Wired For Change? Clean Technology Adoption and Labor Market Transitions

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Abstract

Whether the green transition will harm or benefit workers is a central policy concern. This paper examines transition costs in SME-level electrification, focusing on heating service installers shifting from fossil fuel boilers to heat pumps. Using a subsidy shock and employer-employee data, I find sharp increases in job creation and separations, in line with substantial labor relocation. Stayers increase hours while displaced workers recover within one year. Hourly wages rise for workers exposed early to the technology and with smaller skill gaps, particularly when changing employers. Results demonstrate how market incentives enable on-the-job skill updating, keeping transition costs low despite reallocation.

Keywords: decarbonization, transition costs, labor reallocation, skills upgrading

JEL codes: Q52, J24, O33

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1 Introduction

The energy transition raises significant concerns about job losses and reduced earnings, particularly for blue-collar workers in energy-intensive industries. These concerns fuel opposition to environmental regulations and contributes to anti-environmental political backlash[1]. Green investment programs stand out as an important exception: by supporting the decarbonization of small and medium enterprises, they aim at creating new, local jobs for manual workers[2]. Yet the transition requires major skills updating that, if mismatched, could lead to career's disruptions and foregone earnings[3].

This paper provides the first evaluation of transition costs for workers in small and medium-sized enterprises adopting clean energy technologies. Concerns about a just transition are shaped by the case of workers in the fossil energy sector, especially coal-fired electricity generation and oil extraction[4]. Extending to hard-to-abate industries (cement, chemicals and petrochemicals, and steel industries), around 9% of the workforce in OECD countries is directly threatened by major earning losses and long run displacement costs (Barreto et al. 2024). Yet effects may not generalize to SMEs, which gather 60% of workers (OECD 2023). While energy-intensive industries face fundamental technical and financial barriers[5], the transition of SMEs may prove achievable through proven technologies requiring limited upfront investment (World Economic Forum 2024; European Investment Bank 2025).

In this study, I use an exogenous transition from fossil-fuel boilers to heat-pump installation among French heating service firms. This shift is emblematic of SME-level electrification as it implies major skill transformation. Workers should be trained for handling refrigerants contained in heat pumps and for working safely with electrical systems and high-voltage circuits, along with correctly sizing heat pump systems and programming their control systems. More fundamentally,

[1] In the US, see: "Trump is still courting coal workers. This county shows why it matters." 2024; "Reinvigorating America's Beautiful Clean Coal Industry and Amending Executive Order 14241" 2025. In the EU, see "EU to pare back sustainability rules for companies, draft shows" 2025.

[2] Recent examples include the Inflation Reduction Act (IRA) in the US or the European Green Deal in the EU (European Commission 2020; The White House 2022).

[3] Green recovery packages have come with massive job creation promises, potentially alleviating the negative consequences of the energy transition. Skill gaps constitute a key barrier to achieve this objective: "Biden's 2024 challenge: green jobs" 2024; "Global jobs market shaken by green transition" 2025.

[4] Look et al. 2021 identify more than 100 US or European policies aimed at achieving "a widespread shift from coal to natural gas and renewables", while "prioritizing fairness for workers and communities that have historically depended on fossil energy".

[5] According to Gross 2021, an example of technical barrier is high-temperature heat requirements; financial barriers include capital intensity, long investment cycles and stranded assets.

heat pump installation demands deeper thermodynamic understanding than gas boilers, as pumps move heat through refrigeration cycles rather than simply burning fuel (Carrier University 2024). I compare the labor market outcomes of workers in adopting versus non-adopting establishments for the period 2015-2023. In 2019, a generous subsidy is granted to French households replacing inefficient fossil-fuel boilers by a heat pump[6]. As heating firms switch to this new installation service, changes in earnings and career trajectories reflect the costs and benefits of adapting to this clean technology.

I find that technology adoption yields major labor reallocation at the establishment level. Using a staggered difference-in-difference estimation with matching, I estimate 1.5 job creation and 0.75 job destruction within 18 months. Second, I find little evidence of significant transition costs. In an event-study design on matched employer-employee data, I identify a +10% rise in hours and a +12% rise in labor earnings. Earning gains are mostly driven by stayers working longer hours, yet workers who separate after adoption experience only short-run losses. When moving to a new employer, workers with prior technology exposure or smaller skill gaps experience hourly wage increases, consistent with rising market demand for heat pump installation expertise.

These findings are relevant to a broad literature documenting the labor market consequences of environmental regulations. Workers displaced from polluting sectors and endowed with occupation-specific skills incur major welfare losses (Walker 2013, Yip 2018, and Marin and Vona 2021). A growing literature focuses on the adverse employment effects of resource extraction declines, exemplified by the phase out of coal mining (Haywood, Janser, and Koch 2021, Rud et al. 2024) or the contraction of oil extraction (Ellingsen and Espegren 2022, Garnache, Isaksen, and Nareklishvili 2025). These earning losses are compounded by the fact that workers rarely succeed at moving from more pollution-intensive to greener jobs (Bluedorn et al. 2023, Curtis, O'Kane, and Park 2024).

Yet, existing research has focused predominantly on declining energy-intensive industries rather than on clean energy technology adoption in transitioning SMEs. A potential explanation lies in the empirical challenge to identify quasi-exogenous adoption of clean energy technology, a fundamentally endogenous decision with respect to each firm's own strategy and transition costs. As a result, existing literature cannot separate the effect of technology adoption at the establishment-level from that of the industry-level economic downturn. My empirical setting addresses this

[6] As of January, 2019, all French households benefit from a minimum €2,500 subsidy, more than one fourth of the overall cost (installation included).

challenge by exploiting the unique context of energy efficiency policies in France. I leverage a subsidy shock and a legal requirement—the establishment-level environmental quality certification *RGE*—to identify technology adoption and evaluate its labor market effects. By isolating technology adoption from recessive dynamics, I observe both layoffs and hires, providing a much more nuanced understanding of the labor market effects of clean technology adoption.

The findings in this paper are also relevant to the literature on the skill-bias of clean technologies. The task-based framework developed by Autor, Levy, and Murnane 2003 and Acemoglu and Autor 2011 establishes that technological change reshapes labor markets by altering the skill content of jobs. Accordingly, Gathmann and Schönberg 2010 shows that worker mobility depends on task similarity between occupations. Applying this framework to green transitions, Vona et al. 2015 and Vona et al. 2018 leverage the O*NET classification and demonstrate that green occupations are systematically more intensive in technical, engineering, and managerial skills, while Consoli et al. 2016 confirm these skill differences persist when comparing green and non-green jobs within similar occupations. Saussay et al. 2022 advance this literature by using comprehensive job posting data, revealing that low-carbon vacancies have higher skill requirements across all five major skill groups (cognitive, IT, management, social, technical). They document substantial heterogeneity across occupations, suggesting highly context-specific retraining needs.

Using matched employer-employee data allows me to study how workers actually bridge the skill gaps during technology transitions at SME-level. Longer hours worked by stayers is consistent with on-the-job learning, dramatically reducing the cost of transition by avoiding layoffs. Hourly wage increases for movers endowed with the new technology reveal that green skills still have a genuine market value, but workers must signal these competencies by switching employers to realize wage gains.

The remainder of the paper is organized as follows. Section 2 provides background on France's energy efficiency policy and the 2019 subsidy shock. Section 3 describes the data. Section 4 outlines the empirical strategy. Section 5 presents the results. Section 6 discusses the mechanisms and policy implications, and Section 7 concludes.

2 Context

As the host-country of the Paris Agreement of 2015, France has set ambitious mitigation targets. This includes a 30% reduction in gross greenhouse gas emissions by 2030 compared to 2012 levels. (European Commission 2024)[7]. To achieve this goal, efforts concentrate on the decarbonization of the building stock, which represents 44% of the energy consumed and roughly one quarter of carbon emissions. According to the French Prime Minister's strategic planning agency *France Stratégie*, 72% of all 2030-targets green investments should go to buildings energy renovation (Pisani-Ferry and Mahfouz 2023). This renovation effort relies on two main components, namely, the insulation of buildings envelope and the replacement of heating systems. In this paper, I focus on the second type of investment, and more specifically on the diffusion of heat pumps as a substitute for fossil fuels boilers.

2.1 The French EEOs

France's energy efficiency policy relies on a mix of public and private subsidies, which largely benefits the residential sector. Both types of funding have changed in scale and scope since the mid-2000's, when the first tax credit and the pilot period of the energy efficiency obligations scheme (EEOs) were launched[8]. While public funding has transitioned to a means-tested subsidy mechanism in 2020 (France Stratégie 2024), the private sector remains involved through the EEOs. Each period-specific (3-4 years) national energy savings target breaks down into individual energy savings targets, assigned to retailers of electricity, gas, and gasoline in proportion to their sales, with differing coefficients depending on the type of fuel and their carbon content. This is a direct application of the polluter pays principle (*TFEU* 2016). Obligated parties must fulfill their individual obligations by obtaining energy savings certificates delivered by the regulator for efficiency improvements performed in either the residential, the industrial or the tertiary sectors. In practice, around two thirds of these investments are made in the residential sector. Each certificate is worth one cumulative kWh of saved energy, corresponding to a decrease in future energy use[9].

[7]The 2024 *National Energy and Climate Plan* targets 107 million tones of oil equivalent of final energy consumption in 2030, which is 20% below the 2022 level.

[8]The French government first launched a tax credit for energy efficiency investments in 2005. Called *Crédit d'Impôt Développement Durable (CIDD)*, it was renamed *Crédit d'Impôt pour la Transition Energétique (CITE)* in 2014. Since 2006, the French energy efficiency obligation scheme (*Certificats d'Economies d'Energie, CEE* in French) operates under the supervision of the General Directorate of Energy and Climate.

[9]kWh are cumulative because the energy savings are calculated on the lifetime of the energy operation achieved.

In an energy efficiency obligation system, obligated parties seek to achieve their obligation at the lowest possible cost. For a set total investment cost, this leads to supporting more affluent household who require a smaller subsidy, creating an efficiency-equity tradeoff. Wealthier households facing fewer liquidity constraints are also generally more likely to invest in energy retrofits and receive subsidies (Darmais, Glachant, and Kahn 2024). Moreover, compliance costs are passed to all consumers through increased energy prices, leading to an indirect transfer from low- to high-income households (Rosenow, Platt, and Flanagan 2013). Since 2016, to compensate for these potential regressive impacts, the French EEOs requires that a share of certificates must be obtained from subsidizing renovation efforts from lower-income households (with annual income roughly below the median income in France). There are therefore two individual obligations per obligated party, a general obligation and a low-income obligation, and two types of certificates (general and low-income).

2.2 A subsidy shock for heat pumps

The 4th period of the French EEOs started on January 1st, 2018, with a total energy savings target of 1,600 cumulative TWh over 2018-2020[10]. This doubling of the overall obligation was part of a broader *Climate Plan* announced by the Minister for the Environment Nicolas Hulot in September 2017, which specifically targeted the phase out of fuel oil boilers and conventional (i.e., non-condensing) natural gas boilers [11]. This announcement marked an important milestone in the energy transition. Indeed, fuel oil heating systems emit 324 grams of CO_2 per kWh, compared to 227 grams for natural gas boilers and only 49 grams for heat pumps, making the latter 4 to 7 times less carbon-intensive than conventional heating alternatives (CGDD 2024). In France in 2018, 3.9 million households relied on fuel oil and 11.9 million on natural gas as their main heating source. This represents respectively 13% and 41% of all main residences (Service des données et études statistiques 2022).

To address political acceptance and just transition concerns, the government implemented a bonus system on top of the low-income obligation. Under these new rules, suppliers supporting investments at low-income households could be awarded *bonus* certificates if they committed to

[10] Part of this target (400 cumulative TWh) would go to projects benefiting to low-income households.

[11] The newly appointed Minister for the Ecological and Inclusive Transition Nicolas Hulot uncovered four key measures of his *Climate Plan*, including the phase out of inefficient fossil boilers, in an interview for *Libération* on September 17, 2017 ("Le plan Hulot: quatre mesures écologiques et solidaires" 2017, in French).

specific minimum grant levels (Darmais, Glachant, and Kahn 2024). This approach diverges from the theoretical functioning of Energy Efficiency Obligations (EEOs), where governments typically set individual obligations and allow obligated actors to freely set subsidy levels that minimize overall system costs. This first agreement, formalized in April 2018 in the *Charte Coup de Pouce* (literally in French, *Boost Charter*)[12], set the minimum grant for a heat pumps installation at €3,000 for households in the first quartile of the income distribution [13] and €2,000 for those in the second quartile[14]. Minimum grants were conditional on replacing a fuel oil boiler, a specific focus justified by Prime Minister Édouard Philippe describing fuel oil as an *"expensive, foreign, and polluting"* energy[15]. A few months latter in January 2019, the *Coups de Pouce* minimum grants were extended to conventional gas boiler replacements, i.e., any natural gas boiler except condensing ones, and all household types, with a minimum subsidy for heat pumps set at €4,000 for low-income households in the bottom half of the income distribution, and €2,500 for households in the top half of the income distribution (Assemblée Nationale 2021). Evolution in the level of minimal EEOs grants is depicted in Figure 1.

2.3 Policy-driven technology adoption

The rising support for heat pumps installation created a sudden demand shock, which triggered the conversion of heating technicians to the new technology. Knowledge of basic safety standards is ensured through mandatory worker-level certification in refrigerant handling by application of the European Union's F-Gas Regulation (European Parliament 2014; *Code de l'environnement* 2016). Beyond this individual requirement, adoption can be tracked at the establishment-level through a unique feature of the French energy efficiency policy framework. Since 2015, only works performed by firms holding an environmental quality certification (the so-called *RGE certificate*[16]) qualify for energy efficiency subsidies granted by the state or energy suppliers (Code général des impôts 2014). As shown in Section A.2, each type of work (e.g., insulation, heat pump installation, efficient gas boilers, biomass systems, and photovoltaic installations) requires a specific certificate

[12] See here for an example of such voluntary agreements between the French government and energy companies.

[13] Households in the first quartile are deemed in *extreme energy poverty*, or in French, *Grande Précarité Energétique*. Income thresholds are updated every year and vary for households residing in the Paris region vs. elsewhere, reflecting differences in the cost of living.

[14] The price of an average heat pumps installation in 2019 was at least €8,000, according to Observ'ER 2020.

[15] Prime Minister Édouard Philippe in November 14, 2018, on RTL radio at the height of the Yellow Vest protests. The timing made this declaration particularly controversial, as it reinforced government policy that protesters viewed as burdensome to rural and working-class households dependent on heating oil.

[16] *RGE* stands for *Reconnu Garant de l'Environnement*.

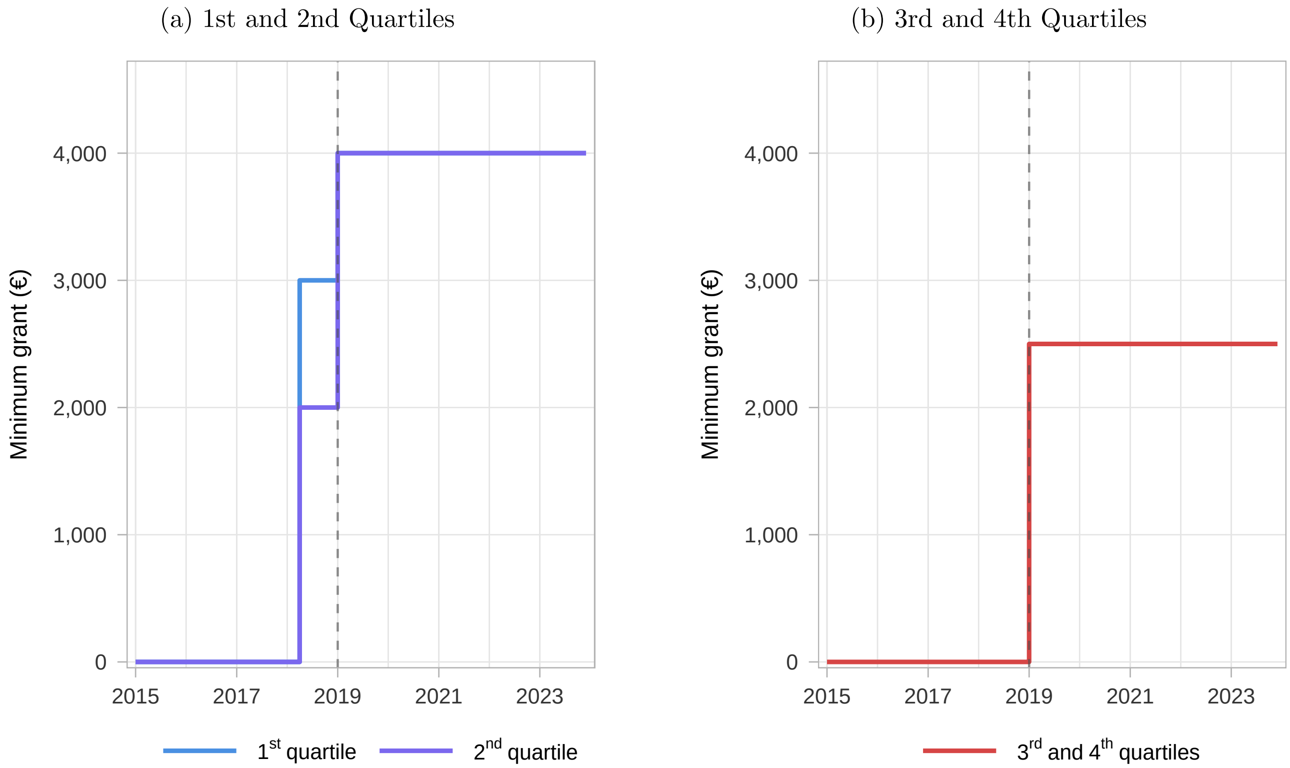


Figure 1: Minimum Grant Levels for Heat Pumps

Notes: The figure shows the evolution of minimum grant levels for heat pump installations under the French Energy Efficiency Obligation (EEO) scheme by income quartiles. The dashed vertical line in January 2019 marks a major policy reform that increased subsidy amounts.

