Making Jobs out of the Energy Transition: Evidence from the French Energy Efficiency Obligations Program

Guillaume Wald*,[1], Victor Kahn[1], and François Cohen[2]

[1]CERNA, Mines Paris - PSL

[2]Universitat de Barcelona, Department of Economics, Energy Sustainability Chair and Institute of Economics of Barcelona

November 2023

Abstract

Recovery packages from COVID-19 are committing nearly one trillion dollars of public spending to green investments globally, with strong expectations of economic growth and job creation. Yet, we crucially lack ex-post validations of the multiplier effects widely used to forecast new green jobs. This is especially the case for energy retrofits in buildings, which are likely to have among the highest potentials for climate action and job creation at the same time. We provide the first ex-post analysis of a large-scale retrofit program on both fixed-term and permanent job creations by exploiting a large discontinuity in the provision of subsidies through the French Energy Efficiency Obligation program. Using a novel synthetic control method to exploit employment variations at the regional level, we estimate that the policy sustains 1.8 jobs per million euros invested annually.

JEL Codes: J21, H23, Q43 and Q48

*Corresponding author: guillaume.wald@minesparis.psl.eu

1 Introduction

Recovery packages[1] from COVID-19 are committing nearly one trillion dollars of public spending to green investments globally, amounting to a third of global recovery spending (O'Callaghan et al. 2021). Not only are these investments expected to drastically reduce Greenhouse Gas Emissions (GHG), but also to significantly boost employment. The European Commission, for instance, believes that meeting the 2030 climate and energy targets could create almost 1 million new green jobs (European Commission 2020b). Such positive expectations for the impact of green investment on employment are supported by several ex-ante forecasts using input-output models (Mikulić, Bakarić, and Slijepčević 2016; Markandya et al. 2016; Dell'Anna 2021) or computed general equilibrium models (Sooriyaarachchi et al. 2015; Wei, Patadia, and Kammen 2010).

However, we considerably lack ex-post confirmations. In particular, we are aware of no ex-post evaluation focusing on the job-creating potential of energy retrofits, even though buildings account for 25% of global emissions (IEA 2020) and this sector is probably one with the highest potential for local green job creation[2]. The empirical evidence is also insufficient to determine which types of green investments are most likely to stimulate employment. Popp et al. 2022 provide the first ex-post analysis of a green investment package on employment, and find that, in the long run, for each million dollars invested in green technologies, the 2009 American Recovery and Reinvestment Act (ARRA) created 2 to 4 jobs in the construction sector. However, they cannot separate the impact of the many types of green investments performed (such as energy renovation, green infrastructure, or the installation of renewable energy technologies). Their estimate is an average that may bundle investments with strong impacts on employment with others with near-zero effect. In that regard, Fabra et al. 2023 find radically different outcomes for solar versus wind energy investments in Spain[3]. Other categories, especially energy retrofits, have not been analyzed in a similar fashion. Moreover, the analysis by Fabra et al. 2023 suggests lower job creation in the

[1] e.g. NextGenerationEU (European Commission 2021) or the American Rescue Plan Act (Office of the Federal Register, National Archives and Records Administration. 2021).

[2] Retrofits are one of the main green investment types. The Renovation Wave in the European Union includes a EUR 200 billion investment in "greening [...] buildings, improving lives and creating jobs"(European Commission 2020a). Moreover, ex-ante studies have forecasted impacts in the range of 12 to 29 direct and indirect jobs created per million dollars invested in energy retrofits, of which about half would be direct hires in the energy retrofit sector (BPIE 2020). Energy retrofits are often performed by SMEs (European Commission 2019b) and involve manual workers who are most likely to be negatively impacted by other environmental policies (Walker 2011); Vona et al. 2018; Yip 2018; Marin and Vona 2019; Vona 2019; Marin and Vona 2021).

