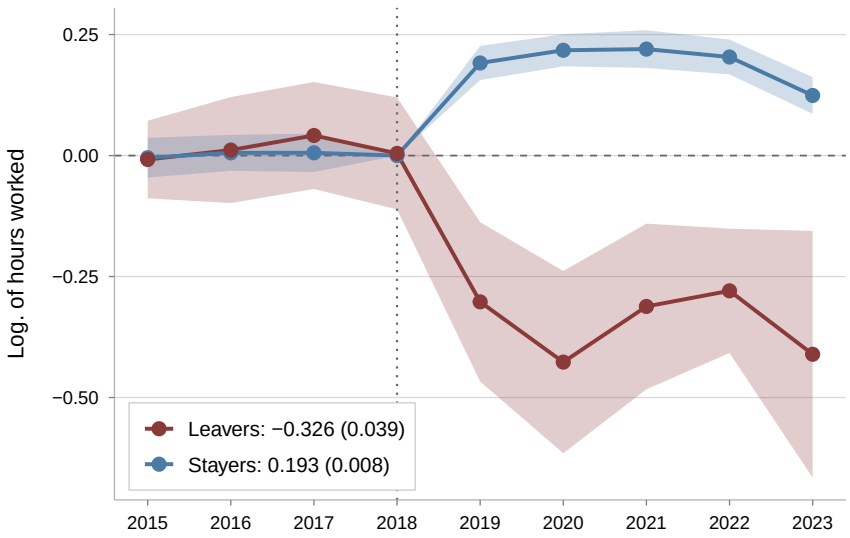
Key question:

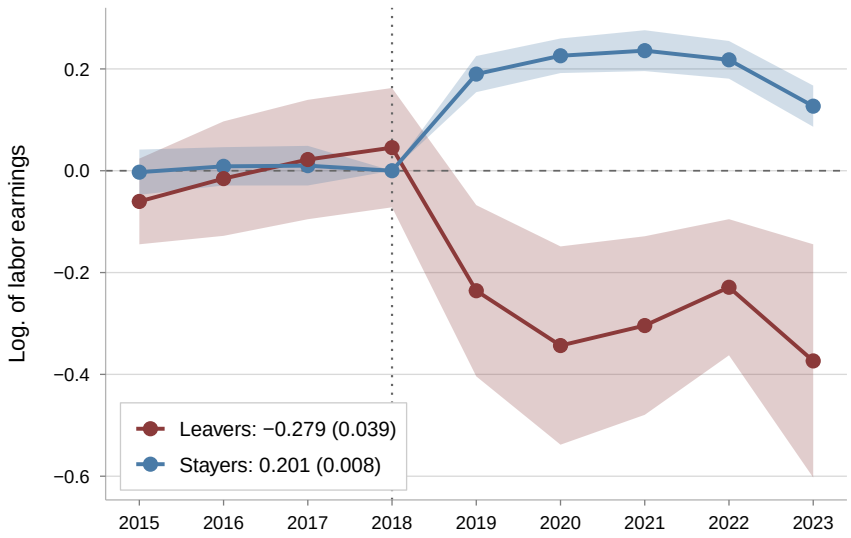
Who drives the average effect? Workers who stay vs. those who leave?

Stayers vs Leavers in Calendar time

▸ Method



Log Total Hours Worked



Log Annual Earnings

- **Stayers drive overall results** with +20% in hours and earnings, immediate and persistent

→ Leavers collectively worse-off, yet cohort specific estimates aggregated in calendar mask individual dynamics.

Stayers: 7,395 treated, 100,890 controls — Leavers: 2,523 treated, 36,576 controls

Labor market effects for movers

Worker exposure to separation/entry post-adoption

Leavers: Present in 2018-19, exit 2020-23
Newcomers: Absent in 2019, enter 2020-23

Empirical Challenges:

- Mobility timing varies across workers
- Need to control for place-time specific trends

Solution:

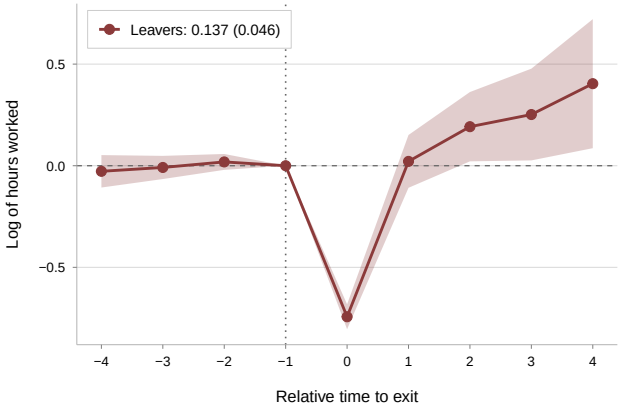
- Event time relative to mobility
- Include CZ $\times$ year FE

Event study design in relative time

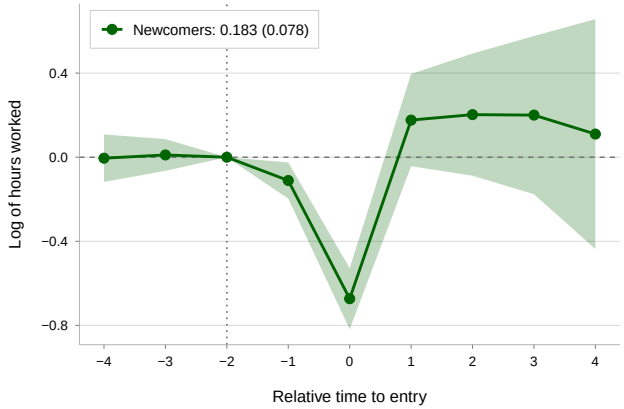
$$\log(y_{ist}) = \sum_{k \neq k_0} \beta_k \times \mathbb{1}\{t = T_i + k\} \times \text{Mover}_i + \alpha_i + \gamma_s + \delta_{z \times t} + \varepsilon_{ist}$$

where T_i = mobility year (separation/entry), k = years relative to mobility, $k_0 = -1$ for leavers, $k_0 = -2$ for newcomers. Standard errors clustered at establishment level.