(France Rénov' 2025). RGE certificates are granted at the establishment-level and involve mandatory training for one employee, who then becomes the establishment's technical referent. On-site audits are performed within two years of qualification and certificates remain valid for four years. Appendix A.3 provides a detailed overview of the certification process, including training requirements, costs, and timeline.

Focusing on the first year of the bonus mechanism reveals a sudden change in the dynamics of heat pumps certification. In Figure 2a, the cumulative adoption rate in the overall population of heating service firms increases sharply, from less than 5% in January 2019 to 7% by mid-2020. As shown in Figure 2b, the monthly count of new adoption, which fluctuates around 0 before the 2019 subsidy shock, becomes positive over a sustained period and reaches a monthly average of more than 100 new installers. The 2019 subsidy shock creates an unexpected and unprecedented incentive for heating service firms to enter the market for subsidized heat pumps. This exogenous shock isolates technology adoption from firm fundamentals, hence offering a unique opportunity to causally estimate the labor market impacts of the clean energy transition.

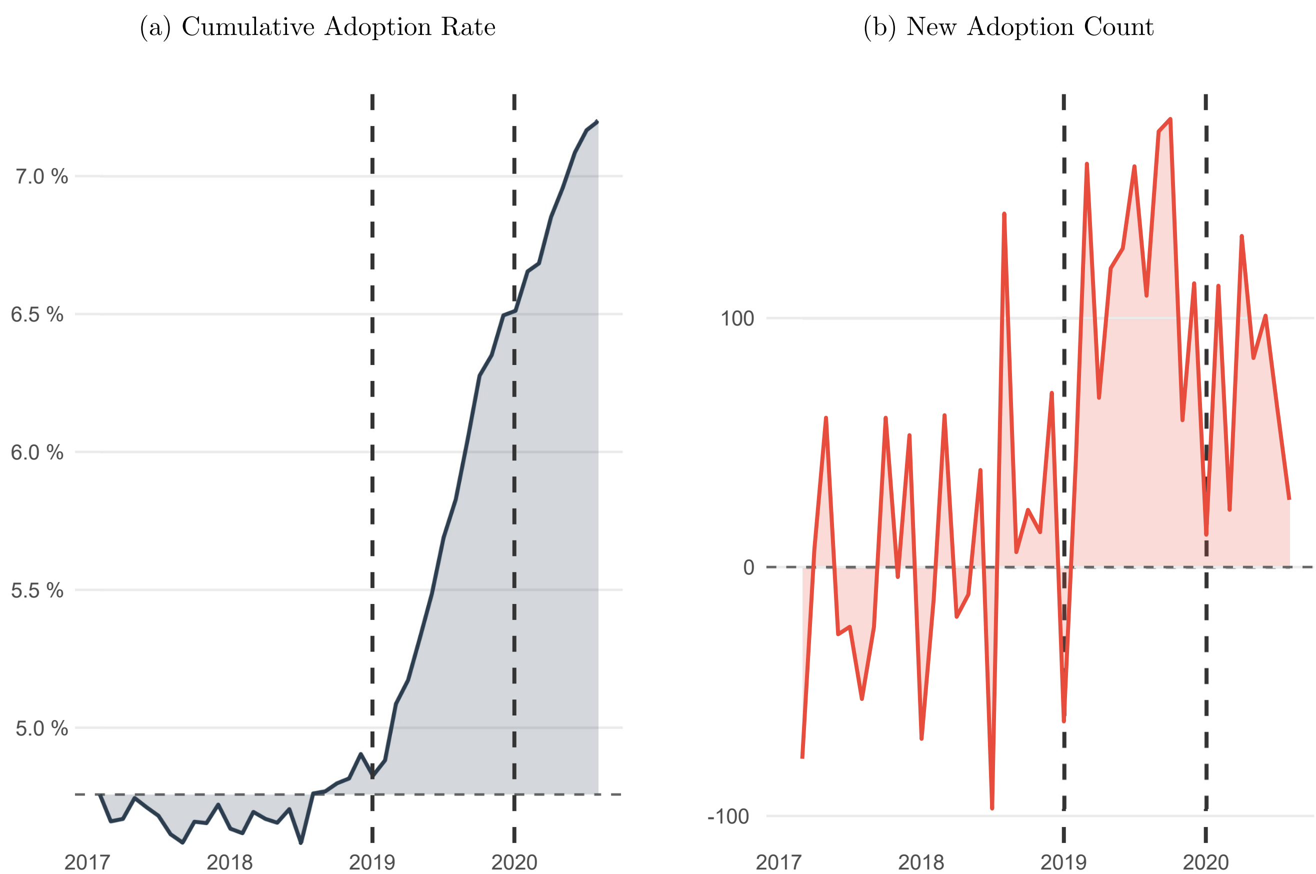


Figure 2: Heat Pumps Technology Adoption Patterns

Notes: The figure shows the supply-side response to the increase in heat pump subsidies over 2019 (dashed lines). The left panel displays the cumulative share of heating service establishments certified to install subsidized heat pumps in France. The right panel shows monthly certification counts.

3 Data

I combine several types of administrative datasets to construct the complete universe of heating services businesses in France and their workforce dynamics around the time of the reform.

The analysis primarily draws on employer-employee linked datasets. The first one is the *Mouvements de Main d'Œuvre (MMO)* dataset (DARES 2025) that provides daily records of all employees entries and exits from any establishment in France, including detailed information on contract types, reasons for exits (economic layoffs, retirement, etc.), and socio-professional categories. The second one is the Base Tous Salariés (INSEE 2025a), which provides yearly hours worked and labor earnings for each wage earner in each business in France. This exhaustive administrative dataset is derived from employer tax declarations. A key feature of these data is the construction of a quasi-exhaustive longitudinal panel, which required overcoming the challenge that individuals are assigned new pseudonymous identifiers each year. Babet, Godechot, and Palladino 2025 developed a matching algorithm that exploits overlapping annual files to track workers across time, achieving approximately 98% successful matching for 2002-2023. This "wide panel" represents a substantial improvement over the traditional narrow panel (1/12th sample) previously used for French labor market analysis, enabling more precise estimation of workers labor market outcomes by capturing the full universe of mobile workers (see Appendix B.1 for detailed methodology).

To identify heat pumps technology adoption, I use the RGE (Reconnu Garant de l'Environnement) registry (ADEME 2025) from the French Energy Management Agency. This certification system indicates whether an establishment is qualified to install subsidized energy-efficient equipment. Each type of work requires specific certification, enabling precise identification of the timing of technology adoption by any certified establishment.

Finally, I rely on the SIRENE database (INSEE 2025b), which serves as the national comprehensive directory for identifying French companies and their establishments. It includes the main activity code (APE at the 5-digit level, in 732 sub-classes), the exact geographic coordinates, and the date of creation of each establishment.

3.1 Defining treatment and control groups

A general concern when studying the labor market effects of technology adoption is the risk of spillovers from treated to untreated establishments and workers (the so-called *stable unit treatment value assumption — SUTVA*). Indeed, heating service firms operate on local markets, and any treatment effect of technology adoption could result in competition or equilibrium dynamics, contaminating the outcomes of seemingly untreated establishments and their workers. On the other hand, heating system installers are exposed to specific dynamics, such as the broad political momentum that benefited energy efficiency investments (heat pumps, but also energy efficient gas boilers) at the French and EU level over 2019-2022[17]. This major stimulus should not conflate the

[17] In 2019, France enacted its *Energy and Climate Act*, which legislated a net zero emissions target for 2050. The law introduced several obligations attached to poorly insulated homes, such as mandatory energy audits before renting or selling, and a progressive ban on rental properties below a set level of energy efficiency. This is in line

effect of technology adoption itself which restricts the choice of potential control establishments.

These two objectives create a tradeoff between avoiding heat pump adoption spillovers and maintaining comparability within the heating system installation industry. To address this challenge, I exclude establishments that adopt heat pump certification after 2019, referred to as "not-yet-treated" units in the modern DiD literature (Chaisemartin and D'Haultfœuille 2020). The exclusion strategy leverages the daily register of heat pump certifications through 2023 to identify future adopters. The underlying rationale is that substantial spillovers should trigger non-adopters facing competitive pressure from early adopters to adopt themselves the certification after 2019. This is supported by the low cost of certification (between €500 and €1,500) and is further reinforced by two contemporaneous developments during the study period. First, the COVID-19 pandemic accelerated the availability of online training programs, substantially reducing practical barriers to certification (FEEBAT 2020). It dramatically reduced travel and accommodation expenses related to the certification, allowing professionals to continue managing their business activities through the training period. Second, the post-pandemic recovery package included a dramatic expansion of subsidies for energy-efficient heating systems, creating strong incentives for establishment-level adoption. Consequently, establishments remaining uncertified through 2023 despite the low adoption costs and the substantial policy incentives likely experienced very few competitive pressures from others, adopting firms. In practice, as shown in section 3.2, control establishments face different markets less favorable to heat pumps adoption, characterized by a lower reliance on fuel oil heating[18], a higher share of multifamily dwellings, or less affluent customers for whom the out-of-pocket cost remained too high even with the increased subsidies. Never-treated establishments therefore provide a valid control group, largely insulated from local spillovers and equilibrium effects.

3.2 Descriptive statistics

The sample construction follows a cross-referencing identification process. First, I identify establishments with heat pumps RGE certificates and extract the list of main activity codes (APE at the 5-digit level). Figure 14 shows the top 10 main activity codes. Second, to distinguish systematic sectoral presence from occasional diversification, I retain only APE codes representing at least

with the EU's *Renovation Wave Strategy* announced in 2020, which aims to renovate 35 million buildings by 2030, at least doubling the annual rate of energy renovations in the EU.

[18]Figure 11 maps the spatial heterogeneity in fuel oil reliance pre-policy.

5% of all certified establishments[19]. The integration of these datasets creates a complete universe of heating service businesses in France from 2015 to 2023. This yields a sample of 60,000-80,000 active establishments annually, employing between 175,000 and 215,000 workers over the study period (see Appendix B.3 for details).

3.2.1 Establishment-level analysis.

I create a monthly panel spanning from January, 2017 to December, 2021. It gathers 65,412 establishments that are either never treated or that become heat pump certified installers over the period of observation.

Table 1: Pre-treatment balance (Establishment level, 2017-2018)

	Treated		Control		Difference
	Mean (1)	SE (2)	Mean (3)	SE (4)	(T-C) (5)
N Establishments	7,153		58,259		
Headcount	6.07	(12.05)	5.80	(19.37)	0.27
Entries	2.75	(6.90)	2.49	(6.60)	0.26
Exits	1.21	(2.76)	1.03	(2.58)	0.18
Turnover rate	0.700	(1.11)	0.82	(3.92)	−0.12
Age (years)	6.71	(9.81)	6.92	(9.27)	−0.22
Population (CZ)	20,577	(48,058)	34,199	(60,580)	−13,323
Share Fuel Oil (CZ)	11.6	(8.4)	8.9	(7.4)	2.6

Notes: The table shows summary statistics for treated and control establishments in the pre-policy period (2017-2018). Treated establishments are those that adopt heat pump certification during the study period (2017-2021). Control establishments never adopt. Standard errors in columns (2) and (4). All statistics calculated as establishment-level averages over 2017-2018.

Table 1 presents establishment-level characteristics for treated and control groups in the pre-policy period (2017-2018). Average headcount is nearly identical at approximately 6 employees,

[19] This includes heating and HVAC[20] (43.22B), water and gas (43.22A), and electrical (43.21A) installation.

and establishment age is also well-balanced at around 7 years, indicating that treated and control establishments are comparable in terms of size and maturity. Three main differences emerge between the groups. First, treated establishments are located in less populated areas, with an average population of 20,577 inhabitants in their commuting zone (CZ) compared to 34,199 for control establishments. Second, treated establishments operate in CZ with an average reliance on fuel oil of 11.6%. This is 2.6pp, or 30% higher than in controls' CZ. Third, control establishments exhibit higher baseline labor market turnover, with a rate of 0.82 compared to 0.7 for treated establishments. These differences point to the same direction: treated establishments operate in less populated, more rural markets where the share of detached housing units equipped with an old fossil fuel boiler is higher. The result is a differential incentive regarding heat pump installation certification, which supports the validity of the never-treated group as a credible counterfactual.

3.2.2 Worker-level analysis.

I create a yearly panel gathering 800,000+ individuals who eventually worked in an establishment of the heating service industry across 2015 to 2023. This dataset provides yearly labor earnings and hours worked, as well as the unique identifier of their main employer's establishment. Socio-economic variables include age and gender, as well as occupational classification assigned by employers following the comprehensive French occupational classification system (*Catégories Socioprofessionnelles, CSP*). All workers are employed full-time (at least 30 hours per week). The register includes all observations over 2015-2023, including for periods of employment outside the heating service industry.

I define treatment as being employed in 2018 and 2019 in an establishment that adopts heat pump technology in 2019. To construct control groups, I match each treated worker to control workers at non-adopting establishments using exact matching on 2018 establishment activity code (APE), socio-professional category (CSP), and gender, followed by nearest-neighbor matching on age. I implement 1:20 matching, pairing each treated worker with up to 20 control workers. This n-to-many matching allows me to leverage the full potential of my sample of 800,000+ worker trajectories. The matching procedure yields 13,499 treated workers (68% retention from 19,921) and 121,681 matched controls (from 479,762). The 32% attrition reflects treated workers for whom no exact match exists across all three dimensions. Nearest-neighbor matching on age achieves near-perfect balance, with treated and control workers at 36.7 and 36.8 years respectively in the matched sample. For gender and occupational composition, aggregate balance is not expected as exact matching controls for sample-level differences within strata rather than through achieving overall balance. The validity of the identification strategy thus relies on parallel pre-treatment trends in outcomes. Appendix B.4 provides detailed balance statistics across all covariates.

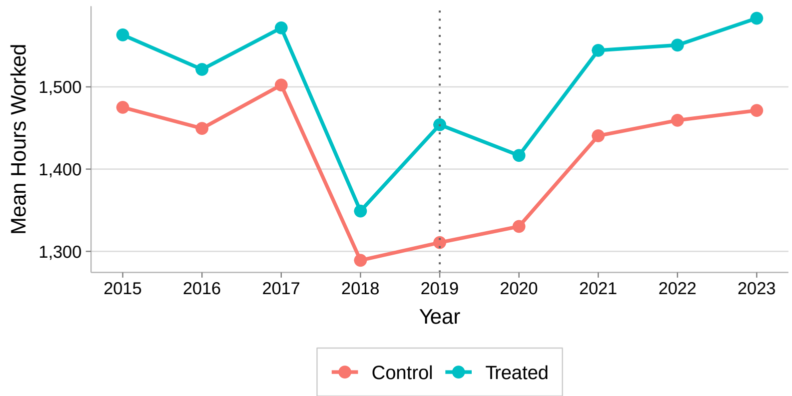
Figure 3 displays the evolution of hours worked, annual earnings, and hourly wages for matched treated and control workers from 2015 to 2023. In 2018, hourly wages averaged €15.45 for treated workers and €16.46 for controls. These wages are slightly above the French median hourly gross wage of €15.2 but remain well below the national mean of €18.1 (INSEE 2021). Workers earn approximately 1.5-1.7 times the minimum wage (€9.88 per hour in 2018). Annual earnings of approximately €22,000 reflect both wage levels and hours worked (around 1,300-1,400 hours annually), substantially below the national average gross annual salary of €36,238, consistent with the blue-collar composition of the workforce. The wage gap between treated and control workers (€1.01 per hour in 2018) reflects compositional differences documented at the establishment level: treated workers are concentrated in more rural areas with lower wage levels.