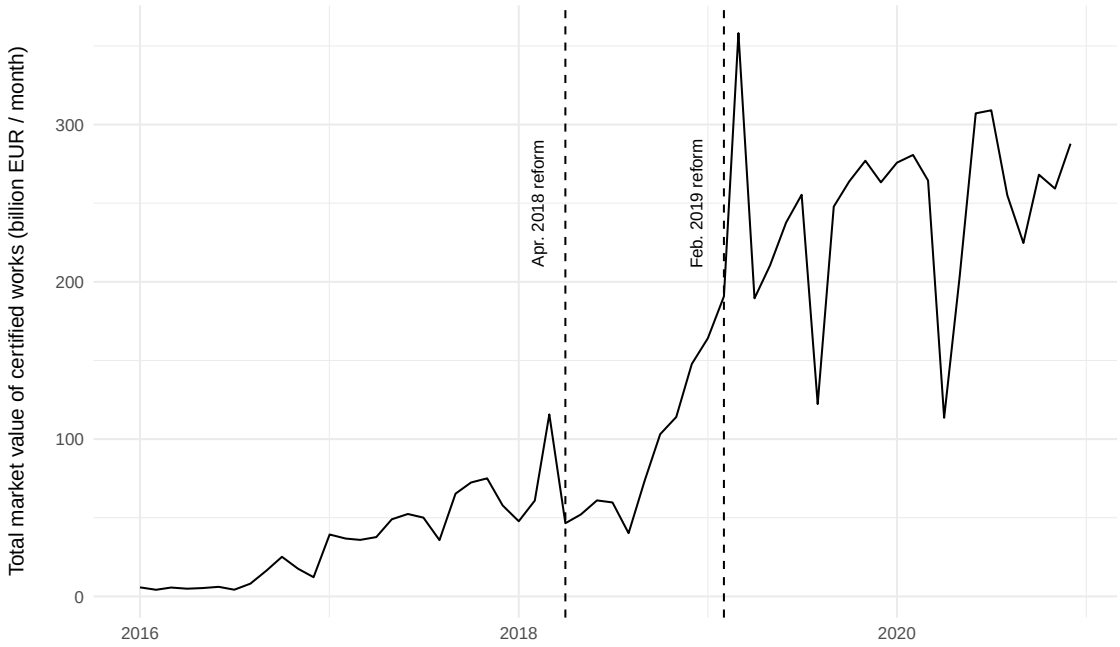
[3] For each million dollars invested in solar panels, 0.8–1.1 local jobs were created. In contrast, they find no effect on local employment for investments in wind energy.

long term for industries that rely on the installation of equipment, since maintenance is likely to be less labor intensive. In contrast, Popp et al. 2022 find stronger impacts in the long term, possibly because investments may allow structuring value chains. Still, neither of the two articles was able to separate between permanent and fixed-term contracts. However, this distinction is of primary concern for government looking for ways to structure the supply chain for energy retrofits. From the employee's perspective, employment stability could be pivotal for the attractiveness of jobs in this new retrofitting industry. From the firm's point of view, hiring on a permanent basis could also be considered as a prerequisite for investment in workers skills, while poor workmanship quality has often been considered as a driver of the energy performance gap (Giraudet, Houde, and Maher 2018).

This paper provides the first ex-post analysis of the employment effect of a large-scale energy retrofit policy in France, which also happens to be among the largest energy efficiency policies in Europe (Broc, Stańczyk, and Reidlinger 2020). We find levels of job creation lower than in ex-ante studies. We also find that energy retrofits might have a similar impact on job creation than the other types of green investments for which there are ex-post evidence. While our analysis is only reliable before the start of the pandemic, we are able to discriminate between temporary and durable job creations, the latter type being the overwhelming majority of new hiring. We exploit a large discontinuity in the provision of subsidies to French households and businesses with two reforms of the French Energy Efficiency Obligation (EEO) Program in April 2018 and January 2019. This discontinuity is observable in Figure 1, where we estimate that the total amount of subsidies to households for insulation and heating retrofit operations through the scheme went from less than EUR 200 million per quarter before 2018 to more than EUR 1,000 million per quarter at the end of 2019.

The presence of such a discontinuity greatly facilitates our analysis. Other analyses (i.e. Popp et al. 2022; Fabra et al. 2023) had to take care of endogenous treatment or local selection effects. In our case, the sudden increase in subsidies allows us to use a synthetic control method (Abadie and Gardeazabal 2003; Abadie, Diamond, and Hainmueller 2010). Our analysis compares affected sectors with unaffected sectors that are pooled and weighted to create a synthetic control whose pre-reform employment trend matches the employment trend of the affected sectors. More precisely, as we exploit variations in employment at the regional level, we rely on Abadie and L'Hour 2021 to design synthetic local retrofitting industries.

Figure 1: Total market value of works certified by the French EEO Program, in mln EUR / month



Source: The graph displays the monthly market value of works certified by the EEO program. We use data from the French Ministry of Ecological Transition to compute the monthly number of certificates generated by projects launched through the EEO program. We then multiply this number by the contemporaneous price of certificates to compute a monthly value of investment driven by the policy.

We discuss methods and hypotheses in detail, including robustness checks to ensure that our findings are not driven by potential biases or shortcomings in the method employed, such as a violation of the stable unit treatment value assumption (SUTVA) or anticipatory effects. We also perform inference tests to ensure our results are robust to specification choices. Stopping the analysis just before the COVID-19 pandemic in February 2020, we observe a clear impact of the change in policy on employment in energy retrofit companies 14 months after the second reform. This impact seems to continue until after the pandemic. We estimate that at least 5,000 jobs were created thanks to the policy, equivalent to 1.8 direct jobs created per million euros invested annually. This figure is lower than ex-ante estimates for direct jobs (at about 4.3 to 9.2 direct jobs per million dollars invested, according to BPIE 2020), and therefore mitigates current expectations of job creation through retrofits. Since Popp et al. 2022 find 2 to 4 jobs in construction sector, and Fabra et al. 2023 find 0.8-1.1 jobs in the solar industry, energy retrofits could have a similar potential for job creation as compared with other types of green investments. However, these figures do not constitute homogeneous comparisons since these studies have a different scope and use different methods[4].