Leavers



Newcomers



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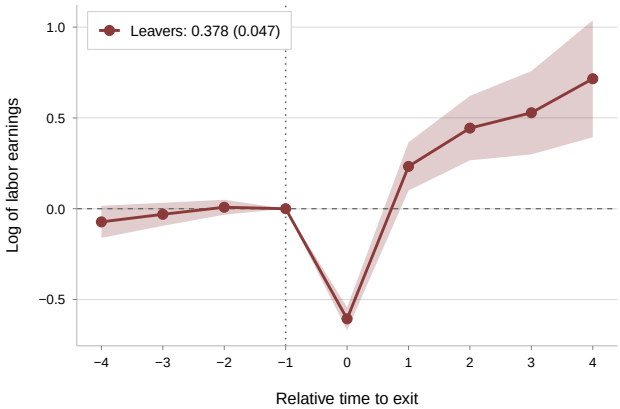
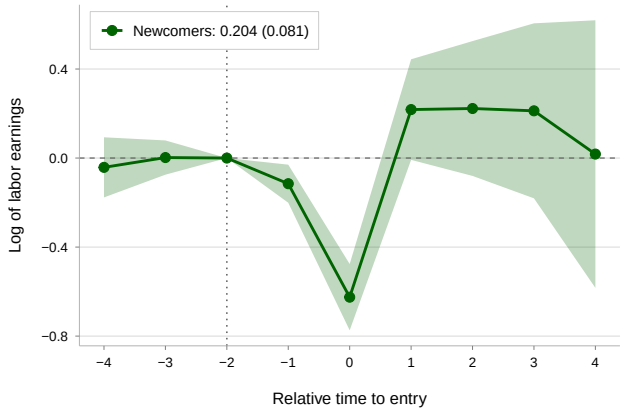


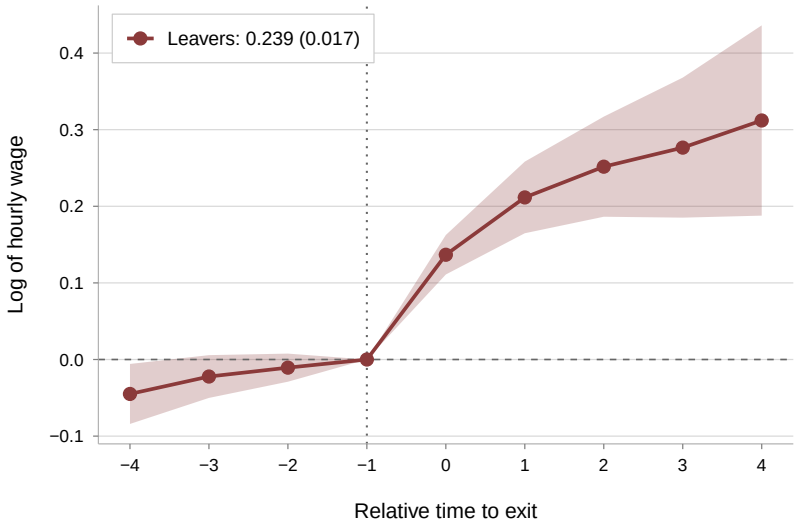


Log Annual Earnings

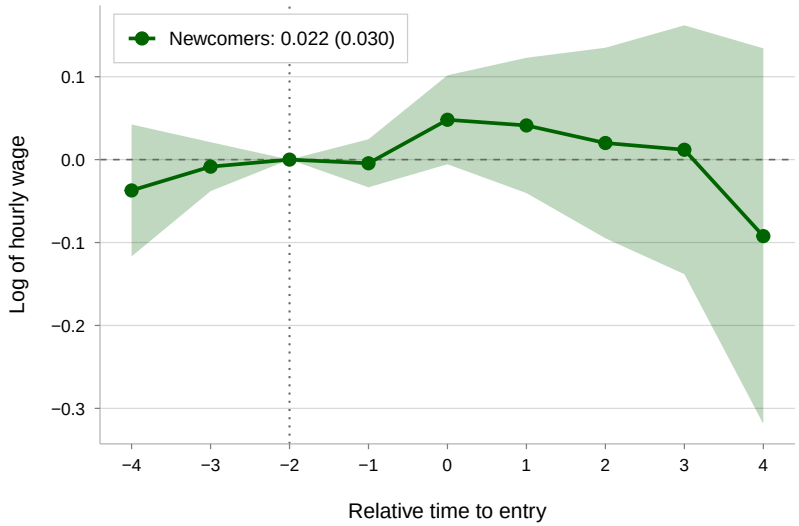
- **Only temporary costs** at $t = 0$ for movers, full recovery by $t = 1$.
- **Leavers** work $+15\%$ and earn $+35\%$.

Leavers: 2,523 treated, 36,576 controls — Newcomers: 1,529 treated, 27,131 controls