Critically, Figure 3 demonstrates parallel trends in all three outcome variables during the pre-treatment period (2015-2018). This supports the identifying assumption, setting the stage for the difference-in-differences estimation strategy presented in Section 4.

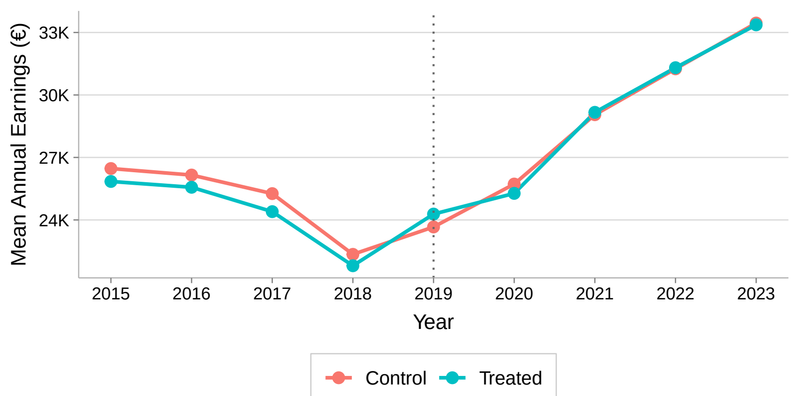
4 Empirical Strategy

To investigate the labor market outcomes of technology adoption, I exploit the surge in heat pumps installation subsidies and the subsequent response of local energy services contractors. My identification strategy leverages a key institutional feature: the requirement for installers to obtain RGE (Reconnu Garant de l'Environnement) certification to access the subsidized market. The certification process involves training workers in heat pump installation techniques and meeting quality standards. The price of the training is quite cheap, with an average cost of €500 per establishment. Moreover, only one worker per establishment has to go through the certification process for the establishment to become *certified*. It can thus be seen as a simple administrative barrier at the entry of the market for subsidized installations. I use two distinct strategies to document the causal effect of technology adoption. First, I focus on employment policy at the establishment level. Second, I analyze earnings and hours at the individual level.

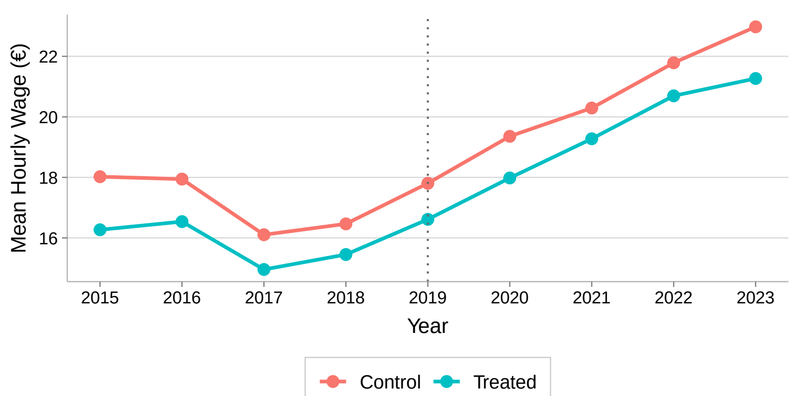
Figure 3: Worker Outcomes Over Time in the Matched Sample (2015-2023)



(a) Hours worked



(b) Annual earnings



(c) Hourly wage

Notes: The figure shows the evolution of hours worked, annual earnings, and hourly wages for matched treated and control workers from 2015 to 2023. Treated workers are employed at establishments that adopt heat pump technology in 2019 (vertical dashed line). Control workers are matched using exact matching on establishment activity code (APE), socio-professional category (CSP), and gender, followed by 1:20 nearest-neighbor matching on age. The parallel trends in all three outcomes during the pre-treatment period (2015-2018) support the identifying assumption for the difference-in-differences analysis.

4.1 Establishment-level analysis

The policy-driven adoption of heat pumps certification by heating service establishments exhibits a staggered timing, as shown by the total adoption curve in Figure 2a. I leverage this behavior and the monthly frequency of my establishment-level dataset to estimate the effect of technology diffusion on employment policy. Staggered treatments pose several econometric challenges, and recent methodological advances have highlighted potential biases in traditional two-way fixed effects estimators when treatment effects are heterogeneous and treatment timing varies (Goodman-Bacon 2021; Callaway and Sant'Anna 2021). In this context, treatment intensity likely varies across establishments, with rural and smaller firms potentially experiencing larger effects due to their own and market characteristics. More importantly, early adopters should not be used as control units for late adopters as their treatment effect is not stable across time, which might bias the estimation. To address these concerns, I employ the Callaway and Sant'Anna 2021 methodology, which provides several advantages for my setting. First, I use never-treated establishments to define a clean control group, avoiding contamination from already-treated units. Second, I estimate group-time specific effects $ATT(g,t)$ for each cohort g (defined by certification timing) and time period t. Third, I use an inverse probability weighting on the establishment age and the headcount of the local industry (defined at the commuting zone level) to account for selection into treatment timing that may correlate with establishments and local market characteristics.

For each establishment i, cohort g and period t, I estimate:

$$ATT(g,t) = \mathbb{E}[Y_{it}(g) - Y_{it}(\infty) \mid G_i = g] \tag{1}$$

where $Y_{it}(g)$ represents the potential outcome under treatment timing g, $Y_{it}(\infty)$ represents the never-treated potential outcome, and $G_i = g$ indicates establishments first certified in period g. This approach allows me to examine dynamic treatment effects while avoiding the pitfalls of conventional difference-in-differences estimators in settings with staggered adoption and heterogeneous effects. I apply this estimation strategy to total employment (entries net of exits), only entries, or only exits.

4.2 Worker-level analysis

To estimate the causal effect of heat pump adoption on worker outcomes, I rely on the matched sample of workers at adopting and non-adopting heating service establishments detailed in Section 3.2.2. The matching procedure addresses potential compositional differences between workers at establishments that adopt heat pump technology in 2019 and those at non-adopting establishments. Since treatment occurs at the establishment level through the adoption decision, worker selection into treatment is not a primary concern. Rather, matching ensures that treated and control workers are comparable in terms of observable characteristics that may influence labor market trajectories independently of the technology shock.

The worker-level analysis proceeds in three parts, each focusing on a distinct subset of workers. First, I estimate the main effect of heat pump adoption on all workers employed at treated establishments in both 2018 and 2019 (to exclude newcomers joining post-adoption in 2019). Second, I decompose treatment effects by distinguishing between stayers and leavers to understand compositional changes within adopting establishments. Stayers are workers employed at the same establishment in both 2018 (pre-shock) and 2023 (the final year of the panel), while leavers are workers present at the establishment in 2018 or 2019 but no longer employed there in 2023. These two groups form complementary subsets of the treated workforce, enabling a comparison of outcomes for workers who remain versus those who separate. Third, I examine the labor market trajectories of movers, comprising both leavers and newcomers, in relative time. I define newcomers as workers not employed at a treated establishment in 2018 or 2019, but present in 2023, having entered the establishment in 2020 or later. For each analysis, I construct a new matched sample specific to the subgroup of treated workers under study, ensuring that treatment and control groups remain comparable within each estimation framework.

4.2.1 Dynamic difference-in-difference of heat pump adoption

The shift from gas boilers to heat pumps affects workers employed at treated establishments in 2019. I estimate the effect of technology adoption on worker outcomes using an event study specification. The baseline model is:

$$\log(y_{ist}) = \sum_{k \neq -1} \beta_k \cdot \mathbb{1}\{t = k\} \cdot \text{Treat}_{st} + \alpha_i + \gamma_s + \delta_t + \varepsilon_{ist} \tag{2}$$

where y_{ist} is hours worked or labor earnings for worker i in establishment s in year t, Treat_{st} is an indicator for establishment s ever adopting heat pump technology, and k measures years relative to 2019 (the adoption year). I include worker, establishment, and year fixed effects (α_i, γ_s, δ_t), and normalize 2018 ($k = -1$) as the reference period. The coefficients β_k trace out the dynamic treatment effects. Standard errors are two-way clustered at the worker and establishment levels.

4.2.2 Stayers vs. leavers: Calendar time comparison

To account for workforce composition effects, I decompose treatment effects for stayers versus leavers, both expressed in calendar time. For stayers (workers present at their 2018 employer through 2023), I estimate equation 2 on the restricted sample of treated workers. For leavers, following the job displacement literature (e.g., Schmieder, Wachter, and Heining 2023), I focus on workers with at least three years of tenure at their pre-separation employer. I estimate the following specification that allows for cohort-specific treatment effects:

$$\log(y_{itc}) = \sum_{k \neq -1} \beta_k^c \times \mathbb{1}\{t = c_i + k\} \times \text{Leaver}_i + \alpha_i + \delta_t + \varepsilon_{itc} \tag{3}$$

where c_i denotes the calendar year when worker i separates (exit cohort), k is years relative to separation, and Leaver_i indicates treatment status compared to matched controls. The interaction $\mathbb{1}\{t = c_i + k\}$ links relative time to calendar years, yielding cohort-specific coefficients β_k^c. I then aggregate these coefficients to calendar time by computing the average effect across all cohorts active in each year:

$$\gamma_t = \frac{1}{N_t} \sum_{\substack{c,k: \\ c+k=t}} \beta_k^c \tag{4}$$

where N_t is the number of cohort-relative time pairs contributing to year t. Standard errors for γ_t are computed using the variance-covariance matrix of the β_k^c estimates to properly account for covariance across the averaged coefficients. This approach, detailed in section C.1, allows direct comparison of treatment effects on stayers versus leavers in the same calendar-time framework.

4.2.3 Movers: Relative time dynamics

To understand the dynamics of worker mobility around the technology transition, I estimate relative-time event studies separately for leavers and newcomers. Leavers are workers with at least three years of tenure who separate from their 2019 employer; newcomers are workers not employed at a treated establishment in 2019 but present in 2023. For both groups, I estimate:

$$\log(y_{ist}) = \sum_{k \neq k_0} \beta_k \times \mathbb{1}\{t = T_i + k\} \times \text{Mover}_i + \alpha_i + \gamma_s + \delta_{z\times t} + \varepsilon_{ist} \tag{5}$$

where T_i is the year of the mobility event (separation for leavers, entry for newcomers), Mover_i indicates treatment status, γ_s are establishment fixed effects, and $\delta_{z\times t}$ are employment zone-by-year fixed effects that flexibly control for local labor market conditions. The reference period is $k_0 = -1$ for leavers (the year before separation) and $k_0 = -2$ for newcomers (two years before entry, as workers entering at $t = 0$ likely separate from their previous employer at $t = -1$). Both leavers and newcomers are compared to matched control workers selected using exact matching on age, socio-professional category (PCS), establishment main activity code, and gender. Standard errors are two-way clustered at the establishment and worker levels.

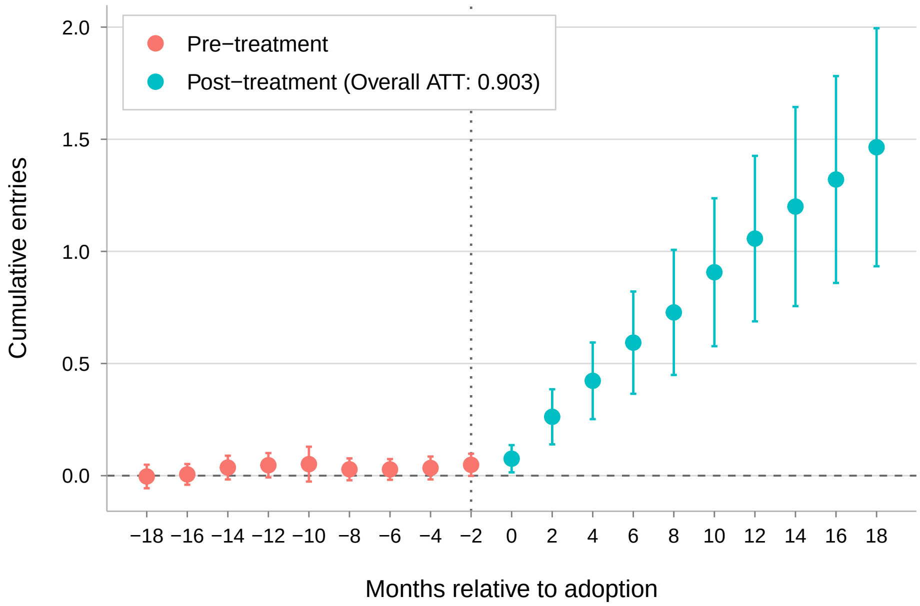
5 Results

5.1 Effects on establishments employment behavior

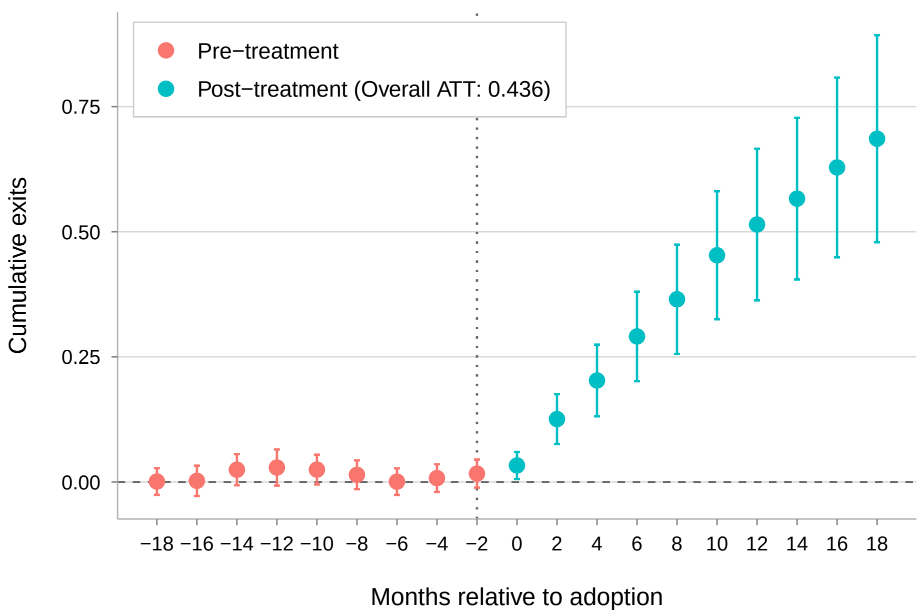
I estimate the staggered difference-in-differences introduced in equation 1 separately on entries and exits at the establishment level on each odd-month from January, 2017 to November, 2021. This bi-monthly panel is centered on 2019, the year of the staggered adoption of heat pumps triggered by the subsidy shock. Averaging continuous variables on odd months allows to smooth idiosyncratic variations from high frequency employment data, while also reducing the the computational burden. Figure 4 presents the cumulative treatment effects over time, showing that 18 months after adoption, the average establishment experience both a higher job creation and a higher job destruction.

The pre-treatment estimates are statistically indistinguishable from zero, supporting the parallel trends assumption underlying the identification strategy. Employment effects emerge immediately upon certification, with adopting establishments experiencing approximately +0.75 job creation and +0.3 job destruction in the first 6 months post-adoption. These effects grow over time, reaching approximately +1.5 jobs created and +0.75 jobs destroyed 18 months after the certification. These are sizable effects considering the average headcount of 8 job-months.

Figure 4: Job entries and exits following heat pump adoption



(a) Entries



(b) Exits

Notes: Event-study estimates of heat pump certification effects on cumulative entries (a) and exits (b) using Callaway and Sant'Anna 2021. Sample: 7,153 treated and 58,259 never-treated control establishments, 2017-2021 (bi-monthly). Estimation by inverse probability weighting with covariates (establishment age, commuting zone heating industry headcount). Dynamic aggregation with 95% confidence intervals. Standard errors clustered at establishment level.