[4]For instance, we focus on direct jobs at national scale whereas Fabra et al. 2023 focus on direct jobs at a very

Recent economic studies have questioned the effectiveness of energy retrofit programs, with realized energy savings being significantly lower than predicted savings (Fowlie, Greenstone, and Wolfram 2018; Liang et al. 2018; Lang and Lanz 2022; Davis, Fuchs, and Gertler 2014). Our paper contributes to the growing literature pointing to significant co-benefits of energy retrofit programs despite lower-than-expected savings, including: comfort gains (Aydin, Kok, and Brounen 2017); public health benefits (Howden-Chapman et al. 2007); economic transfers from high-income households to low-income ones (Darmais, Glachant, and Kahn 2022); and, in the case of our paper, job creation. Furthermore, empirical research on the green transition has focused on the employment effect of restrictive policies to cut down emissions (Walker 2011; Hafstead and Williams 2018; Vona et al. 2018; Yip 2018; Marin and Vona 2019; Vona 2019; Metcalf and Stock 2020; Marin and Vona 2021), with much fewer analyses looking at investment policies. This paper contributes to fill this gap, finding a moderate job potential of investments in energy retrofits. The remainder of this paper is organized as follows. Section 2 describes the policy under study. Section 3 presents our data and Section 4 our method. Section 5 presents our results, which we discuss in Section 6; Section 7 concludes.

2 The French Energy Efficiency Obligation program

In 2006, the French government established a regime of energy efficiency obligations (*Certificats d'Economies d'Energie* in French) under the supervision of the General Directorate of Energy and Climate (*Direction Générale de l'Energie et du Climat, GDEC* in French). The scheme consists of periods of three to four years during which a national energy savings target must be met. It is in its 5^{th} period since January 1st, 2022 and the total energy savings target for 2022-2025 is set at 2,500 cumulative TWh[5] Each period-specific national energy savings target is broken down into individual targets of energy savings for all obligated parties. The obligated parties are energy providers, mainly gasoline, electricity, and natural gas providers. They must fulfill their individual obligations by obtaining energy saving certificates delivered by the regulator for efficiency improvements performed

local scale (finer than our regional resolution). Popp et al. 2022 use a method that should provide overall results for both indirect and direct job creations.

[5]TWh are cumulative because the energy savings are calculated on the lifetime of the energy operation achieved. Part of this target (730 cumulative TWh during the 5^{th} period) must go to projects benefiting to low-income households, as explained in the following pages.

in either the residential, the industrial or the tertiary sectors. These individual obligations depend on the amount and type of fuel they sell during the period in the residential and tertiary sectors. For instance, during the 4^{th} period (2018-2021), for each MWh of electricity sold, energy providers had to obtain 0.604 energy saving certificates. In addition, since 2016, a share of certificates must be obtained from subsidizing renovation efforts in 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). It is possible to fulfil a general obligation with low-income certificates, but it is not possible to use general certificates to fulfil low-income obligations.

To obtain certificates, the obligated parties must have an active role and provide an incentive to a renovation project, i.e. fund entirely or in part the project. They must be mentioned as such on the project invoice. As a result, in 2019, the obligated parties provided EUR 2.5 billion of grants for energy efficiency projects through the scheme in the residential sector (Darmais, Glachant, and Kahn 2022). Renovation projects can be undertaken on behalf of residential, industrial, or tertiary actors. Once the renovation is complete, the obligated party claims the quantity of certificates corresponding to the retrofit operations undertaken as part of the project. The number of certificates associated with each energy retrofit operation is set in advance by the regulator. This quantity essentially depends on the energy savings that each operation conveys. There are more than 200 standard energy retrofit operations that correspond to a set number of certificates. For instance, in 2019, one square meter of insulated wall in an electricity-heated house in the north of France was associated with 2.4 certificates. If the renovation effort benefits a household with income below a threshold close to the national median, then the certificate obtained is a low-income certificate. Moreover, the number of certificates obtained from the same renovation effort is doubled if the renovation benefits a household belonging to the 1^{st} quartile of income. The obligated parties can delegate all or part of their obligations to third-party companies, called delegated parties, usually energy service providers or simply traders. Obligated and delegated parties are allowed to exchange certificates through over-the-counter operations. Therefore, while there is no organized market for certificates, these are still traded between different parties. Monthly price indices for general and low-income certificates are publicly available from the national register of EEOs (called EMMY)[6]. They correspond to

[6]For more information on the register, see: https://opera-energie.com/emmy-registre-national-cee/