Leavers



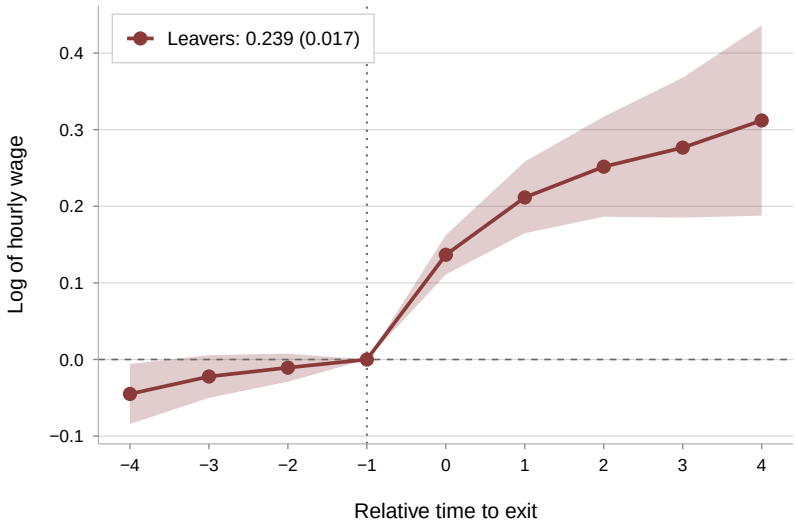
Newcomers



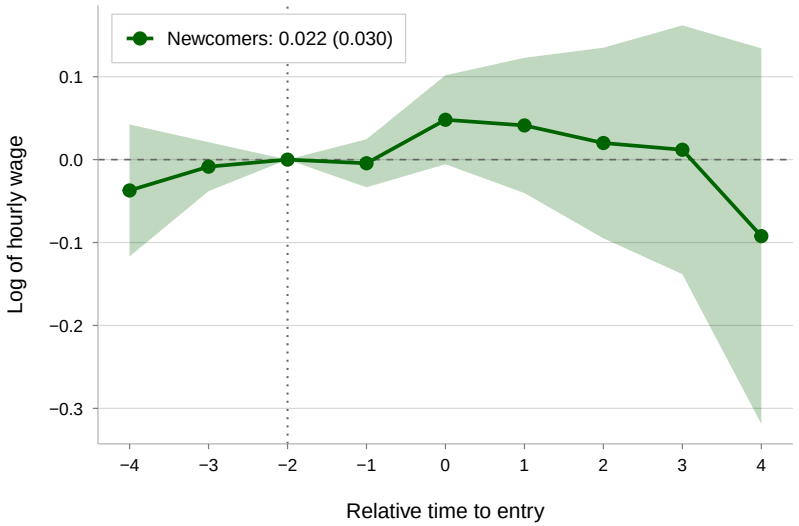
Log Hourly Wage

- **Leavers**: +20% wage premium post-separation
  - Hired for their newly acquired skills
  - → **Escape monopsony power** of previous employer
- **Newcomers**: Flat wages
  - Hired for general labor
  - → Require **on-the-job reskilling**.

Leavers



Newcomers



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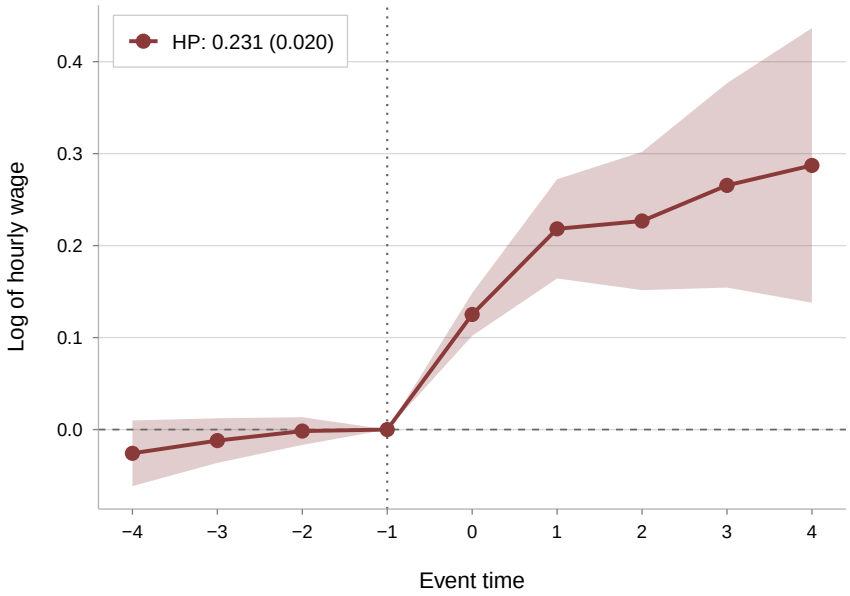
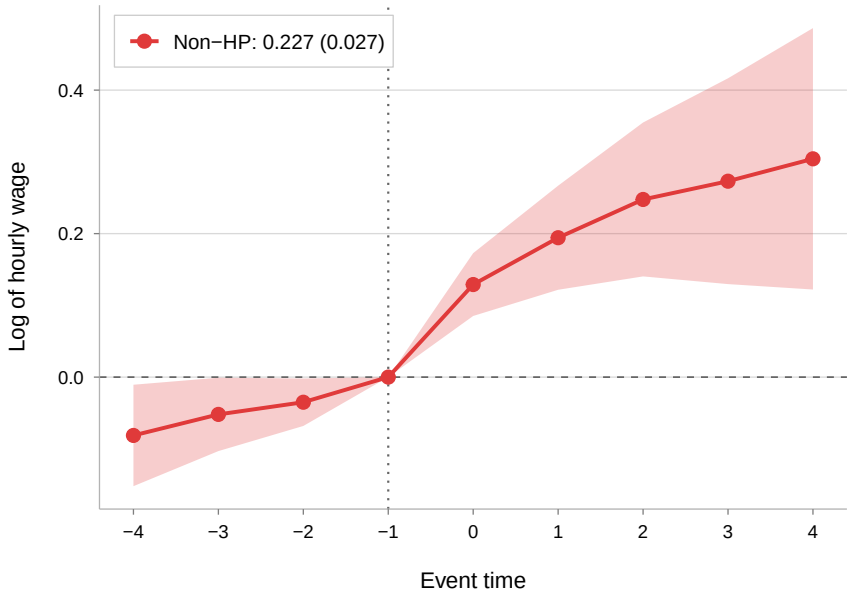
⇒ Do effects vary by **mover's destination/origin?**