While positive net job creation is consistent with expanding demand for heat pump services, the substantial job destruction occurring simultaneously is more concerning. The magnitude of worker separations, which represents approximately half the rate of new hires, suggests that certification triggers significant labor reallocation rather than simple workforce expansion. This pattern likely reflects changing skill requirements as establishments pivot toward heat pump technology, combined with productivity-based sorting as firms adjust their workforce composition. These dynamics create potential winners and losers among incumbent workers, raising distributional concerns central to just transition policy. Whether displaced workers successfully transition to new opportunities or bear substantial adjustment costs, and how these costs compare to gains for newly hired workers, cannot be assessed at the establishment level. I turn to individual worker trajectories in Section 5.2 to quantify these worker-level labor market effects.

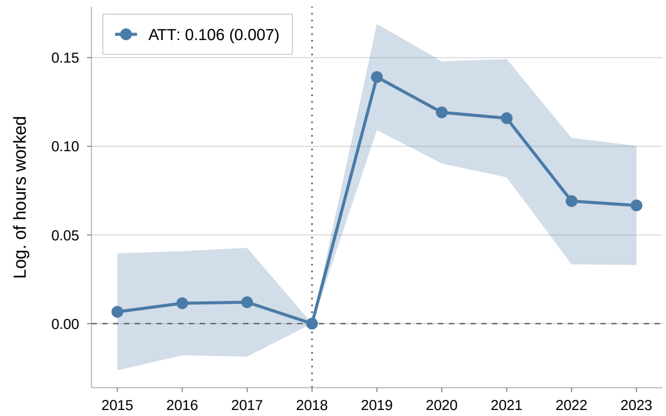
5.2 Workers-level Career Trajectories

5.2.1 Effect on incumbent workers

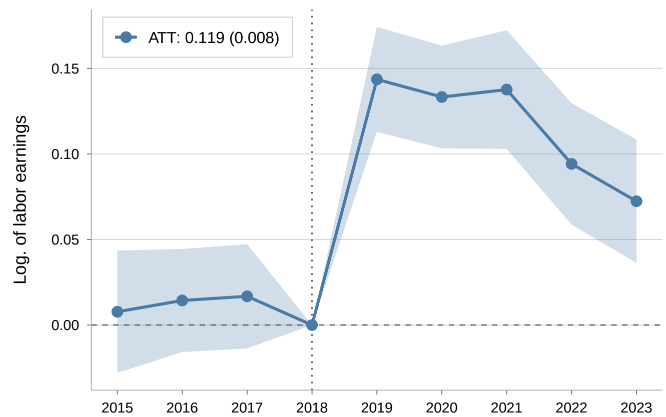
I start by estimating the effect of heat pump certification on all workers employed at treated establishments in 2018 and 2019, regardless of whether they subsequently remain at or separate from the establishment. This provides an overall assessment of exposure to technology adoption for the incumbent workforce. I construct a matched control group of workers at never-treated establishments as detailed in section 3.2.2. I then estimate standard dynamic difference-in-differences (DiD) specifications comparing outcomes for treated and control workers over 2015-2023. Figure 5 presents the results for three labor market outcomes: log. total hours worked, log. annual labor earnings, and log. hourly wages.

Several patterns emerge. First, treated workers experience substantial increases in both hours worked and labor earnings beginning immediately in 2019, the year of certification adoption. Hours worked and earnings increase by approximately 14 percent relative to matched control workers. These effects slightly decrease in subsequent years, but the average treatment over the treated (ATT) remains at or above 10 percent by 2020-2021. Second, the dynamics for hourly wages differ markedly from hours and earnings. Hourly wages show no significant effect in 2019 despite the large increases in hours and earnings. Significant hourly wage gains emerge only in 2020-2022, reaching approximately 2 percent above control workers. This pattern indicates that the primary adjustment margin in the immediate aftermath of certification is labor supply: workers increase

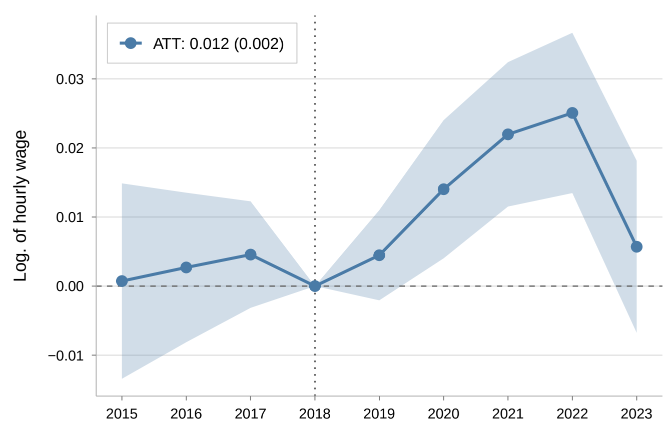
Figure 5: Effects of Heat Pump Certification on Incumbent Workers



(a) Log. Total Hours Worked



(b) Log. Annual Labor Earnings



(c) Log Hourly Wage

Notes: Event-study estimates of the effect of heat pump certification on labor market outcomes for workers employed at treated establishments in 2018 and 2019. The sample includes 11,229 treated workers and 117,748 matched control workers from never-treated establishments. Control workers matched exactly on establishment activity code (APE), socio-professional category (CSP), and gender, followed by nearest-neighbor matching on age. Shaded areas represent 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in the legend are precision-weighted averages over 2019-2023.

hours at roughly constant hourly wages, with wage adjustments occurring only in subsequent years.

These average effects, while positive overall, mask substantial heterogeneity in outcomes between workers who remain at adopting establishments and those who separate. I turn to this decomposition in the next subsection.

5.2.2 Decomposing Effects: Stayers versus leavers

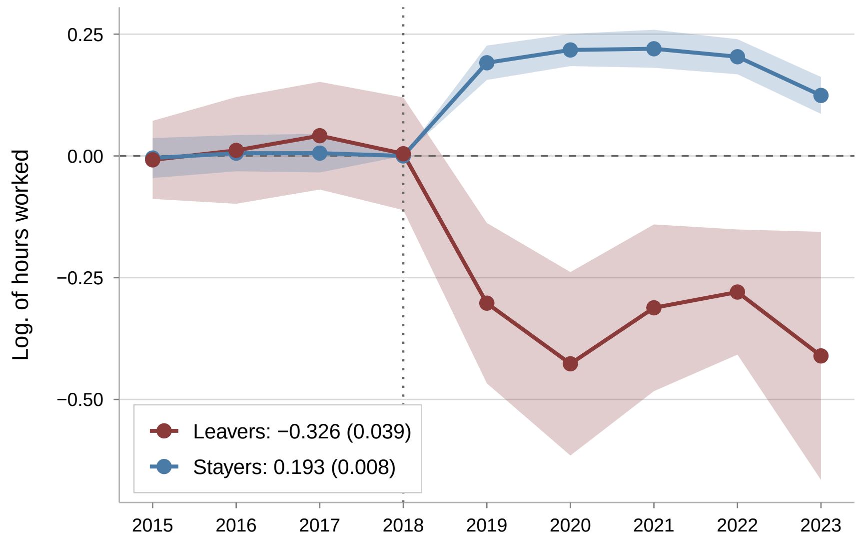
The average positive effects documented for incumbent workers aggregate over two distinct groups: workers who remain at adopting establishments (stayers) and those who eventually separate (leavers). To understand the composition of these aggregate effects, I decompose treatment effects by employment continuity. I define stayers as workers employed at the same establishment in both 2018 (pre-adoption), 2019 (treatment year) and 2023 (the final year of the panel); and leavers as workers present in 2018 and 2019 but no longer employed at the establishment by 2023. As a result, the leavers group aggregates in one sample all cohorts of exits over 2020-2023.

For both groups, I construct a new matched control sample using the same matching procedure detailed in section 3.2.2, which yields 7,395 treated stayers matched to 100,890 controls. Following the job displacement literature (e.g., Schmieder, Wachter, and Heining 2023), I further restrict the treatment group to workers with at least three years of tenure at their pre-separation employer. This yields 2,523 treated leavers matched to 36,576 controls. Figure 6 present the results for hours worked and labor earnings. The contrast between stayers and leavers is stark. Stayers experience immediate and substantial gains beginning in 2019, with hours worked and labor earnings increasing by approximately 20 percent relative to matched controls. These gains persist through 2022 before moderating slightly to 12.5 percent in 2023. In sharp contrast, leavers experience deteriorating outcomes following certification adoption. Their hours and earnings decline progressively, stabilizing around -30 percent by 2021-2022 relative to matched control workers who also eventually separate from their establishments.

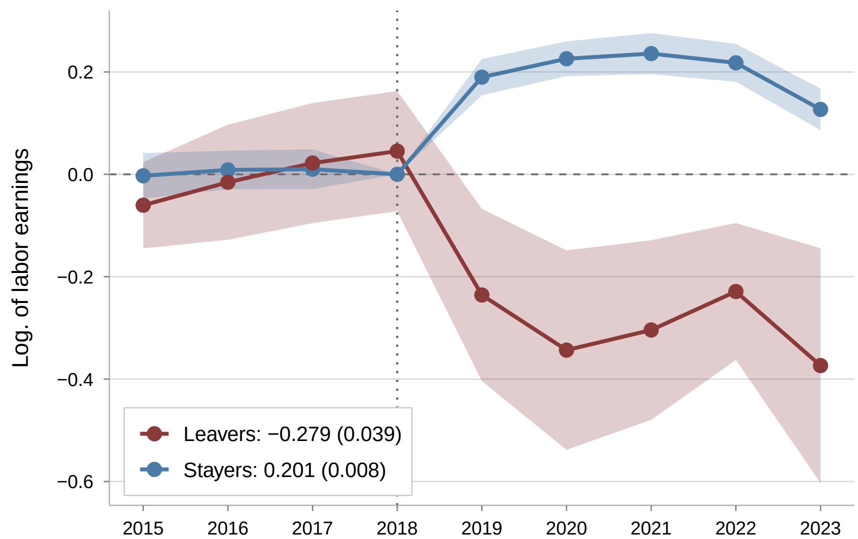
For stayers, I can additionally examine hourly wages. Figure 7 shows that stayers experience modest wage gains of around 1 percent beginning in 2020, consistent with the pattern observed for incumbent workers overall, although slightly lower.

The combination of increased hours and weakly higher wages explains the substantial earnings gains observed for stayers. The negative outcomes for leavers is consistent with substantial losses from separation. However, this interpretation requires careful consideration. The leaver sample

Figure 6: Effects of Heat Pump Certification on Stayers versus Leavers



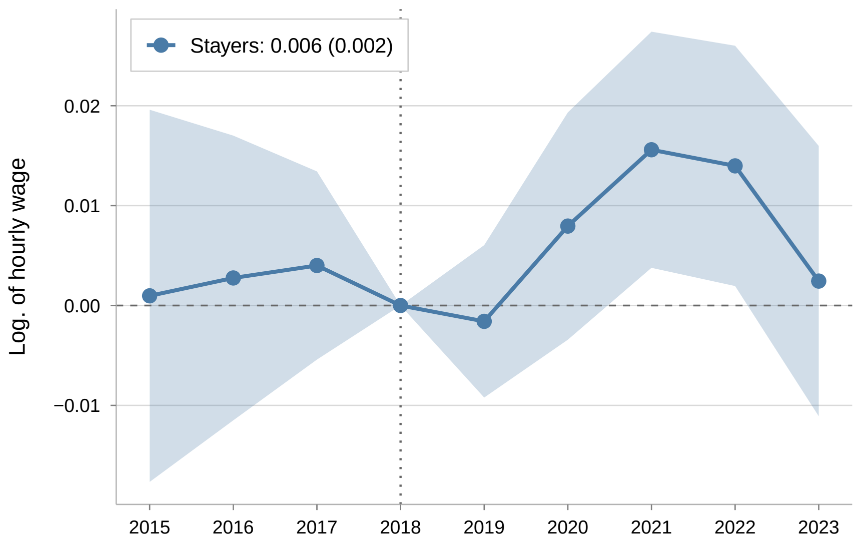
(a) Log. Total Hours Worked



(b) Log. Annual Labor Earnings

Notes: Event-study estimates of the effect of heat pump certification decomposed by employment continuity. Stayers (blue lines) are workers employed at the same establishment in both 2018, 2019, and 2023 (N = 7,395 treated, 100,890 matched controls). Leavers (red lines) are workers present in 2018 and 2019 but no longer employed at the establishment by 2023, having separated between 2020 and 2023 (N = 2,523 treated, 36,576 matched controls). Each treatment group is matched to its own control group of workers at never-treated establishments using the procedure detailed in section 3.2.2. Shaded areas represent 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in legend are precision-weighted averages over 2019-2023.

Figure 7: Effects of Heat Pump Certification on Hourly Wages: Stayers



Notes: Event-study estimates of the effect of heat pump certification on log hourly wages for stayers—workers employed at the same establishment in both 2018, 2019 and 2023 (N = 7,395 treated, 100,890 matched controls). Hourly wage estimates for stayers only, as leavers experience unemployment following separation, precluding meaningful calendar-time comparisons across cohorts. Matching procedure and specification identical to Figure 6. Shaded area represents 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in legend are precision-weighted averages over 2019-2023.

in any given calendar year comprises workers who separated at different times following adoption, some immediately in 2019, others in 2020, 2021, or later. Consequently, the calendar-time effects aggregate over workers at different stages of their post-separation trajectories. A worker who separated in 2019 and found new employment appears in the 2022 estimate alongside workers separating for the first time in 2022. This aggregation obscures individual adjustment dynamics and may not reflect the true costs borne by displaced workers. Understanding whether movers actually get persistent individual-level losses or only incur a temporary transition requires tracking workers in event time relative to their displacement. I turn to this analysis in the next subsection.

5.2.3 Worker Mobility and Adjustment Dynamics

The previous analysis revealed that workers who separate from adopting establishments experience deteriorating outcomes in calendar time, but this comparison aggregates workers at different stages of their post-displacement trajectories. To assess individual-level adjustment costs, I examine worker outcomes in event time relative to their mobility event. I focus on two groups of movers: leavers who separate from treated establishments, and newcomers who enter them. While both groups involve labor mobility, they represent distinct phenomena. Leavers exit establishments that adopted certification in 2019, while newcomers enter these establishments after adoption.

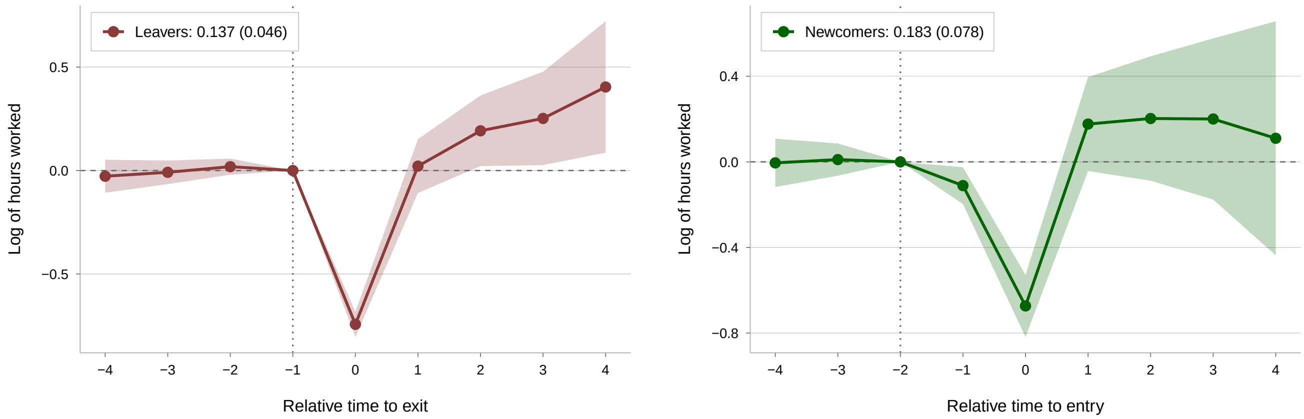
For leavers, I use the definition introduced in subsection 5.2.2, which requires workers to be at the same treated establishment from 2016 to 2019 onward, while leaving in one year of 2020-2023. For newcomers, I examine workers not employed at a treated establishment in 2019 but present in 2023, having entered between 2020 and 2023. As a result, treated samples comprises 2,523 leavers and 1,529 newcomers matched to control groups using the same matching procedure detailed in section 3.2.2. It yields 36,576 matched control workers for leavers and 27,131 for newcomers. I estimate relative-time event studies separately for each group as in equation 5. The reference period is $k_0 = 1$ for leavers (the year before separation) and $k_0 = 2$ for newcomers (two years before entry, chosen to capture the pre-exit baseline since workers entering at $t = 0$ likely separated from their previous employer at $t = 1$).