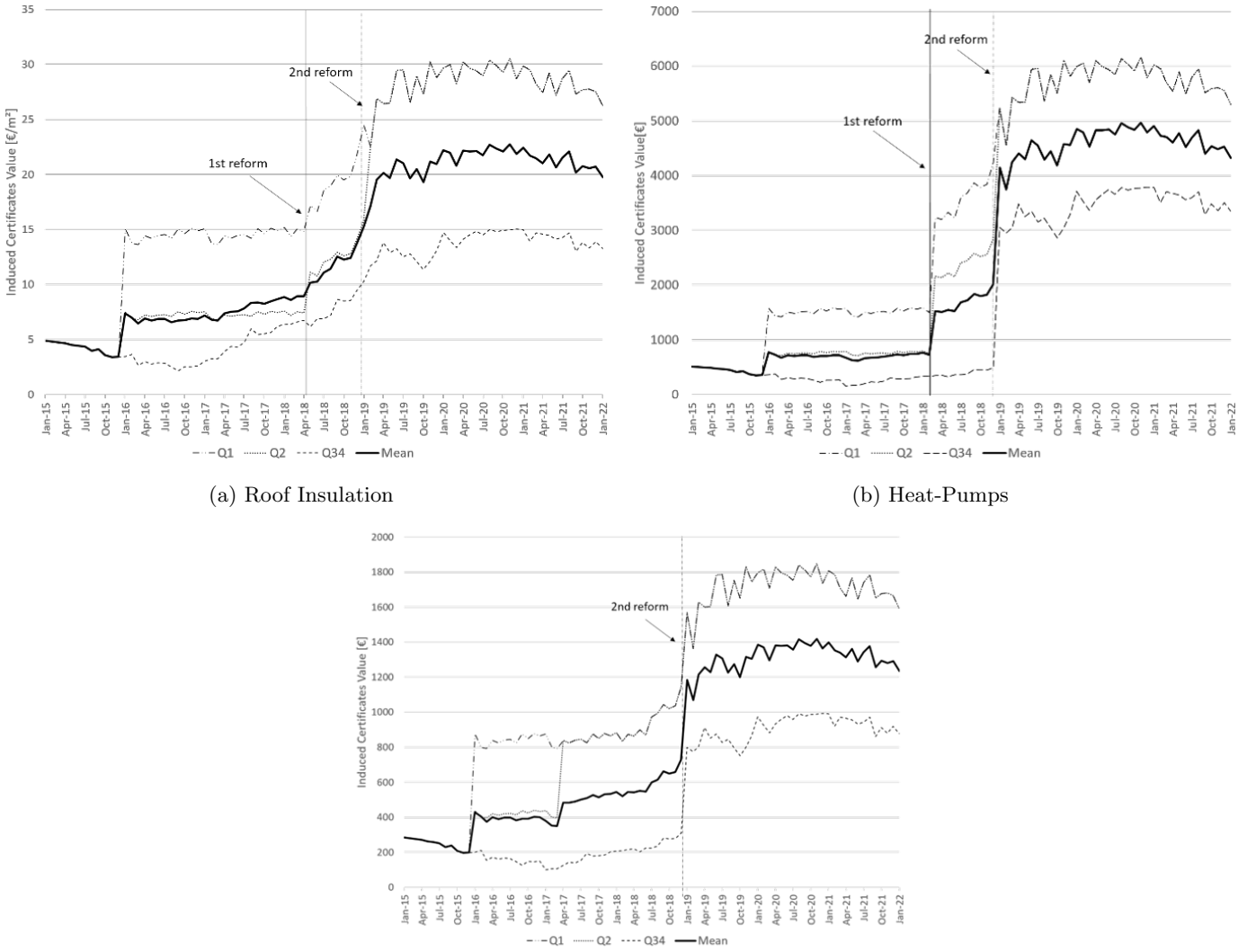
the average price of all the certificates sold during a month[7]. These indices are used as a signal by stakeholders, who may monitor their activities and make decisions under the scheme based on the evolution of these indices. Even though obligated and delegated parties freely set the financial conditions for the home improvements that they subsidize, energy efficiency grants to households and businesses ultimately depend on the number of certificates associated with each energy retrofit operation, and the price of certificates as signaled by the price indices of certificates. This is considering that obligated parties can always buy certificates to others through over-the-counter operations.

Figure 2 displays the evolution of the market value of the certificates that obligated and delegated parties obtained when undertaking selected energy retrofit operations. This value has been computed by multiplying the price of certificates with the number of certificates associated with each operation. We provide this information separately for different income quartile of households since the value of the operations is different. As explained before, the obligated and delegated parties can claim low-income certificates for home improvements performed in the 1st and 2^{nd} quartiles of income, and twice as many of these certificates for improvements benefitting the 1^{st} quartile. Figure 2 shows that, for each operation, the market value of the certificates was very stable between January 2016 and March 2018, and then increased sharply until it plateaued in 2019. For instance, the total value of the certificates obtained for one square meter of roof insulation went from less than 10 euros to more than 20 euros on average[8]. For heat pumps, the financial value of certificates was multiplied by about 5. Altogether, the value of subsidies delivered to households through the French EEO scheme increased substantially, from less than EUR 1 billion in 2017 to EUR 2.5 billion in 2019 (Darmais, Glachant, and Kahn 2022).