Leavers: Wage Effect by Destination



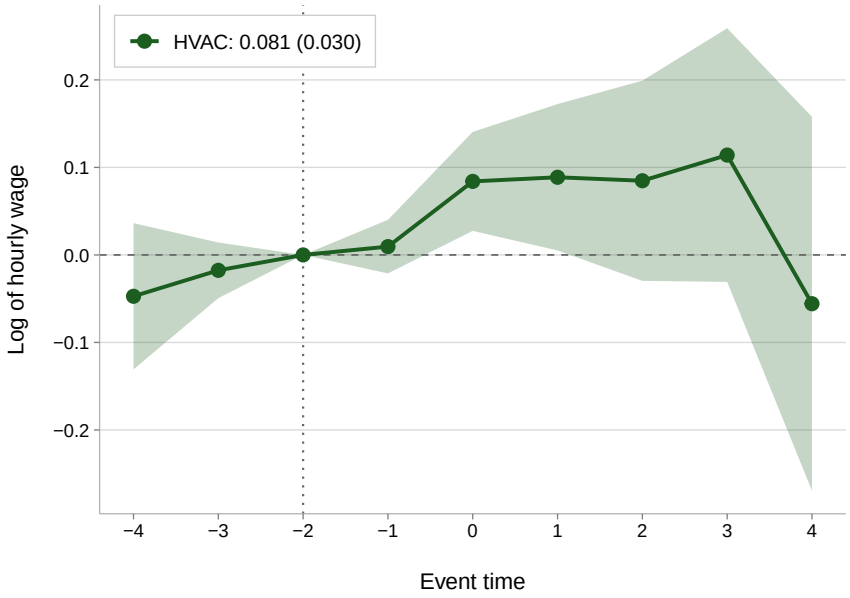


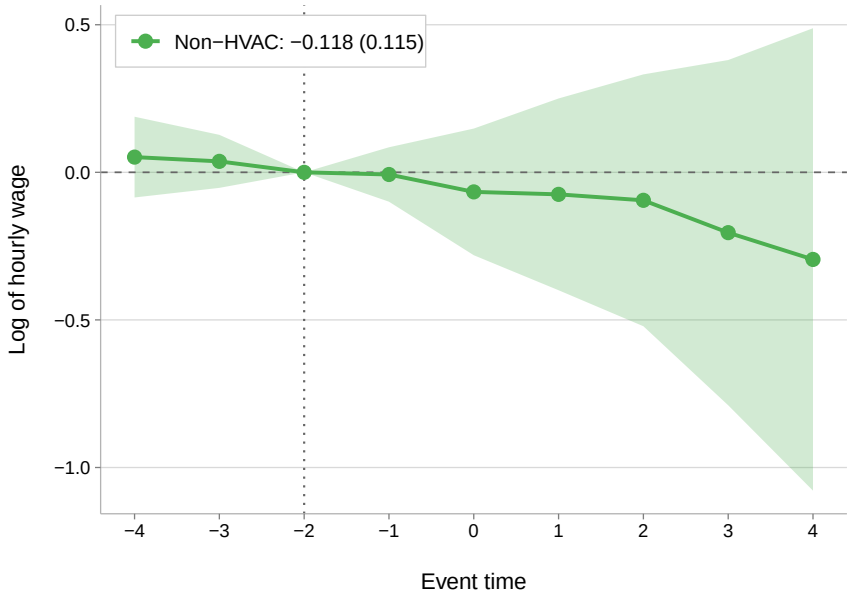
- Similar +20% wage premium regardless of destination type

→ Workers exposed to technology adoption get **portable skills** that are not firm-specific.

Sample: HP destination N = 13,425 — Non-HP destination N = 3,538 (treated leavers only)

Newcomers: Wage Effects by Industry Origin





- **HVAC origin:** +8.1% wage premium (significant)

→ **Smaller skills gap** lowers adjustment costs & allows wage gains.

Sample: HVAC origin N = 19,494 — Non-HVAC origin N = 2,912 (treated newcomers only)

Implications for the design of a just transition

1. **Support within-firm adoption through market incentives**
   - On-the-job training minimizes disruption vs. creative destruction
   - Limited skill distance mitigates adjustment cost
2. **Set minimum quality standards & provide training**
   - Build training capabilities in advance to avoid bottlenecks
   - Regulate monopsony power to ensure reward on skills updating and further reduce transition costs
3. **Set incentives on both demand AND supply sides**

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$\Rightarrow$ The energy transition **needs not create mass displacement** when the right market incentives are set and retraining cost is minimized.

Future research

- Separate voluntary quits from involuntary layoffs

→ Potential long-run losses if forced displacement

- Skill transferability across different technology contexts

→ Detailed origin-destination matrices

Thank you!

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☞ I am on the 2025-26 Academic Job Market!

Appendix

From certification to technology adoption

- Certification is tied to a training covering 3 dimensions
  - **Technical competencies**: thermodynamic principles, sizing calculations, COP optimization
  - **Regulatory knowledge**: subsidy eligibility, environmental regulations, product durability standards
  - **Customer communication**: explaining technology choices and long-term maintenance requirements to clients.

Timeline

- Contractors get listing on public registers promoted by governmental agencies, helping new entrants building credibility