Figure 8 presents the results. For leavers (left column), outcomes exhibit a clear V-shaped pattern. Hours worked drop sharply by 80 percent in the separation year ($t = 0$), but recover fully by the following year ($t = 1$) where the point estimate returns to zero. In subsequent years, hours worked rise substantially, reaching approximately 20 percent above pre-separation levels by $t = 2$ and $t = 3$, following an upward trajectory similar to that observed for stayers. Labor earnings follow a parallel pattern: a 60 percent decline at separation, followed by rapid recovery that exceeds pre-displacement earnings as early as the first post-displacement year. The average treatment effect across all post-displacement years reaches nearly 40 percent. Most strikingly, hourly wages increase sharply following displacement, rising by more than 20 percent on average across post-displacement years. This wage premium, combined with increased hours, drives the substantial earnings gains.

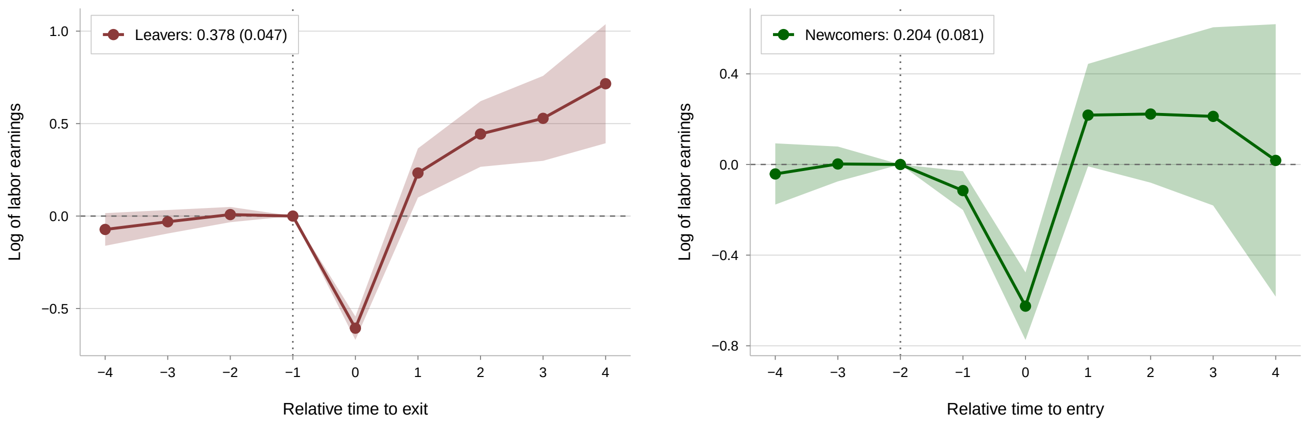
For newcomers (right column), the dynamics differ notably. Hours worked drop by 70 percent at entry ($t = 0$), consistent with the interpretation that entry often follows separation from a previous employer at $t = 1$. Following entry, hours stabilize at around 15 percent above matched controls, and remains relatively constant across post-entry years, rather than exhibiting the rising trend observed for leavers. However, none of the point estimates is significant at any conventional level. Labor earnings show a similar pattern, with non-significant gains of around 20 percent in $t = 1$ that remain stable or decline slightly in subsequent years. Crucially, hourly wages for newcomers remain flat throughout the post-entry period, though estimates are imprecise as expected from the

Figure 8: Labor Market Dynamics for Movers in Event Time

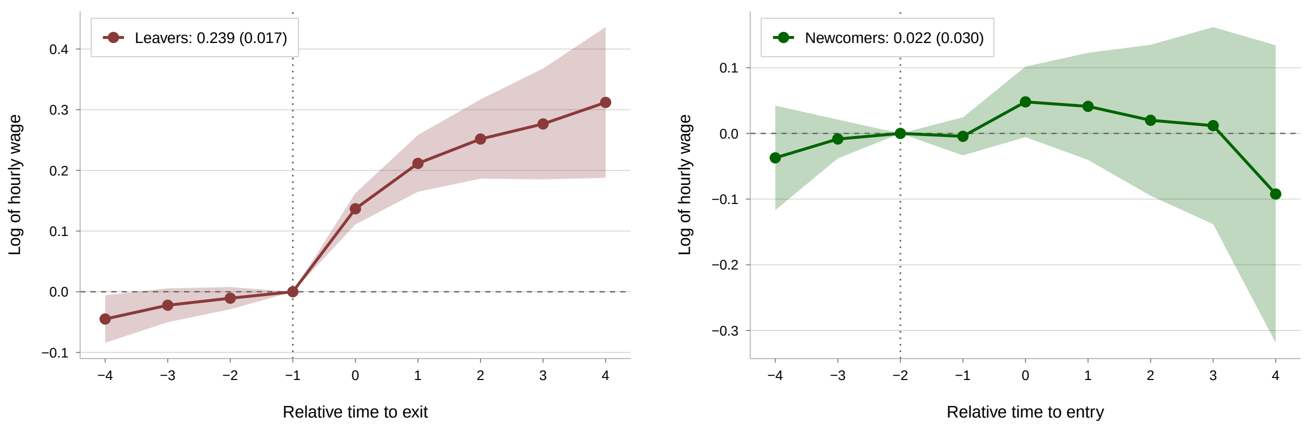
Leavers **Newcomers**



(a) Log Total Hours Worked



(b) Log Annual Labor Earnings



(c) Log Hourly Wage

Notes: Event-study estimates in relative time around mobility events. Left column: leavers (N = 2,523 treated, 36,576 matched controls). Right column: newcomers (N = 1,529 treated, 27,131 matched controls). Matched controls selected using the matching procedure detailed in section 3.2.2. Specifications include worker fixed effects, establishment fixed effects, and employment zone-by-year fixed effects. Shaded areas represent 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in legend are precision-weighted averages over 2019-2023.

already non-significant results in both hours and earnings.

These patterns reveal rapid adjustment with minimal persistent displacement costs. Both leavers and newcomers experience sharp but temporary disruptions at the time of their mobility event ($t = 0$), but recover swiftly. Leavers not only recover their pre-separation employment levels but substantially exceed them, benefiting from both increased hours and higher hourly wages. The wage premium suggests that skills acquired at establishments adopting heat pump certification are valued in the labor market by other firms (i.e., non firm-specific human capital), enabling workers to secure improved matches following separation. Newcomers, while not experiencing wage gains, benefit from expanded employment opportunities and higher labor earnings through increased hours. The contrast between rising wages for leavers and flat wages for newcomers suggests that experience at establishments engaged in heat pump installation confers valuable skills, while newcomers may be hired for their general labor capacity and trained on the job.

5.3 Heterogeneity Analysis

The average effects documented in section 5.2 aggregate over workers with different characteristics and career trajectories. In this section, I examine heterogeneous treatment effects along three dimensions: occupational skill level for stayers, destination establishment's heat pump certification status for leavers, and industry origin for newcomers.

I decompose the wage effects for stayers by occupational category using the French occupational classification system (PCS), distinguishing between blue-collar workers (primarily trained plumbers, heating technicians, and electricians) and higher-skilled technicians and managers. For leavers, I examine whether wage outcomes differ depending on whether they transition to heat pump-certified versus non-certified establishments. For newcomers, I distinguish between workers arriving from HVAC-related establishments (heating, air conditioning, ventilation) versus those originating from non-HVAC sectors. For each analysis, I estimate the relevant specification (equation 2 for stayers, equation 5 for leavers and newcomers) on the subsample of treated workers matched to their respective control groups following the procedure detailed in section 3.2.2.

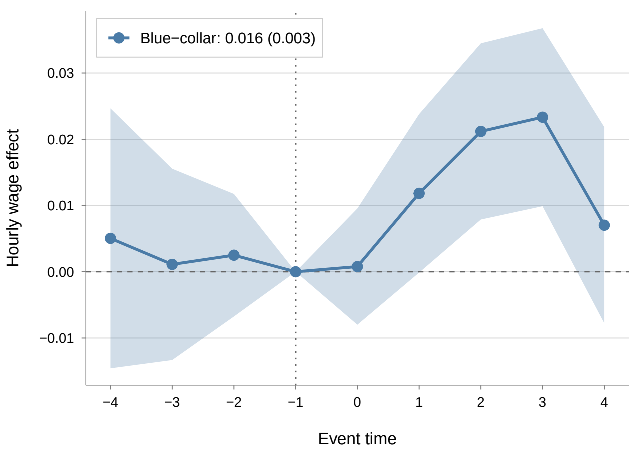
I decompose the wage effects for stayers by occupational category using the French occupational classification system (PCS), distinguishing between blue-collar workers (primarily trained plumbers, heating technicians, and electricians) and higher-skilled technicians and managers[21].

[21] The first level of the French occupational classification system comprises 6 socio-economic groups. The het-

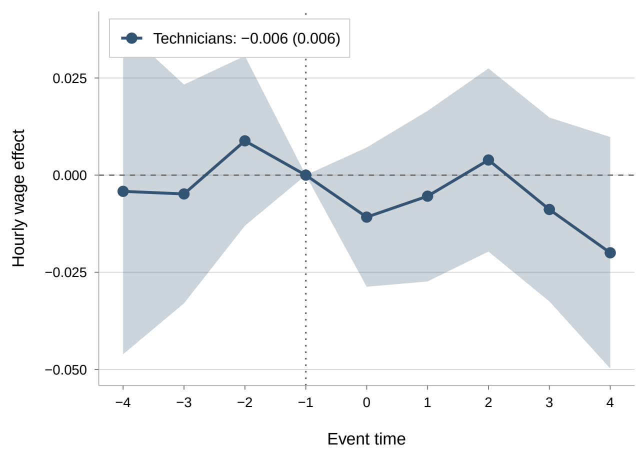
For workers who separate from adopting establishments, I examine whether wage outcomes differ depending on whether they transition to heat pump-certified versus non-certified establishments. For newcomers, I distinguish between workers arriving from HVAC-related establishments (heating, air conditioning, ventilation) versus those originating from non-HVAC sectors. For each analysis, I estimate the relevant specification (equation 2 for stayers, equation 5 for leavers and newcomers) on the subsample of treated workers matched to their respective control groups following the procedure detailed in section 3.2.2.

Figure 9 presents the results for hourly wages across the two groups of stayers. Blue-collar stayers experience a significant wage increase of 1.6 percent on average across post-treatment years (panel 9a), while technicians and managers show a non-significant decline of 0.6 percent (panel 9b). The modest wage effect for stayers is thus driven entirely by blue-collar workers.

Figure 9: Heterogeneous Effects on Hourly Wages by Occupation: Stayers



(a) Blue-Collar Workers



(b) Technicians and Managers

Notes: Event-study estimates of the effect of heat pump certification on log hourly wages for stayers, decomposed by occupational category. Sample restricted to workers employed at the same establishment in 2018, 2019, and 2023. Blue-collar workers (N = 33,238 treated, matched controls) comprise trained plumbers, heating technicians, and electricians. Technicians and managers (N = 9,404 treated, matched controls) include higher-skilled technical and managerial positions. Each group matched to separate control workers at never-treated establishments following the procedure detailed in section 3.2.2. Specification follows equation 2. Shaded areas represent 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in legends are precision-weighted averages over 2019-2023.

Leavers experience similar wage premiums of approximately 20 percent regardless of whether they transition to heat pump-certified establishments (panel 10a) or non-certified establishments (panel 10b), revealing broad transferability of skills across the HVAC sector. Workers arriving

erogeneity compares group *(6) Ouvriers* versus groups *(3) Cadres et Professions Intellectuelles Supérieures & (4) Professions Intermédiaires.*

from HVAC-related establishments experience a significant wage premium of 7 percent on average across post-entry years (panel 10c), while those originating from non-HVAC sectors experience a non-significant wage decline (panel 10d). The flat average wage effect for newcomers thus masks substantial heterogeneity by workers' origin, with skill distance governing adjustment costs.

6 Discussion

The findings in 5 document substantial labor market reallocation following clean energy technology adoption—simultaneous job creation and destruction at adopting establishments—yet without imposing persistent costs on displaced workers. Stayers benefit from expanded hours and modest wage gains; separating workers recover swiftly and secure substantial wage premiums; newly hired workers gain employment opportunities and higher earnings. These findings challenge pessimistic narratives about environmental transitions and suggest adaptation within existing SMEs may prove less costly than fossil fuel sector phase-outs dominating just transition debates.

6.1 Mechanisms

Two complementary mechanisms explain the observed patterns of labor market adjustment following clean energy technology adoption: portable skill acquisition combined with job mobility, and within-firm reskilling.

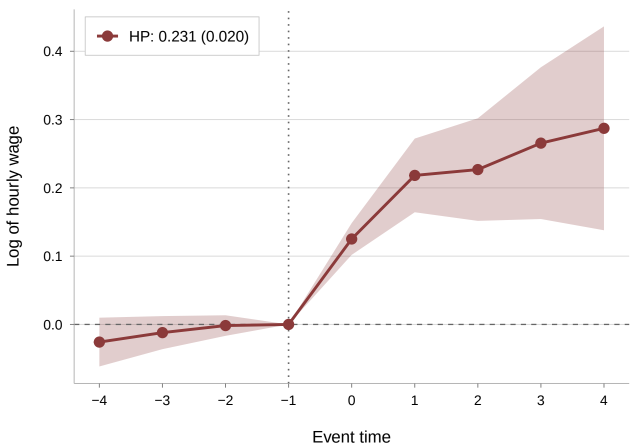
6.1.1 Portable Skills and Job Mobility

The sharp contrast in wage outcomes reveals a canonical job ladder pattern: stayers experience 1% wage gains despite technology exposure, while leavers secure 12% premiums one year after separation, rising thereafter. While both groups acquired similar heat pump exposure, only workers who change employers capture returns on these general skills.

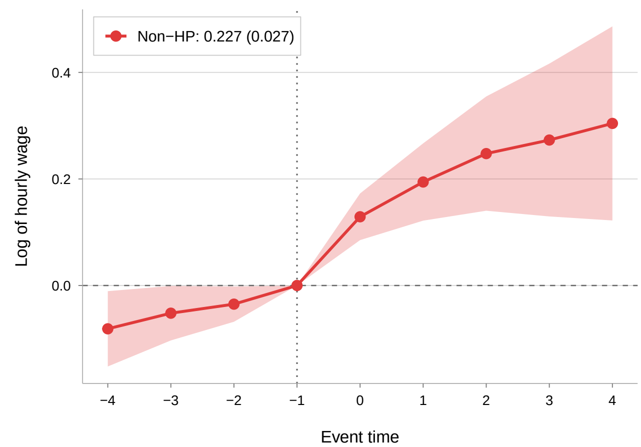
Heat pump competencies, such as electrical systems, refrigerant handling, complex diagnostics and thermodynamic principles, transfer across diverse HVAC applications. Leavers experience 20% wage premiums regardless of destination certification status (Figures 10a-10b), demonstrating broad skill transferability. Job ladder literature shows most lifetime wage growth occurs through job-to-job transitions (Topel and Ward 1992; Postel-Vinay and Robin 2002); workers signal acquired skills through employer changes to realize gains.