[7]This price index is sometimes difficult to interpret because it includes certificates sold in very different conditions, not only certificates traded with contracts *"on the spot"* happening during month m, but also certificates from forward contracts that came to maturity during month m. Moreover, the price index also includes price information from trades happening between subsidiary companies belonging to the same mother company.

[8]These values do not account for inflation. Inflation was however very low in the Eurozone between 2016 and 2019.

Figure 2: Evolution of the market value of the certificates associated to a selection of operations covered by the EEO scheme



(a) Roof Insulation

(b) Heat-Pumps

(c) High-Efficiency Boilers

Source: French Ministry of Ecological Transition (Direction Générale de l'Energie et du Climat 2022). The full line represents the average market value of certificates associated with either roof insulation (Figure 2a), heat pumps (Figure 2b) or boilers (Figure 2c) that fulfil the energy efficiency eligibility conditions of the scheme (e.g. this is only high efficiency boilers in the case of boilers). Other lines break down the market value by type of residential household (Q1 for those in the first quartile of income, Q2 for those in the second quartile, and Q34 for those in either the 3rd or 4th quartile). The value of certificates is calculated by multiplying the number of certificates associated with each energy operation by the relevant price index (for either general or low-income certificates). Units on the y-axis are in current euros/sq. meter (Figure 2a) and in current euros (Figure 2b and 2c).

Three changes explain this increase in the value of individual operations. First of all, the price of general and low-income certificates increased. Especially, the scheme entered its fourth period of implementation in January 2018. The total obligation, set at 2,133 cumulative TWh for 2018-2021, was nearly twice as ambitious as the total obligation of 1,166 cumulative TWh of the previous period (2014-2017). The price indices of certificates increased steadily at the beginning of the fourth

implementation period, e.g. from EUR 5 in January 2018 to EUR 8 in December 2018 for general certificates. They stabilized after that. In parallel, the French government increased the number of certificates that it would grant for specific operations. A first reform occurred in April 2018. The number of certificates was multiplied by 4.5 for all heat pumps. The regulator also increased by 10 percent the number of certificates obtained for attic, roof and floor insulation benefitting to households belonging to the first two quartiles of income. In January 2019, there was another reform in the delivery of certificates. The number of certificates delivered for all heating-system related operations was doubled. The regulator also increased the number of certificates that would be granted for insulation operations: by 17 percent for general certificates and by 60 percent for low-income certificates (i.e. for operations benefitting households with income below the national median).

The April 2018 and January 2019 reforms explain the sudden jumps in the values displayed in Figure 1 and 2. After 2019, the value of certificates could cover some installations in full, for instance energy efficient boilers (with certificate values of EUR 1,800) or roof insulation (EUR 30 per square meter) for low-income households. Commercial offers to replace boilers and insulate homes for one symbolic euro boomed in 2019 and 2020.

3 Data

To estimate the impact of the EEO scheme on employment, we obtained monthly data on all hires and terminations of employment contracts per establishment in Metropolitan France from the Worker Movement Database (WMD) of the French Ministry of Labour (DARES 2023). The data is available from 2015 to 2021 and includes a total of 732 codes corresponding to different sectors. Later on, we focus on the two sectors most affected by the policy, which are those corresponding to "insulation works" and the "installation of heating equipment"[9]. The WMD collates all records from an official document that companies must fill every month and which is entitled the Nominative Social Declaration (NSD)[10]. The NSD contains information about employee activity periods including, among other things, the start and end dates of each employment contract, the type of contract (e.g. permanent or fixed-term), sick leaves, maternity and paternity leaves. Therefore, the

[9] In the dataset, these are codes 4329A and 4322B respectively.
[10] *Déclaration Sociale Nominative* in French

NSD provides information that can be aggregated to determine the number of people entering or leaving a certain business or sector each month.