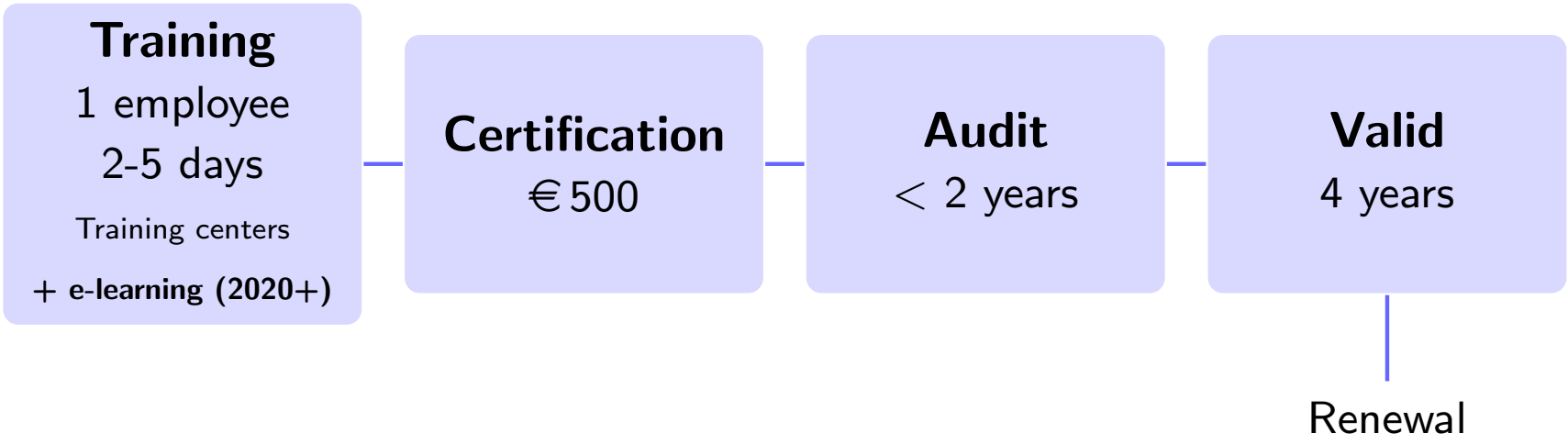
Listing

- Virtually no heat pump installation by non-certified installers in the pre-reform period: certification marks the start of a competency-building process.

Coverage

Back to adoption

Certification timeline



- 2011: Creation of the RGE certification to ensures minimum quality level for subsidized works
- 2015: RGE certification becomes mandatory to access both public & private subsidies
- 2020: Covid-19 accelerates e-learning solutions → reduced costs

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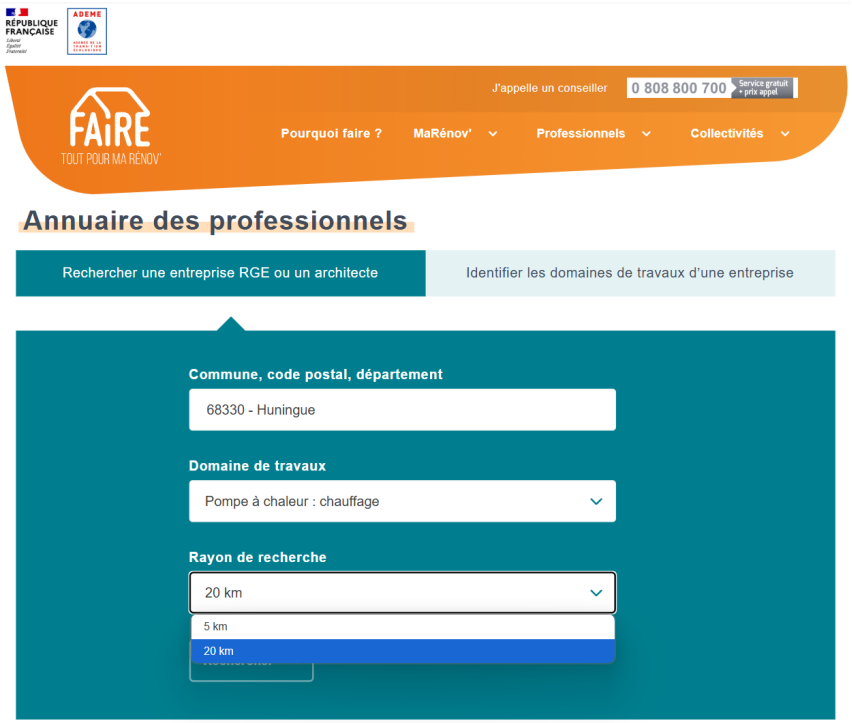
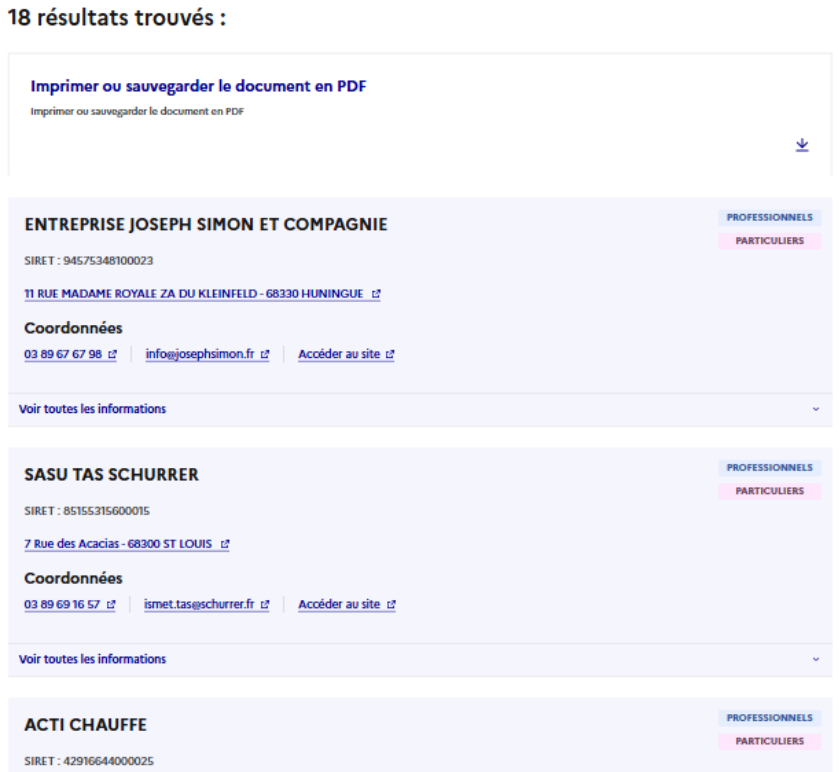
Certified contractors get public listing on government registers



Search engine at `faire.gouv.fr` (2018)



List of contractors in a 20km radius, ranked by Euclidian distance with municipality centroid

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Certification Coverage of Heat Pump Renovation Market

Year	CITE (installations)	CEE (installations)	Renovation (installations)	CITE + CEE coverage (%)
2016	23,600	4,750	35,003	67—81
2017	28,800	5,528	43,301	66—79
2018	38,100	9,245	69,225	55—68

- Both tax credits (CITE) and EEO grants required RGE-certified contractors
- Coverage of 55–81% demonstrates substantial subsidy penetration and near-universal use of certified installers in renovation market