Figure 10: Heterogeneous Effects on Hourly Wages: Leavers and Newcomers

Leavers by Certification Status at Destination

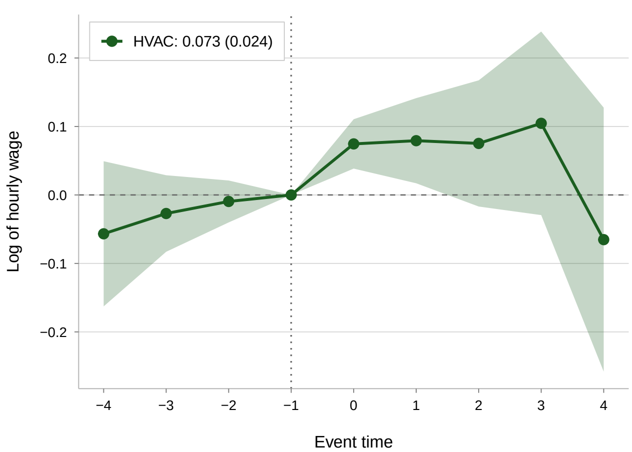


(a) Destination: HP-Certified

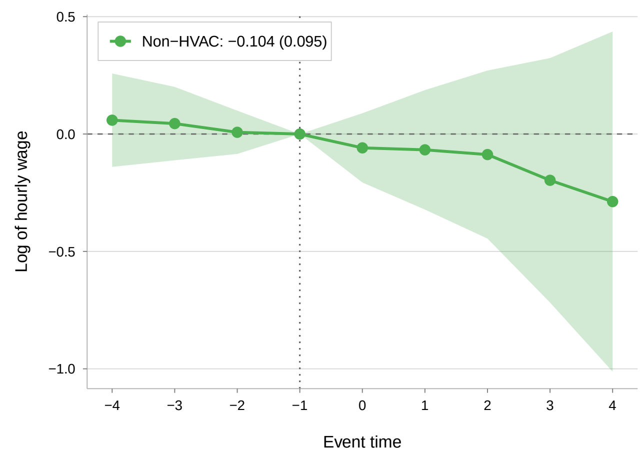


(b) Destination: Non-Certified

Newcomers by Industry Origin



(c) Origin: HVAC Industry



(d) Origin: Non-HVAC Industries

Notes: Event-study estimates in relative time around mobility events. Panels (a)-(b): Leavers present 2016-2019 who separated by 2023, decomposed by destination establishment type. HP-certified destinations (N = 13,425 treated, matched controls) hold heat pump RGE certification at worker entry. Non-certified destinations (N = 3,538 treated, matched controls) lack heat pump certification. Panels (c)-(d): Newcomers absent in 2019 but employed in 2023 (entry 2020-2023), decomposed by industry of origin. HVAC origin (N = 19,494 treated, matched controls) includes prior employment in heating, air conditioning, or ventilation. Non-HVAC origin (N = 2,912 treated, matched controls) includes all other sectors. Each group matched to separate control workers at never-treated establishments following the procedure in section 3.2.2. Specification follows equation 5. Shaded areas represent 95% confidence intervals based on standard errors clustered at the establishment level. Post-treatment ATTs in legends are precision-weighted averages over post-mobility years.

Rapid leaver recovery supports this mechanism. Hours and earnings drop sharply at separation but recover fully within one year, then exceed pre-separation baselines by 14% (hours) and 35% (earnings) on average post-separation. Swift adjustment indicates labor market recognition of heat pump expertise. Positive average outcomes suggest predominantly voluntary mobility though average effects may mask heterogeneity, particularly for forced displacements.

6.1.2 Within-Firm Reskilling

Stayers increase hours 20% immediately post-adoption with only 1% wage gains—adjustment through intensive margin consistent with on-the-job learning. Establishments retain and retrain incumbents rather than replacing with trained workers. Newcomers work substantially more hours with flat wages, suggesting hiring for general capacity with on-the-job training. Absence of immediate wage returns during learning contrasts sharply with leaver premiums, reinforcing the case for within-establishment training.

Skill distance—the gap between existing and required competencies—determines adjustment costs. Newcomers from HVAC establishments (smaller skill gaps) earn 7% premiums (Figure 10c); those from non-HVAC sectors face 10% declines (Figure 10d). Among stayers, blue-collar workers (who acquire novel electrical/refrigerant competencies) gain 1.6% wages, driving aggregate effects; technicians/managers—who may already possess broader technical competencies or whose roles are less affected by technological change—show no significant effects (Figure 9).

Establishment-level results complement these patterns: adopting establishments create 1.5 positions within 18 months, enabling workforce expansion rather than replacement. These patterns align with the task-based framework (Autor, Levy, and Murnane 2003; Acemoglu and Autor 2011) showing technology reshapes labor demand by altering job skill content. Establishments facilitate adaptation through on-the-job learning, dramatically reducing displacement costs. Effectiveness depends critically on skill distance: smaller gaps enable smoother, less costly transitions, in line with the task similarity central in Gathmann and Schönberg 2010.

6.2 Implications for Just Transition Policy

The two mechanisms have important implications for the design of policies aimed at facilitating a just energy transition. The findings suggest three priorities for policymakers seeking to minimize worker adjustment costs while supporting decarbonization.

6.2.1 Support Technology Adoption Through Market Incentives

The first priority is to create strong market incentives enabling technology adoption within incumbent establishments rather than through creative destruction. Establishment-level analysis documents +1.5 jobs within 18 months; worker-level analysis shows stayers benefit from expanded hours and modest wage gains through within-firm reskilling. This minimizes disruption: workers retain employment relationships, establishments retain institutional knowledge, and communities avoid concentrated job losses from closures.

These findings contrast sharply with research on fossil fuel industry declines, where workers displaced from coal mining or oil extraction experience substantial and persistent earnings losses (Walker 2013; Haywood, Janser, and Koch 2021; Ellingsen and Espegren 2022; Rud et al. 2024). Hard-to-abate sectors face fundamental contraction as production declines, with job losses that cannot be offset by comparable opportunities within the same firms—or even local labor market. In contrast, SME adoption of clean energy technology adoption expands the demand for low-carbon skills, enabling job creation alongside transformation within existing establishments. The 2019 subsidy shock triggered household demand, making heat pump installation profitable and incentivizing voluntary establishment adoption without political resistance from mandated phase-outs. Policymakers should therefore prioritize demand-side subsidies creating robust clean technology markets, making adoption economically attractive for incumbent establishments and facilitating within-firm transitions minimizing worker displacement.

6.2.2 Prioritize Near Transitions and Ensure Training Infrastructure

The second priority recognizes that not all technology transitions are equally feasible or equally costly for workers and establishments. Skill distance fundamentally shapes adjustment costs, requiring two-part strategy: prioritize transitions where skill gaps are manageable (ex-ante targeting), and ensure accessible but rigorous and market-relevant training infrastructure (ex-post support). Heat pump installation represents such a near transition for heating technicians: core competencies in system installation or customer interaction transfer readily, while electrical and refrigerant handling skills and more advanced thermodynamics can be acquired through focused training programs. Newcomers from HVAC industries experience modest wage premiums while those from non-HVAC sectors face flat wages despite increased hours, demonstrating that smaller skill distances reduce adjustment costs and improve outcomes.

Near transitions prove economically viable for establishments: retraining incumbents costs less than layoffs plus hiring and screening trained replacements, avoiding severance costs, recruitment expenses, and turnover productivity losses. This explains establishment preference for within-firm reskilling as evidenced by the longer hours of stayers that drive the average effect of adoption (Section 5.2.2). Blue-collar stayers acquiring electrical and refrigerant competencies become more productive and benefit from increased within-firm bargaining power, as shown by their rising hourly wage.

Accessible training infrastructure enables workers to acquire necessary technical competencies—including portable certifications for handling refrigerants. Low training costs (€500-€1,500 per establishment), combined with available subsidies through professional training schemes, kept certification accessible even for small firms. The training environment proved key to avoiding bottlenecks: by 2019, France's system possessed substantial capacity through a geographically distributed network of accredited centers. This established infrastructure, operational since 2010 for heat pump certification, absorbed the demand surge and enabled rapid adoption.

6.2.3 Coordinate Demand and Supply Interventions

The third priority recognizes that successful transitions require coordinated demand and supply interventions. The French policy mix illustrates effective coordination: 2019 subsidy increases created household demand (demand side) while RGE certification requirements ensured quality standards and worker training (supply side). Established training infrastructure—accredited centers offering standardized courses—enabled thousands of rapid certifications, facilitating swift supply-side response (Figure 2a).

Policymakers should design policy packages coupling technology adoption incentives with workforce development programs. Demand-side interventions create market pull incentivizing adoption; supply-side interventions ensure that workers and establishments possess response capabilities. Coordinated approaches facilitate rapid, equitable transitions by aligning market incentives with worker capabilities, enabling both within-firm adaptation and successful mobility for workers leveraging newly acquired skills.

6.3 Limitations and Future Research

Several limitations merit consideration. First, I cannot distinguish voluntary quits from involuntary layoffs. While average leaver outcomes are positive, this may mask heterogeneity: some displaced workers may have experienced persistent losses hidden in aggregate effects. Future research should leverage administrative data on separation reasons to examine self-selected versus forced movers, clarifying whether technology adoption creates genuine losers.

Second, detailed origin-destination matrices would illuminate worker flows. Do transitions occur within narrow sectoral boundaries or across broader HVAC applications? Do newcomers originate from related industries or diverse sectors? These patterns matter for policy: narrow flows suggest binding supply constraints as adoption scales; broad sourcing indicate larger adjustment capacity and wider skill investment benefits.

Third, the 2019-2023 window captures only short-run dynamics. Extending the time horizon would test whether early-adopter advantages persist as SMEs electrification advances, or whether initial gains fade as technologies mature and standardize. Long-run analysis could reveal dynamics invisible in this study's window.

Finally, generalization requires careful consideration. Comparative analysis across countries with different advancement in the decarbonization, or sectors with varying skill distances, would establish boundary conditions for the mechanisms identified here, strengthening evidence for designing just transition policies.

7 Conclusion

This paper examines labor market outcomes following clean energy technology adoption in France's heating services industry, a sector emblematic of the SME-level electrification required to achieve net-zero emissions targets. Heat pump certification triggers substantial labor reallocation—simultaneous job creation and destruction—yet workers experience positive average outcomes through portable skill acquisition enabling job mobility with wage premiums, and within-firm reskilling preserving employment relationships. Adjustment costs vary with skill distance: workers building on partially transferable competencies secure better outcomes.

Three policy priorities emerge: create market incentives for within-establishment adoption through demand subsidies; prioritize manageable skill-distance transitions with accessible training infrastructure; and coordinate demand and supply interventions. This coordination proves essential. Unlike declining fossil sectors imposing persistent displacement costs through creative destruction, adapting sectors with expanding demand enable within-firm transitions when policy aligns market incentives with workforce capabilities. Demand-side subsidies create profitable adoption opportunities; supply-side training infrastructure ensures establishments and workers can respond. This coordinated approach produces voluntary adoption, transferable skill acquisition, and minimal persistent adjustment costs.

The French case offers cautious optimism: transitions need not create mass displacement when workers acquire transferable competencies, demand remains strong, establishments invest in reskilling, and policy coordinates incentives with training infrastructure. Encouraging within-establishment adaptation may reduce adjustment costs while supporting decarbonization goals, contributing to a just energy transition.

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A Energy Efficiency Policy in France

A.1 Geographic Distribution of Fuel Oil Heating

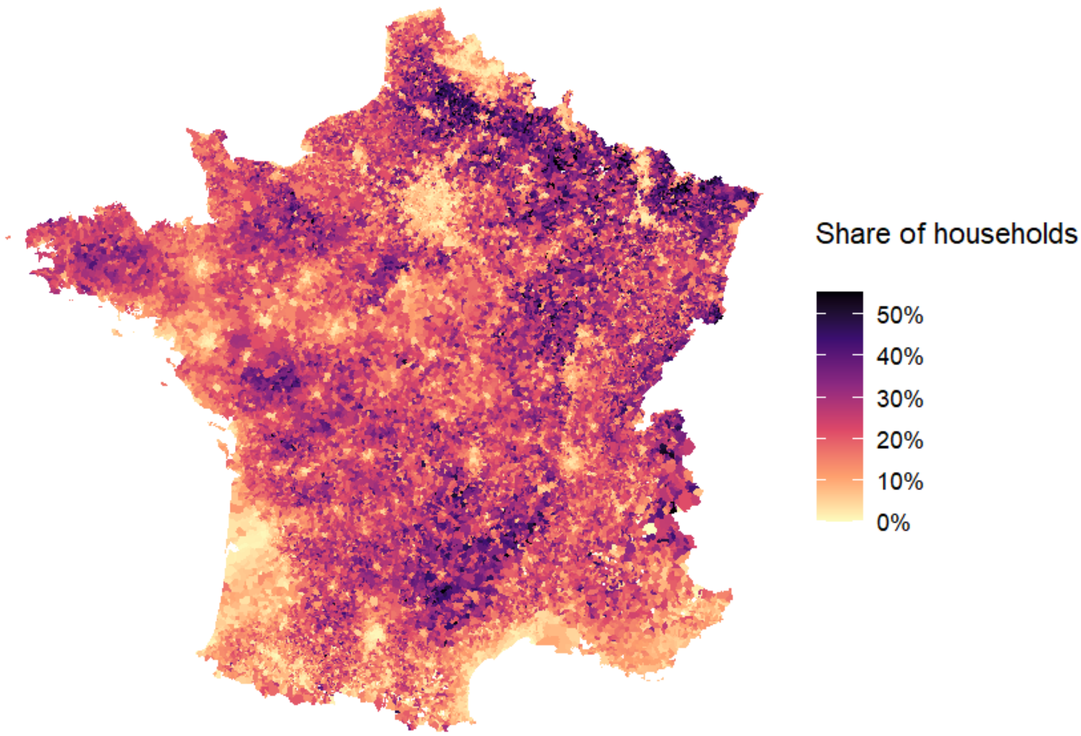


Figure 11: Reliance on a Fuel Oil as Main Heating Source by Municipality, 2017

Notes: The map displays the percentage of primary residences using fuel oil as their main heating source across French municipalities in 2017. Darker shading indicates higher reliance on fuel oil heating. Data from the French Statistical Office (INSEE).

Fuel oil heating is mostly used in detached houses located in rural areas, for which a heat pump represents the main alternative. While the April 2018 reform specifically targeted low-income households, the January 2019 revision granted eligibility to all French households. Figure 11 shows heterogeneity in fuel oil heating across French municipalities in 2017, highlighting the differential incentives created by the policy installers in rural versus urban areas.

A.2 RGE Certification by Technology Category

Figure 12 presents the distribution of RGE (Reconnu Garant de l'Environnement) certificates across different technology categories and certification providers. Heat pump certifications represent a significant share of the total, reflecting both the policy priority assigned to this technology and the substantial training infrastructure developed by certification bodies. The figure also illustrates the diversity of energy efficiency technologies covered by the RGE system, including insulation, efficient gas boilers, biomass heating systems, and photovoltaic installations. Each technology category requires separate certification, creating distinct skill pathways within the broader energy efficiency sector.

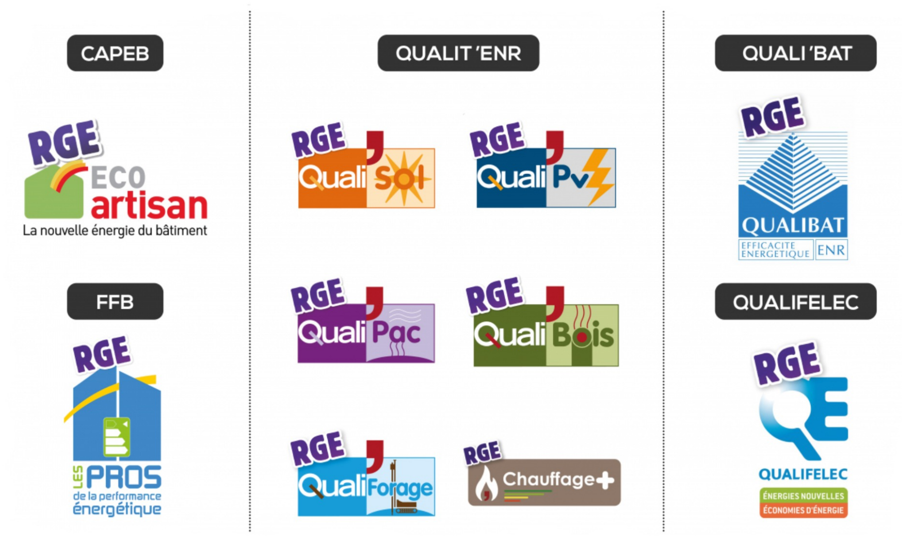


Figure 12: RGE Certificates by Technology Category and Certification Provider

Notes: The figure shows the distribution of active RGE certificates across technology categories (heat pumps, insulation, efficient gas boilers, biomass systems, photovoltaic installations, and others) and the main certification providers. Each establishment must obtain a separate certificate for each technology category in which they seek to perform subsidized work. Data from ADEME (French Environment and Energy Management Agency).

A.3 RGE Certification Process

The RGE certification follows a structured process designed to ensure quality standards for subsidized energy efficiency work. Figure 13 illustrates the key steps and timeline.