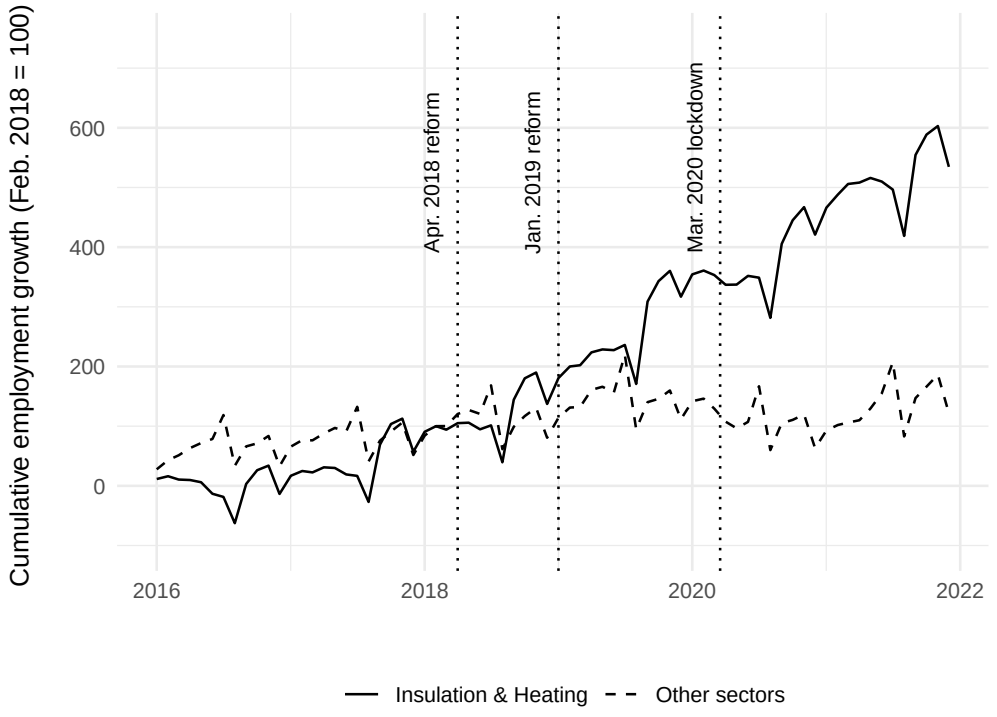
Nonetheless, the total numbers of hires and terminations at sector level should not be directly compared over time due to missing data. The NSD came out of an effort from the French government to harmonize and simplify business declarations. It started as a voluntary scheme in 2013, became compulsory for large companies in 2015 and finally for all businesses that hire employees in 2017. Despite being compulsory since 2017, several small companies did not fill any NSD before 2019, when automation ensured that all companies were finally registered and filling their NSD every month. At the beginning of 2016, only 33% of businesses filed an NSD. They were 60% in 2017 and 80% in 2018. Compliance rates strongly depended on business size. More than 90% of companies with more than 50 employees where already filing their NSD by mid-2016, against only half of businesses with less than 10 employees. The Ministry of Labour (DARES 2018) has developed a method of weights to extrapolate entries and exits for all sectors over time from missing declarations. In a nutshell, the method consists in associating a weight to each observation (a business in month m and year t), each weight being inversely proportional to the probability that an observation would have filled the NSD. This is very close to what would be done in a survey, where weights are given to each respondent according to their inverse probability of response. Inverse probabilities were estimated for different classes of respondents according to the number of employees in the business, the number of subsidiary businesses the mother company has, the region of the business, and its activity sector (tertiary, industry or construction), the age and the revenue of the business. All in all, the weighted data can be swiftly used to recalculate total employment levels and movements across classes, especially at sector level. Using these weights, we compute the total number of entries and exits in each month and in each sector, by regions in Metropolitan France between 2016 and 2020[11]. At the start of this period, the retrofitting industry gathered around 100,000 workers, or about 1% of total employment in France. To account for variations in the sector's employment, we define a new variable called *cumulative employment growth*[12]. It is displayed for the "insulation" and "installation of heating equipment" sectors, versus all other sectors in France, in Figure 3.

[11]The dataset starts in the second semester of 2015. However, the data collection quality at the beginning was lower due to the progressive rollout of NSDs. For that reason, we do not use 2015 data in our baseline analyses.

[12]To obtain this measure, we use the movement (entry and exits) data for each month and sector. New hires increase employment in each sector, while terminations decrease it. We therefore weight each movement (either an entry or exit) by the time span between the movement date and the end of the month. We then aggregate this weighted measure of employment growth at the sector level for each month, and compute its cumulative sum.

This cumulative employment growth can be seen as the stock of net job creations as of the start of our observation period (January 2016). The two first vertical lines in Figure 3 correspond to the introduction of the major changes in the attribution of certificates in April 2018 and January 2019. The third one indicates the beginning of the COVID-19 lockdown in France. To evaluate the effect of these policy change on employment in the insulation and heating sectors, we want to compare the evolution of total national employment in these two sectors and in other sectors that are unaffected by the reforms of the EEO program. Figure 3 shows that the total number of employees across other sectors grows slowly, while employment in the two energy renovation sectors experienced a much faster growth. Cumulative employment growth went from $+316,002$ in February 2018 to $+439,087$ in February 2020, as compared to January 2016: this is a $+38.95\%$ increase. On the contrary, cumulative employment growth for the retrofitting industry went from $+3,586$ to $+12,936$, i.e., a $+260.74\%$ increase.

Figure 3: Cumulative employment growth for insulation and heating, versus all other sectors (Feb. 2018 = 100)



Note: The energy renovation sectors are those corresponding to "insulation" and the "installation of heating equipment". They correspond to codes 4329A and 4322B respectively in the data from DARES 2023. National aggregates are computed monthly and rely on the weights developed by DARES 2018to account for missing NSD files.