Sources: CITE from DGFIP (2023); CEE from CASD; Market data from Observ'ER (2020)

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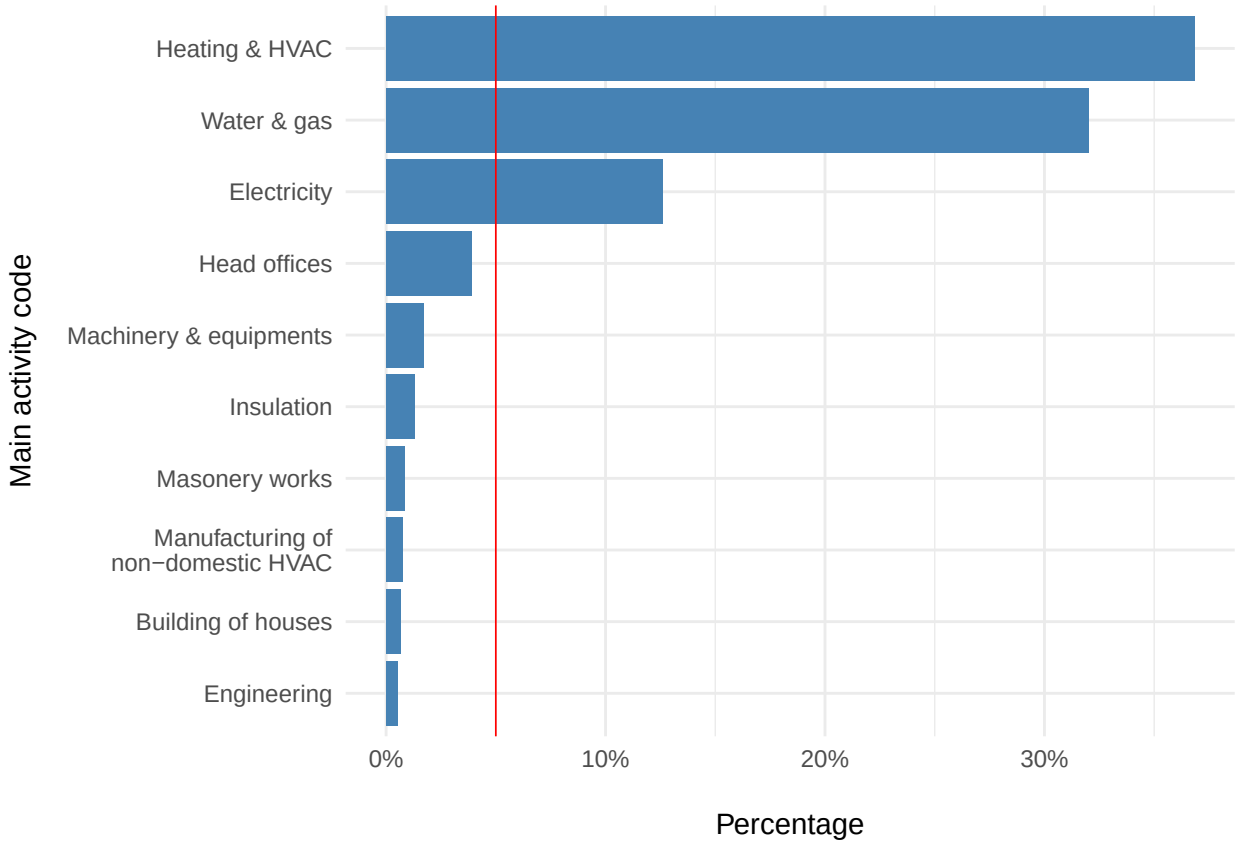
Sample Construction