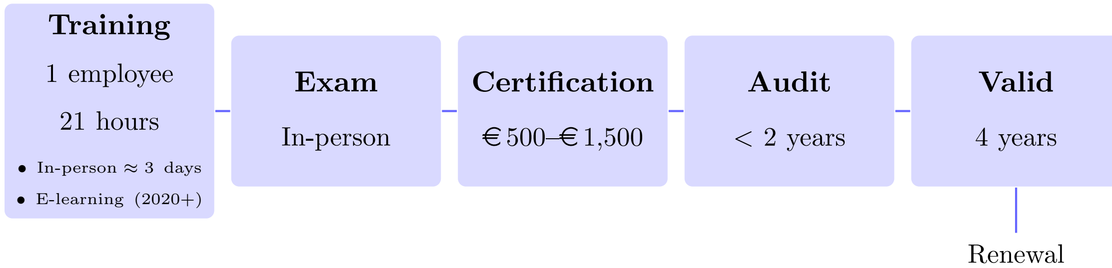


Figure 13: RGE Certification Process Timeline

Notes: Training consists of 21 hours delivered in-person (typically 2-3 consecutive days) or via distance learning. The final QCM exam must be completed in-person regardless of training format (Direction de l'Habitat, de l'Urbanisme et des Paysages 2025). Certification costs approximately €500 to €1,500 per establishment and covers a specific technology category. Certificates remain valid for four years.

Distance Learning Options. While distance learning was technically permitted under the 2014 regulatory framework (Ministère de l'Écologie, du Développement durable et de l'Énergie 2014), it expanded substantially starting in 2020, accelerated by the COVID-19 pandemic (FEEBAT 2020). E-learning can be delivered asynchronously (self-paced modules accessible 24/7) or synchronously (live virtual classrooms) (Elysia Formation 2022; FEEBAT 2025). Training costs for e-learning formats range from €700 to €900, comparable to traditional in-person options (Rénovation et Travaux 2023; Promee 2024). However, distance learning provides substantial indirect cost savings by eliminating travel and accommodation expenses, and reduces business disruption by allowing employees to complete training without extended absences from ongoing projects (Sonergia 2025). The asynchronous format enables learners to progress at their own pace through interactive content including videos, quizzes, and case studies, potentially improving knowledge retention.

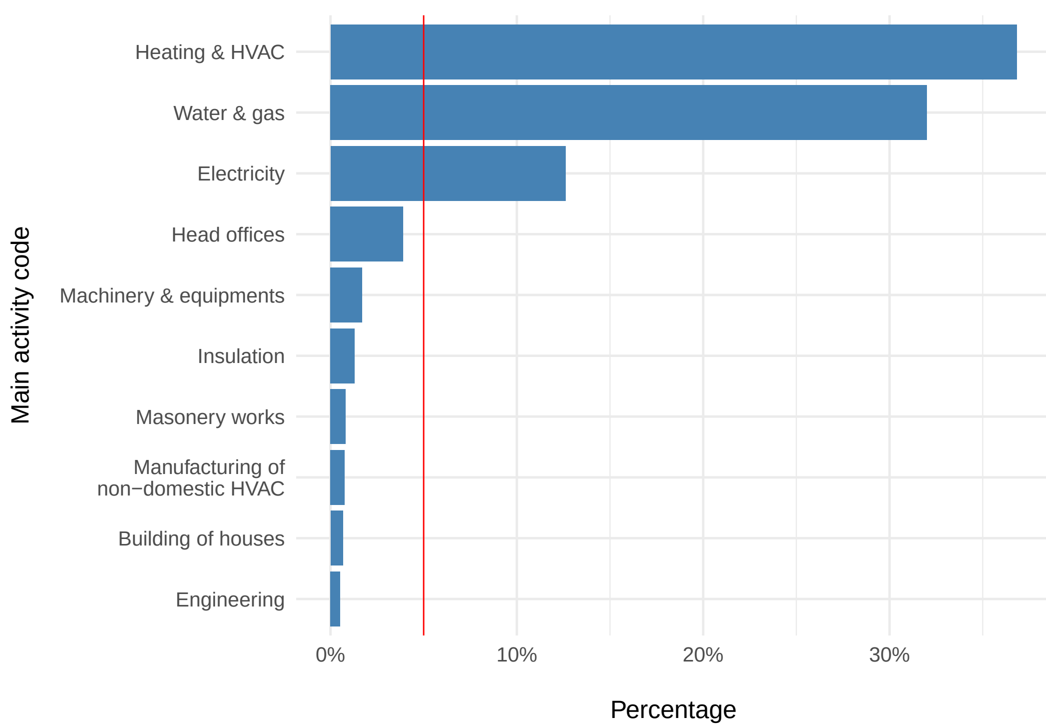
B Data sources

B.1 Worker-level data

I use the *Base Tous Salariés (BTS)*, formerly known as *Déclarations Annuelles de Données Sociales (DADS)*, an exhaustive administrative dataset of French wage earners compiled from employer tax declarations. A key methodological challenge is that the raw data assign each individual a new pseudonymous identifier each year, preventing direct longitudinal tracking. To overcome this limitation, Babet, Godechot, and Palladino 2025 developed a matching algorithm that exploits the overlapping structure of the annual files: each year's file contains data for both the current and previous year. They match individuals across consecutive years using a combination of stable characteristics including establishment identifier, gender, hours worked, job duration, start and end dates, earnings, age, and municipality of work and residence. This procedure achieves approximately 98% successful matching for the 2002-2023 period, creating what the authors term a "wide panel"—a quasi-exhaustive pseudo-panel that dramatically improves upon the traditional narrow panel (1/12th sample) previously used for French labor market research. The matching algorithm is publicly available and documented in their Appendix C. This enhanced dataset enables more precise estimation of worker and firm fixed effects in the Abowd-Kramarz-Margolis (AKM) framework by including the full universe of mobile workers across firms.

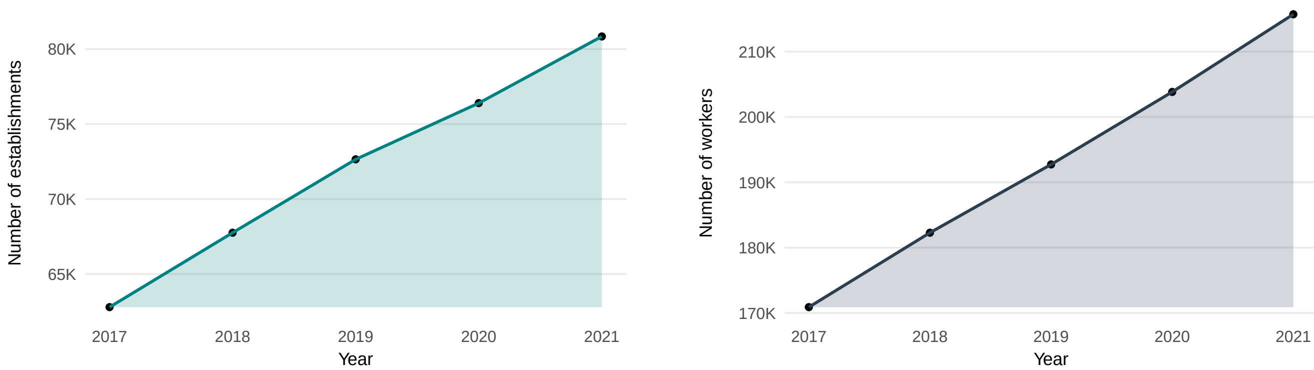
B.2 Sample construction

Figure 14: Top 10 main activity codes across heat pumps certified establishments



B.3 Sample Coverage

Figure 15 illustrates the scope of the final dataset. The sample includes between 60,000 and 80,000 active establishments annually over the 2017-2021 period, with a workforce ranging from 175,000 to 215,000 individual workers. This scale reflects the fragmented structure of the heating services sector, which is dominated by small establishments operating on local markets.



(a) Number of Establishments

(b) Number of Workers

Figure 15: Annual Sample Coverage: Establishments and Workers

Notes: Panel (a) shows the annual count of active establishments in the heating services industry over 2017-2021. Panel (b) shows the corresponding number of employed workers. Establishments are identified through main activity codes (APE) representing at least 5% of heat pump-certified firms: heating and HVAC installation (43.22B), water and gas installation (43.22A), and electrical installation (43.21A). Worker counts reflect all individuals employed in these establishments during each calendar year based on matched employer-employee data from the Base Tous Salariés.

B.4 Worker-Level Balance

Table 2 presents detailed worker-level characteristics in 2018 before and after matching. I report age, share of female workers, share of blue-collar workers (primarily trained plumbers, heating technicians, and electricians) and of higher-skilled technicians and managers[22]. Exact matching on gender and occupational categories means aggregate balance is not expected on these dimensions—sample-level differences are addressed through the exact matching itself rather than through covariate balance. Thus, important imbalances persist: female share (15.0% vs. 13.3%), blue-collar workers (67.0% vs. 62.0%), and higher-skilled technicians and managers (17.8% vs. 23.4%). Outcome variables converge: the hourly wage gap narrows from €1.53 to €1.01 and annual earnings converge from €1,290 to €547, while the hours worked gap rises slightly from 54 to 60 hours.

[22]The two groups build on the first level of the French occupational classification system (6 socio-economic groups). Blue-collar workers are *(6) Ouvriers*; Higher-skilled technicians and managers are *(3) Cadres et Professions Intellectuelles Supérieures & (4) Professions Intermédiaires.*

Table 2: Worker-Level Balance

	Treated		Control		Difference
	Mean	SD	Mean	SD	(T-C)
	(1)	(2)	(3)	(4)	(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
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

Notes: The table shows worker-level characteristics in 2018 before and after matching. Panel A presents the full sample of all full-time workers (employed at least 30 hours per week) in heating service establishments. Treatment is defined as being employed at an establishment that adopts heat pump technology in 2019. Panel B shows the matched sample using exact matching on establishment activity code (APE), socio-professional category (CSP), and gender, followed by 1:20 nearest-neighbor matching on age. Standard deviations in parentheses.

C Empirical appendix

C.1 Standard Error Calculation for Calendar-Time Aggregation

The calendar-time coefficients γ_t are linear combinations of the cohort-specific event-study coefficients β_k^c. To compute standard errors for γ_t, I use the delta method, which accounts for the covariance structure across the underlying coefficients (Greene 2018).

Let $\boldsymbol{\beta}$ denote the vector of all estimated cohort-specific coefficients $\{\beta_k^c\}$, with corresponding variance-covariance matrix $\boldsymbol{V}$ obtained from equation (3). Each calendar-time coefficient can be expressed as:

$$\gamma_t = \boldsymbol{w}_t' \boldsymbol{\beta} \tag{6}$$

where $\boldsymbol{w}_t$ is a weight vector with elements:

$$w_t^{(c,k)} = \begin{cases} \frac{1}{N_t} & \text{if } c + k = t \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

and $N_t = \sum_{c,k} \mathbb{1}\{c + k = t\}$ is the number of cohort-relative time pairs contributing to calendar year t.

By the delta method, the variance of γ_t is:

$$\text{Var}(\gamma_t) = \boldsymbol{w}_t' \boldsymbol{V} \boldsymbol{w}_t \tag{8}$$

Expanding this expression yields:

$$\text{Var}(\gamma_t) = \frac{1}{N_t^2} \sum_{\substack{c,k: \\ c+k=t}} \sum_{\substack{c',k': \\ c'+k'=t}} \text{Cov}(\beta_k^c, \beta_{k'}^{c'}) \tag{9}$$

The standard error of γ_t is then:

$$\text{SE}(\gamma_t) = \sqrt{\text{Var}(\gamma_t)} \tag{10}$$

This calculation properly accounts for two sources of correlation: (1) correlation between different relative-time coefficients within the same cohort, which arises from shared individual fixed effects and common shocks affecting that cohort; and (2) correlation between coefficients from different cohorts that contribute to the same calendar year, which can occur due to overlapping observations or common calendar-time shocks captured in the residuals.

For inference, I construct confidence intervals using:

$$\mathrm{CI}_{1-\alpha}(\gamma_t) = \gamma_t \pm z_{\alpha/2} \times \mathrm{SE}(\gamma_t) \tag{11}$$

where $z_{\alpha/2}$ is the appropriate critical value from the standard normal distribution.

D Estimation Results Tables

D.1 Effects on establishments employment behavior

Table 3: Staggered DiD Estimates: Job Entries Following Heat Pump Adoption

Event Time	Estimate	Std. Error	95% Conf. Band
Pre-treatment period			
$t = -18$	-0.004	(0.020)	[-0.056, 0.049]
$t = -16$	0.006	(0.017)	[-0.040, 0.052]
$t = -14$	0.036	(0.020)	[-0.017, 0.089]
$t = -12$	0.047	(0.021)	[-0.008, 0.101]
$t = -10$	0.051	(0.029)	[-0.026, 0.129]
$t = -8$	0.028	(0.018)	[-0.021, 0.077]
$t = -6$	0.028	(0.017)	[-0.018, 0.074]
$t = -4$	0.034	(0.019)	[-0.017, 0.085]
$t = -2$	0.048	(0.019)	[-0.001, 0.098]
Post-treatment period			
$t = 0$	0.076**	(0.023)	[0.015, 0.136]
$t = 2$	0.262***	(0.046)	[0.140, 0.385]
$t = 4$	0.423***	(0.064)	[0.252, 0.594]
$t = 6$	0.593***	(0.086)	[0.365, 0.821]
$t = 8$	0.728***	(0.105)	[0.449, 1.010]
$t = 10$	0.907***	(0.124)	[0.577, 1.240]
$t = 12$	1.060***	(0.139)	[0.688, 1.430]
$t = 14$	1.200***	(0.167)	[0.756, 1.640]
$t = 16$	1.320***	(0.174)	[0.859, 1.780]
$t = 18$	1.460***	(0.200)	[0.934, 2.000]
Overall ATT (post-treatment): 0.903*** (0.107)			
Treated establishments	7,153		
Control establishments	58,259		
Estimation method	Inverse Probability Weighting		

Notes: This table presents the regression estimates underlying Figure 4a. Staggered difference-in-differences estimates using Callaway and Sant'Anna 2021 methodology. Dependent variable is cumulative job entries at the establishment level. Event time measured in months relative to heat pump RGE certification (bimonthly observations). Control group comprises never-treated establishments. Estimation uses inverse probability weighting with covariates: establishment age and commuting zone heating industry headcount. Standard errors clustered at establishment level in parentheses. Overall ATT is the aggregated average treatment effect across all post-treatment periods weighted by group size and treatment exposure. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Staggered DiD Estimates: Job Exits Following Heat Pump Adoption

Event Time	Estimate	Std. Error	95% Conf. Band
Pre-treatment period			
$t = -18$	0.001	(0.010)	[-0.026, 0.028]
$t = -16$	0.002	(0.011)	[-0.028, 0.033]
$t = -14$	0.025	(0.011)	[-0.007, 0.056]
$t = -12$	0.029	(0.013)	[-0.007, 0.065]
$t = -10$	0.025	(0.011)	[-0.005, 0.055]
$t = -8$	0.014	(0.011)	[-0.015, 0.043]
$t = -6$	0.001	(0.010)	[-0.026, 0.027]
$t = -4$	0.008	(0.010)	[-0.020, 0.035]
$t = -2$	0.017	(0.010)	[-0.011, 0.045]
Post-treatment period			
$t = 0$	0.033**	(0.010)	[0.006, 0.060]
$t = 2$	0.126***	(0.018)	[0.076, 0.175]
$t = 4$	0.203***	(0.026)	[0.131, 0.274]
$t = 6$	0.291***	(0.033)	[0.201, 0.380]
$t = 8$	0.365***	(0.040)	[0.256, 0.474]
$t = 10$	0.453***	(0.047)	[0.325, 0.581]
$t = 12$	0.514***	(0.055)	[0.363, 0.666]
$t = 14$	0.566***	(0.059)	[0.405, 0.728]
$t = 16$	0.628***	(0.065)	[0.449, 0.808]
$t = 18$	0.686***	(0.075)	[0.479, 0.893]
Overall ATT (post-treatment): 0.437*** (0.041)			
Treated establishments	7,153		
Control establishments	58,259		
Estimation method	Inverse Probability Weighting		

Notes: This table presents the regression estimates underlying Figure 4b. Staggered difference-in-differences estimates using Callaway and Sant'Anna 2021 methodology. Dependent variable is cumulative job exits at the establishment level. Event time measured in months relative to heat pump RGE certification (bimonthly observations). Control group comprises never-treated establishments. Estimation uses inverse probability weighting with covariates: establishment age and commuting zone heating industry headcount. Standard errors clustered at establishment level in parentheses. Overall ATT is the aggregated average treatment effect across all post-treatment periods weighted by group size and treatment exposure. *** p<0.01, ** p<0.05, * p<0.1.