Moreover, the WMD distinguishes between permanent and fixed-term contracts. We provide descriptive statistics on the two types of hires in Section A in the appendix. Both before and after April 2018, the share of permanent contracts in total employment growth is higher than 80% in the retrofitting industry. This can be explained by the fast expansion of the market for energy efficient services, with substantial needs in terms of workforce. Thus, the growth of the renovation sector started way before the reform of the EEO scheme and we cannot directly compare this industry to the rest of the economy. To select carefully control sectors, we therefore use a synthetic control method.

4 Methodology

4.1 Empirical strategy

To choose the control sectors, we use a synthetic control method (Abadie and Gardeazabal 2003; Abadie, Diamond, and Hainmueller 2010). This method has been widely used in the past few years in labour economics (Bohn, Lofstrom, and Raphael 2014; Allegretto et al. 2017; Reich, Allegretto, and Godoey 2017; Peri and Yasenov 2019; Wiltshire 2021; Jardim et al. 2022). Synthetic control methods are appropriate for policies implemented at aggregate level and affecting a small number of units (Abadie 2021). The reform of the French EEOs, which affected the 13 metropolitan regions at the same time, clearly fits with this description. Moreover, the expected magnitude of the policy has to be high-enough to be detectable We believe this is likely to be the case because investment through the EEO scheme increased from EUR 600 million in 2017 to more than EUR 2.75 billion in 2019 after the policy change, as shown in Figure 1.

In our setting, we observe employment in the "insulation" and the "installation of heating equipment" sectors, as well as in the 730 other sectors. A subset of these other sectors can be used to approximate counterfactual employment without any policy change. Falkenhall, Månsson, and Tano 2020 followed a similar approach, using control sectors to analyse the impact of a VAT reform Sweden. The rationale behind our synthetic control approach is to match employment in the treated unit (here, the retrofitting industry) to a weighted average of employment in the donor pool that most closely resembles the characteristics of the retrofitting sector before the first reform. The policy evaluation then relies on the estimated wedge in employment between the treated unit and its synthetic control. More precisely, we include as potential donors all sectors except those related

to manufacturing industries, building, real estate services, as well as communication, financial and specialized services[13]. Removing other construction-related sectors from the pool of control sectors is of primary importance as we believe they may have been impacted by the increase in funding, even if these sectors were not the main recipients of the policy[14]. For instance, households could insulate their home and decide to perform other improvements at the same time, such that other professionals could indirectly benefit from the policy. In the U.S., Cohen, Glachant, and Söderberg 2017 show that households tend to perform several house improvements at the same time. This has also been noted by Peñasco and Anadón 2023 in the UK, where loft or cavity walls insulation is often performed at the same time as building extensions.

According to Abadie and L'Hour 2021, synthetic controls have several appealing properties as compared with other econometric tools commonly used for policy evaluation. As opposed to regression-based estimators, synthetic control weights are explicitly reported after the estimation procedure, and as for matching, they are sparse, non-negative and sum to one, thus avoiding extrapolation outside the support of the data (Abadie, Diamond, and Hainmueller 2015). Synthetic controls are, however, more flexible than matching estimators as they allow weights to be different for each donor, and do not require an arbitrarily fixed number of matches. Moreover, the comparative advantages of the synthetic control method have been reinforced by the development of applications using disaggregated data. In such a case, the policy shock may well affect a single unit from a macro-economic point of view, as for the French retrofitting industry in April 2018. However, it is also possible, and even desirable, to exploit variations in employment at an infra-national (say, regional) level to ensure that worst-case interpolation biases are minimized. In short, the framework developed by Abadie and L'Hour 2021, which we exploit in this analysis, is designed to estimate the effect of an aggregate policy shock based on the aggregation of multiple synthetic controls, one for each treated unit. To exploit regional variations in employment, we define one "insulation" and "installation of heating equipment" sector within each of the 13 French regions[15]. The key challenge in this disaggregated setting lies in the management of a larger pool of donors, as compared with the aggregated case. Indeed, a larger pool increases the probability that a single untreated sector

[13]Our donor pool thus includes sectors related to agriculture, forestry and fishing, extractive industries, water and waste management, retail, transportation, hosting and catering, administration, health, and other services.

[14]There are 36 construction-related sectors. In the WMD, those have sector codes starting by 41, 42 or 43.

[15]This regional divide has been in place since 2016, when some of the 22 former metropolitan regions (corresponding to the NUTS 2 level) were merged to improve their cost-effectiveness.

provides a close match for a given treated sector. Thus, when computing each synthetic control, a tradeoff arises between (i) minimizing the discrepancy between the regional sector and its synthetic control as a whole (what Abadie and L'Hour call the "synthetic control case") and (ii) minimizing the discrepancy between the regional sector and each control sector that contributes to its synthetic control (the "matching case"). The penalized synthetic control (PSC hereafter) framework proposed by Abadie and L'Hour 2021 precisely deals with this trade-off.