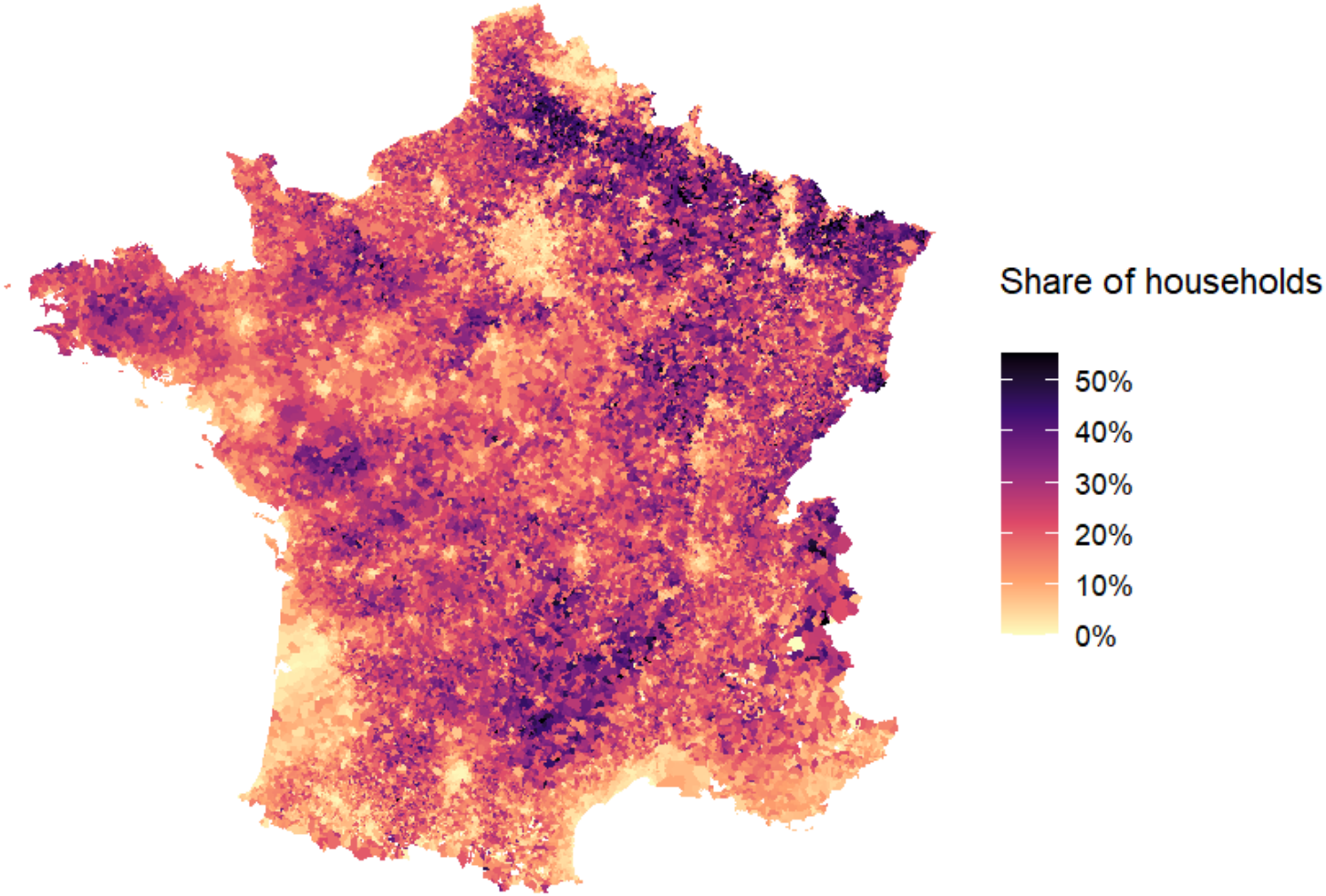


Top 10 main activity codes across heat pump certified establishments

Note: Retained sectors (5%+ threshold): heating/HVAC (43.22B), water/gas (43.22A), electrical installation (43.21A)

◂ Back

Fuel Oil Use in 2017



Reliance on a Fuel Oil as Main Heating Source by Municipality, 2017

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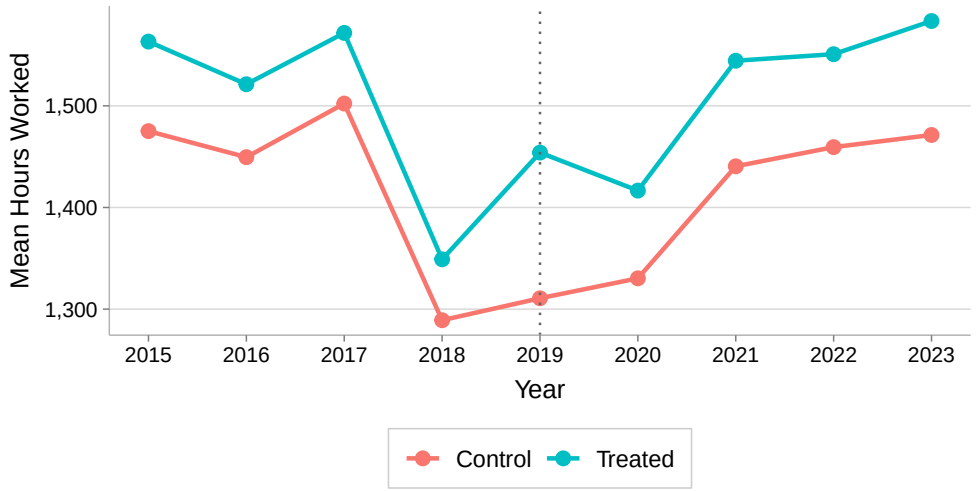
Worker-Level Balance: Full Sample

	Treated		Control		Difference
	Mean (1)	SD (2)	Mean (3)	SD (4)	(T-C) (5)
Panel A: Full Sample (2018)					
N Workers	19,921		479,762		
Age (years)	36.59	(12.63)	37.30	(12.31)	−0.71
Female (%)	15.69	(36.37)	13.33	(33.99)	2.36
Blue collar (%)	64.44	(47.87)	53.68	(49.86)	10.76
Managers (%)	20.10	(40.07)	32.84	(46.96)	−12.74
Hours worked	1,216.19	(670.40)	1,161.97	(687.28)	54.22
Annual earnings (€)	20,117.23	(16,786.53)	21,407.63	(19,241.84)	−1, 290.40
Hourly wage (€)	15.79	(8.85)	17.32	(11.06)	−1.53

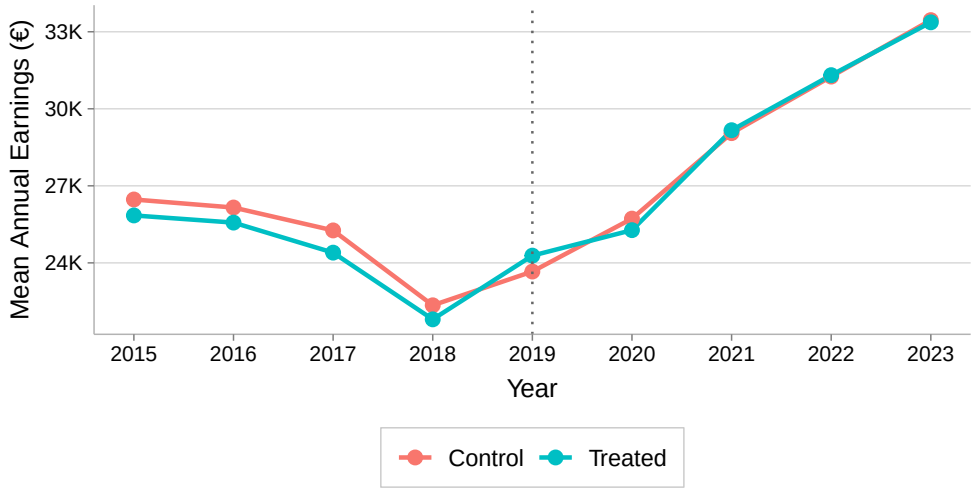
Worker-Level Balance: Matched Sample

	Treated		Control		Difference
	Mean (1)	SD (2)	Mean (3)	SD (4)	(T-C) (5)
Panel B: Matched Sample (2018)					
N Workers	13,499		121,681		
Age (years)	36.71	(12.42)	36.84	(12.09)	−0.13
Female (%)	14.97	(35.68)	13.28	(33.94)	1.69
Blue collar (%)	66.97	(47.03)	62.02	(48.53)	4.95
Managers (%)	17.78	(38.24)	23.39	(42.33)	−5.61
Hours worked	1,348.99	(627.43)	1,289.09	(649.36)	59.90
Annual earnings (€)	21,800.65	(15,509.55)	22,347.42	(17,613.84)	−546.77
Hourly wage (€)	15.45	(8.01)	16.46	(8.83)	−1.01