D.2 Workers-level Career Trajectories

D.2.1 Effect on incumbent workers

Table 5: Effect of Heat Pump Certification on Incumbent Workers: Log Total Hours Worked

Event Time	Estimate	Std. Error
Pre-treatment period		
$t = -4$	0.007	(0.017)
$t = -3$	0.011	(0.015)
$t = -2$	0.012	(0.016)
$t = -1$	[Reference period]	
Post-treatment period		
$t = 0$	0.139***	(0.015)
$t = 1$	0.119***	(0.015)
$t = 2$	0.116***	(0.017)
$t = 3$	0.069***	(0.018)
$t = 4$	0.067***	(0.017)
Observations	870,187	
Treated workers	11,229	
Control workers	117,748	
Worker FE	Yes (128,221)	
Establishment FE	Yes (35,295)	
Year × CZ FE	Yes (2,583)	
Within R^2	0.0005	

Notes: This table presents the regression estimates underlying Figure 5a. Event-study estimates of the effect of heat pump certification on log total hours worked for workers employed at treated establishments in 2018 and 2019. Event time measured in years relative to certification year (2019). Control workers matched exactly on establishment activity code (APE), socio-professional category (CSP), and gender, followed by 1:20 nearest-neighbor matching on age. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Effect of Heat Pump Certification on Incumbent Workers: Log Annual Labor Earnings

Event Time	Estimate	Std. Error
Pre-treatment period		
$t = -4$	0.008	(0.018)
$t = -3$	0.014	(0.015)
$t = -2$	0.017	(0.016)
$t = -1$	[Reference period]	
Post-treatment period		
$t = 0$	0.144***	(0.016)
$t = 1$	0.133***	(0.015)
$t = 2$	0.138***	(0.018)
$t = 3$	0.094***	(0.018)
$t = 4$	0.072***	(0.018)
Observations	870,207	
Treated workers	11,229	
Control workers	117,748	
Worker FE	Yes (128,222)	
Establishment FE	Yes (35,296)	
Year × CZ FE	Yes (2,583)	
Within R^2	0.0006	

Notes: This table presents the regression estimates underlying Figure 5b. Event-study estimates of the effect of heat pump certification on log annual labor earnings for workers employed at treated establishments in 2018 and 2019. Event time measured in years relative to certification year (2019). Control workers matched exactly on establishment activity code (APE), socio-professional category (CSP), and gender, followed by 1:20 nearest-neighbor matching on age. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Effect of Heat Pump Certification on Incumbent Workers: Log Hourly Wage

Event Time	Estimate	Std. Error
Pre-treatment period		
$t = -4$	0.001	(0.007)
$t = -3$	0.003	(0.006)
$t = -2$	0.005	(0.004)
$t = -1$	[Reference period]	
Post-treatment period		
$t = 0$	0.004	(0.003)
$t = 1$	0.014**	(0.005)
$t = 2$	0.022***	(0.005)
$t = 3$	0.025***	(0.006)
$t = 4$	0.006	(0.006)
Observations	870,187	
Treated workers	11,229	
Control workers	117,748	
Worker FE	Yes (128,221)	
Establishment FE	Yes (35,295)	
Year × CZ FE	Yes (2,583)	
Within R^2	0.0001	

Notes: This table presents the regression estimates underlying Figure 5c. Event-study estimates of the effect of heat pump certification on log hourly wage for workers employed at treated establishments in 2018 and 2019. Event time measured in years relative to certification year (2019). Control workers matched exactly on establishment activity code (APE), socio-professional category (CSP), and gender, followed by 1:20 nearest-neighbor matching on age. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

D.2.2 Decomposing Effects: Stayers versus leavers

Table 8: Effects on Hours Worked: Stayers vs. Leavers (Calendar Time)

	Stayers		**Leavers**	
Calendar Year	Estimate	Std. Error	Estimate	Std. Error
Pre-treatment period				
2015	−0.004	(0.021)	−0.008	(0.041)
2016	0.006	(0.019)	0.011	(0.056)
2017	0.006	(0.020)	0.042	(0.056)
2018	[Reference]		0.004	(0.059)
Post-treatment period				
2019	0.191***	(0.018)	−0.302***	(0.084)
2020	0.218***	(0.017)	−0.427***	(0.096)
2021	0.220***	(0.020)	−0.312***	(0.087)
2022	0.204***	(0.018)	−0.279***	(0.066)
2023	0.124***	(0.019)	−0.411***	(0.130)
Observations	739,022		–	
Treated workers	7,395		2,523	
Control workers	100,890		36,576	
Cohorts aggregated	–		1–3	

Notes: This table presents the regression estimates underlying Figure 6a. Comparison of treatment effects on log total hours worked for stayers versus leavers, both expressed in calendar time. **Stayers** are workers employed at the same establishment in 2018, 2019, and 2023. Event-study specification with worker fixed effects, establishment fixed effects, and year-by-commuting zone fixed effects. Standard errors clustered at establishment level. **Leavers** are workers present in 2018-2019 but separated by 2023 (minimum 3 years tenure). Estimates are calendar-time aggregations of cohort-specific event-study coefficients from equation (3), averaged across separation cohorts active in each year. Standard errors computed using delta method accounting for covariance across cohorts. Each group matched to separate control workers at never-treated establishments. *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Effects on Annual Earnings: Stayers vs. Leavers (Calendar Time)

	Stayers		**Leavers**	
Calendar Year	Estimate	Std. Error	Estimate	Std. Error
Pre-treatment period				
2015	−0.003	(0.023)	−0.060	(0.043)
2016	0.009	(0.019)	−0.015	(0.057)
2017	0.010	(0.020)	0.022	(0.060)
2018	[Reference]		0.045	(0.060)
Post-treatment period				
2019	0.190***	(0.018)	−0.236***	(0.086)
2020	0.226***	(0.017)	−0.343***	(0.099)
2021	0.236***	(0.020)	−0.304***	(0.089)
2022	0.218***	(0.019)	−0.229***	(0.068)
2023	0.127***	(0.021)	−0.374***	(0.117)
Observations	739,038		–	
Treated workers	7,395		2,523	
Control workers	100,890		36,576	
Cohorts aggregated	–		1–3	

Notes: This table presents the regression estimates underlying Figure 6b. Comparison of treatment effects on log annual labor earnings for stayers versus leavers, both expressed in calendar time. **Stayers** are workers employed at the same establishment in 2018, 2019, and 2023. Event-study specification with worker fixed effects, establishment fixed effects, and year-by-commuting zone fixed effects. Standard errors clustered at establishment level. **Leavers** are workers present in 2018-2019 but separated by 2023 (minimum 3 years tenure). Estimates are calendar-time aggregations of cohort-specific event-study coefficients from equation (3), averaged across separation cohorts active in each year. Standard errors computed using delta method accounting for covariance across cohorts. Each group matched to separate control workers at never-treated establishments. *** p<0.01, ** p<0.05, * p<0.1.

Table 10: Effect of Heat Pump Certification on Hourly Wages: Stayers

Event Time	Estimate	Std. Error
Pre-treatment period		
$t = -4$	0.001	(0.010)
$t = -3$	0.003	(0.007)
$t = -2$	0.004	(0.005)
$t = -1$	[Reference period]	
Post-treatment period		
$t = 0$	−0.002	(0.004)
$t = 1$	0.008	(0.006)
$t = 2$	0.016**	(0.006)
$t = 3$	0.014**	(0.006)
$t = 4$	0.002	(0.007)
Observations	739,022	
Treated workers	7,395	
Control workers	100,890	
Worker FE	Yes (107,590)	
Establishment FE	Yes (32,189)	
Year × CZ FE	Yes (2,583)	
Within R^2	0.00004	

Notes: This table presents the regression estimates underlying Figure 7. Event-study estimates of the effect of heat pump certification on log hourly wage for stayers—workers employed at the same establishment in 2018, 2019, and 2023. Event time measured in years relative to certification year (2019). Control workers matched exactly on establishment activity code (APE), socio-professional category (CSP), and gender, followed by nearest-neighbor matching on age. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), and year-by-commuting zone fixed effects. Standard errors clustered at establishment level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

D.2.3 Worker Mobility and Adjustment Dynamics

Table 11: Labor Market Dynamics for Leavers in Event Time

	Hours		**Earnings**		**Hourly Wage**	
Rel. Time	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.
Pre-separation						
$t = -4$	−0.027	(0.041)	−0.072	(0.045)	−0.045**	(0.020)
$t = -3$	−0.009	(0.029)	−0.031	(0.032)	−0.022	(0.014)
$t = -2$	0.019	(0.020)	0.008	(0.021)	−0.011	(0.009)
$t = -1$	[Reference period]					
Post-separation						
$t = 0$	−0.743***	(0.031)	−0.606***	(0.032)	0.137***	(0.013)
$t = 1$	0.021	(0.066)	0.233***	(0.068)	0.212***	(0.024)
$t = 2$	0.192**	(0.087)	0.444***	(0.091)	0.252***	(0.033)
$t = 3$	0.252**	(0.115)	0.528***	(0.117)	0.277***	(0.047)
$t = 4$	0.404**	(0.162)	0.716***	(0.164)	0.312***	(0.063)
Observations	19,352					
Treated workers	2,523					
Control workers	36,576					
Separation cohorts	4 (2020–2023)					
Worker FE	Yes (2,674)					
Establishment FE	Yes (1,776)					
Year × CZ FE	Yes (2,032)					

Notes: This table presents the regression estimates underlying Figure 8 (left column). Event-study estimates in relative time around separation for leavers—workers present at treated establishments 2016-2019 who separated by 2023 (minimum 3 years tenure). Relative time $t = 0$ is the separation year; $t = -1$ (year before separation) is the reference period. Outcomes are log total hours worked, log annual labor earnings, and log hourly wage. Control workers matched exactly on age, socio-professional category (PCS), establishment activity code, and gender. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), cohort fixed effects, and year-by-commuting zone fixed effects. Standard errors clustered at establishment level. *** p<0.01, ** p<0.05, * p<0.1.

Table 12: Labor Market Dynamics for Newcomers in Event Time

	Hours		**Earnings**		**Hourly Wage**	
Rel. Time	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.
Pre-entry						
$t = -4$	−0.005	(0.058)	−0.042	(0.069)	−0.037	(0.041)
$t = -3$	0.011	(0.038)	0.002	(0.039)	−0.008	(0.015)
$t = -2$			[Reference period]			
$t = -1$	−0.111**	(0.044)	−0.115**	(0.044)	−0.004	(0.015)
Post-entry						
$t = 0$	−0.673***	(0.074)	−0.625***	(0.076)	0.048*	(0.027)
$t = 1$	0.177	(0.112)	0.218*	(0.115)	0.041	(0.042)
$t = 2$	0.203	(0.148)	0.223	(0.155)	0.020	(0.059)
$t = 3$	0.200	(0.192)	0.212	(0.201)	0.012	(0.077)
$t = 4$	0.110	(0.279)	0.018	(0.307)	−0.092	(0.116)
Observations			13,975			
Treated workers			1,529			
Control workers			27,131			
Entry cohorts			2020–2023			
Worker FE			Yes (1,611)			
Establishment FE			Yes (2,347)			
Year × CZ FE			Yes (1,868)			

Notes: This table presents the regression estimates underlying Figure 8 (right column). Event-study estimates in relative time around entry for newcomers—workers not employed at treated establishments in 2019 but present in 2023 (entry 2020-2023). Relative time $t = 0$ is the entry year; $t = -2$ (two years before entry) is the reference period, chosen to capture the pre-exit baseline since workers entering at $t = 0$ likely separated from their previous employer at $t = -1$. Outcomes are log total hours worked, log annual labor earnings, and log hourly wage. Control workers matched exactly on age, socio-professional category (PCS), establishment activity code, and gender. Specification includes worker fixed effects, establishment fixed effects (SIREN and NIC), and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels. *** p<0.01, ** p<0.05, * p<0.1.

D.3 Heterogeneity Analysis

Table 13: Heterogeneous Effects on Hourly Wages by Occupation: Stayers

	Blue-Collar		**Technicians & Managers**	
Event Time	Estimate	Std. Error	Estimate	Std. Error
Pre-treatment period				
$t = -4$	0.005	(0.010)	-0.004	(0.021)
$t = -3$	0.001	(0.007)	-0.005	(0.014)
$t = -2$	0.002	(0.005)	0.009	(0.011)
$t = -1$	[Reference period]			
Post-treatment period				
$t = 0$	0.001	(0.004)	-0.011	(0.009)
$t = 1$	0.012*	(0.006)	-0.005	(0.011)
$t = 2$	0.021**	(0.007)	0.004	(0.012)
$t = 3$	0.023***	(0.007)	-0.009	(0.012)
$t = 4$	0.007	(0.008)	-0.020	(0.015)
Sample composition				
Treated workers	–		–	
Control workers	–		–	

Notes: This table presents the regression estimates underlying Figure 9. Event-study estimates of the effect of heat pump certification on log hourly wages for stayers, decomposed by occupational category. Sample restricted to workers employed at the same establishment in 2018, 2019, and 2023. **Blue-collar workers** comprise trained plumbers, heating technicians, and electricians (PCS: *Ouvriers*). **Technicians and managers** include higher-skilled technical and managerial positions (PCS: *Cadres & Professions Intellectuelles Supérieures* and *Professions Intermédiaires*). Each group matched to separate control workers at never-treated establishments following the matching procedure detailed in section 5.2. Specification includes worker fixed effects, establishment fixed effects, and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels. *** p<0.01, ** p<0.05, * p<0.1.

Table 14: Heterogeneous Effects on Hourly Wages by Destination: Leavers

	HP-Certified Dest.		**Non-Certified Dest.**	
Rel. Time	Estimate	Std. Error	Estimate	Std. Error
Pre-separation				
$t = -4$	−0.026	(0.018)	−0.081**	(0.036)
$t = -3$	−0.012	(0.012)	−0.052**	(0.026)
$t = -2$	−0.002	(0.008)	−0.035**	(0.017)
$t = -1$		[Reference period]		
Post-separation				
$t = 0$	0.125***	(0.012)	0.129***	(0.022)
$t = 1$	0.218***	(0.028)	0.194***	(0.037)
$t = 2$	0.227***	(0.038)	0.248***	(0.055)
$t = 3$	0.265***	(0.057)	0.273***	(0.073)
$t = 4$	0.287***	(0.076)	0.304***	(0.093)
Sample composition				
Treated workers	–		–	
Control workers	–		–	

Notes: This table presents the regression estimates underlying Figure 10 (panels a-b). Event-study estimates in relative time around separation for leavers, decomposed by destination establishment certification status. Sample: workers present at treated establishments 2016-2019 who separated by 2023 (minimum 3 years tenure). Relative time $t = 0$ is the separation year; $t = -1$ is the reference period. **HP-certified destinations** hold heat pump RGE certification at worker entry. **Non-certified destinations** lack heat pump certification. Each group matched to separate control workers at never-treated establishments. Specification includes worker fixed effects, establishment fixed effects, cohort fixed effects, and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels. *** p<0.01, ** p<0.05, * p<0.1.

Table 15: Heterogeneous Effects on Hourly Wages by Industry Origin: Newcomers

	HVAC Origin		**Non-HVAC Origin**	
Rel. Time	Estimate	Std. Error	Estimate	Std. Error
Pre-entry				
$t = -4$	−0.057	(0.054)	0.059	(0.101)
$t = -3$	−0.027	(0.029)	0.045	(0.080)
$t = -2$	−0.010	(0.016)	0.007	(0.047)
$t = -1$		[Reference period]		
Post-entry				
$t = 0$	0.075***	(0.018)	−0.059	(0.075)
$t = 1$	0.079**	(0.032)	−0.067	(0.130)
$t = 2$	0.075	(0.047)	−0.087	(0.183)
$t = 3$	0.105	(0.068)	−0.197	(0.266)
$t = 4$	−0.065	(0.098)	−0.288	(0.370)
Sample composition				
Treated workers	–		–	
Control workers	–		–	

Notes: This table presents the regression estimates underlying Figure 10 (panels c-d). Event-study estimates in relative time around entry for newcomers, decomposed by industry of origin. Sample: workers not employed at treated establishments in 2019 but present in 2023 (entry 2020-2023). Relative time $t = 0$ is the entry year; $t = -1$ is the reference period. **HVAC origin** includes prior employment in heating, air conditioning, or ventilation establishments. **Non-HVAC origin** includes all other sectors. Each group matched to separate control workers at never-treated establishments. Specification includes worker fixed effects, establishment fixed effects, and year-by-commuting zone fixed effects. Standard errors two-way clustered at worker and establishment levels. *** p<0.01, ** p<0.05, * p<0.1.