Parallel Trends in the Matched Sample



(a) Hours worked



(b) Annual earnings

Stayers vs Leavers Analysis

◂ Results

Sample decomposition

Stayers: Present at same establishment in 2018-19 & 2023
Leavers: Present at same establishment in 2018-19, separated by 2023

Empirical Challenges:

- Separating on post-treatment outcomes is endogenous
- Leavers exit in different years

Solution:

- Restrict to workers with 3+ years tenure & match stayers and leavers separately
- Cohort-specific estimation for leavers

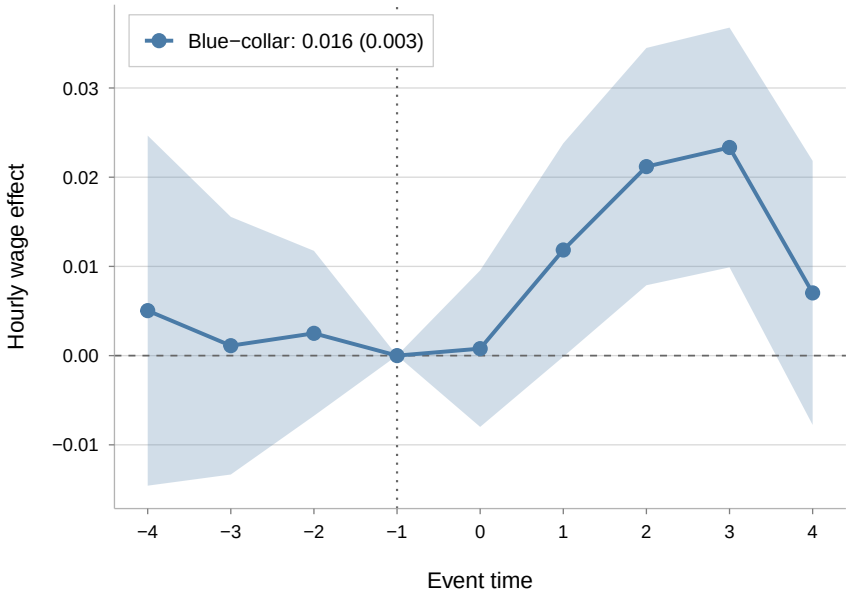
Event study designs

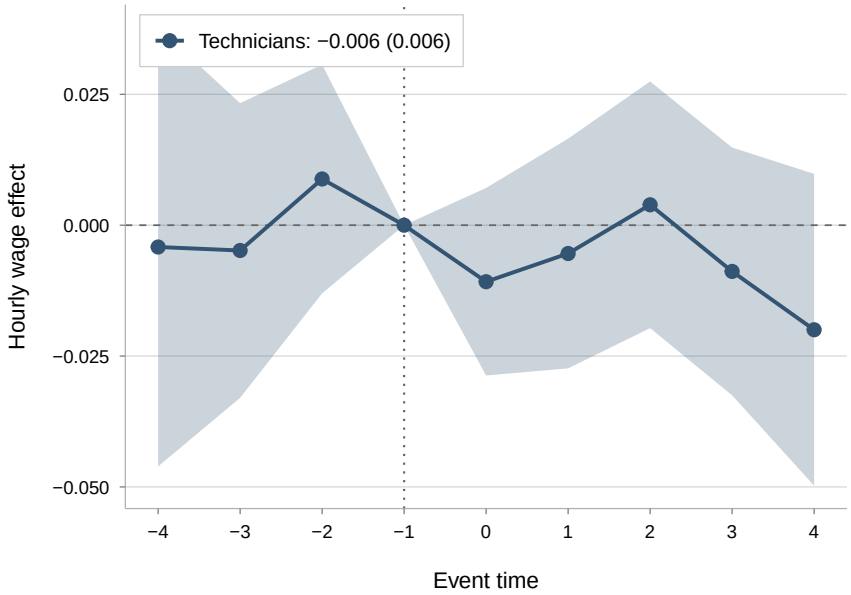
Stayers: Standard event study
Leavers: Cohort-specific aggregated to calendar time (Schmieder et al. 2023)

$$\log(y_{itc}) = \sum_{k \neq -1} \beta_k^c \times \mathbb{1}\{t = c_i + k\} \times \text{Leaver}_i + \alpha_i + \delta_t + \varepsilon_{itc}$$

where c_i = separation year. Calendar effects: $\gamma_t = \frac{1}{N_t} \sum_{c,k:c+k=t} \beta_k^c$

Stayers: Wage Effect by Occupation





- **Blue-collar:** +1.6% hourly wage gain (significant)
- **Technicians:** -0.6% hourly wage (non-significant)

→ Modest aggregate effect (+1%) driven entirely by blue-collar workers

Interpretation: Heat pump adoption rewards lower-skilled workers acquiring new competencies, improving their bargaining power within-firm

Sample: Blue-collar N = 33,238 — Technicians/Cadres N = 9,404 (treated stayers only)

Summary of Key Mechanisms

Why do we observe rapid adjustment with minimal costs?

- **Within-firm reskilling:** Stayers & newcomers work longer hours without immediate wage gains
  - On-the-job training for workers without prior heat pump experience
  - HVAC-origin workers face lower adjustment costs (smaller skill gap)
- **Portable skills:** Heat pump competencies (electrical systems, refrigerants, diagnostics) are not firm-specific
  - Leavers wage premium reflects market value of acquired skills, allowing to escape employers monopsony power
  - Skills are portable across the entire HVAC sector