4.2 Definition of the Penalized Synthetic Controls

To establish our own PSC estimator, we define $n = n_1 + n_0$ the number of regional sectors observed, with $n_1 = 13$ treated sectors and $n_0 = 3511$. For each sector i, we define Y_i as the realized outcome, namely cumulative employment growth since January 2016, measured as of February 2020. Thus, in Rubin 1974's potential outcomes framework, Y_{1i} and Y_{0i} respectively refer to the potential outcomes under treatment ($D_i = 1$) and under no treatment ($D_i = 0$). We also define X_i as the $1 \times T_0$ vector of pre-treatment predictors of Y_{0i}, where $T_0 = 26$ is the duration, in month, of our pre-treatment period from January 2016 to February 2018. Notice that the policy shock occurs at time $T = 28$, namely April 2018, but we carefully exclude March 2018 to alleviate anticipatory effects. We rely solely on cumulative employment growth at $t \leq T_0$ to predict Y_{0i}. Finally, data is pooled into a single dataset $\{(Y_i, D_i, X_i)\}_{(i=1)}^{n}$, where the n_1 treated observations come first. The treatment effect on the treated $\tau_i = Y_{1i} - Y_{0i}$ (for $i = 1, \ldots, n_1$) is estimated using a synthetic counterfactual Y_{0i}.

Each treated regional sector is matched to a weighted average of untreated sectors, where the n_0-vector of weights $W_i^*(\lambda) = (W_{i,n_1+1}^*, \ldots, W_{i,n}^*)$ is solving:

$$\begin{aligned} \min_{W_i \in \mathbb{R}^{n_0}} \quad & ||X_i - \sum_{j=n_1+1}^{n} W_{i,j} X_j||^2 + \lambda \sum_{j=n_1+1}^{n} W_{i,j} ||X_i - X_j||^2 \\ \text{s.t.} \quad & W_{i,n_1+1} \geq 0, ..., W_{i,n} \geq 0, \\ & \sum_{j=n_1+1}^{n} W_{i,j} = 1. \end{aligned} \tag{1}$$

$W_{i,j}^*$ is the j^{th} element of $W_i^*(\lambda)$ weighting control sector j in the synthetic control sector of treated sector i. The tuning parameter λ accounts for the component-wise versus aggregate fit trade-off. Thus, the optimal set of weights $W_i^*(\lambda)$ is a function of λ: when weighting potential donors, it favors untreated sectors j that are closer to the treated one i, hence minimizing interpolation biases.

The definition of the optimal λ^* relies on a data-driven process which we detail in Appendix B. The penalized synthetic control estimates for each treated sector are given by:

$$\hat{\tau}_i(\lambda) = Y_i - \sum_{j=n_1+1}^{n} W^*_{i,j}(\lambda) Y_j \tag{2}$$

Here, we depart from Abadie and L'Hour 2021 as we do not look for an average, but rather an aggregate effect on the treated:

$$\hat{\tau}(\lambda) = \sum_{i=1}^{n_1} \left(Y_i - \sum_{j=n_1+1}^{n} W^*_{i,j}(\lambda) Y_j \right) \tag{3}$$

We are nevertheless also interested in the individual treatment effects $\hat{\tau}_i(\lambda)$ as they give us a precise estimate of the regional distribution of the policy's effects on employment.

4.3 Inference

Our inferential framework is adapted from Abadie, Diamond, and Hainmueller 2010. It relies on the comparison between a test statistic computed over the actual treatment effect estimates, and the same statistic computed over placebo treatment effect estimates. Placebo estimates are induced by a random reassignment of the treatment variable to control sectors $i \in (n_1 + 1, n)$; the resulting test statistics can then be used to define a permutation distribution of the actual treatment effect estimates test statistic. Intuitively, the purpose of these randomly assigned placebo treatments is to define a benchmark for the value of the test statistic obtained over the original data. We follow the procedure for the *inference on aggregate effects* proposed for penalized synthetic control estimation by Abadie and L'Hour 2021.

We start by estimating the treatment effect $\hat{\tau}_i(\boldsymbol{D^{obs}})$ for treated sectors $i = 1, \ldots, n_1$, with penalization parameter λ^* under the original treatment assignment $\boldsymbol{D^{obs}} = (D_1, \ldots, D_n)$. The test statistic $\hat{T}(\boldsymbol{D^{obs}})$ is defined as the average treatment effect across the $n_1 = 13$ regional sectors:

$$\hat{T}(\boldsymbol{D^{obs}}) = \frac{1}{n_1} \sum_{i=1}^{n_1} \hat{\tau}_i(\boldsymbol{D^{obs}}). \tag{4}$$

We then set $B = 100$, the number of random reassignments. At each iteration, we set the treatment dummy D_i to 1 for a new subset of $n_1 = 13$ regional sectors randomly selected among the whole pool of regional sectors ($n_1 + n_0 = 3,524$). We then compute the penalized synthetic controls for this

treatment assignment and obtain the resulting individual placebo treatment effect estimates, which we denote $\hat{\tau}_i(\boldsymbol{D^{(b)}})$. Thus, for each permutation $b = 1, \ldots, B$, one can compute the corresponding test statistic $\hat{T}(\boldsymbol{D^{(b)}})$:

$$\hat{T}(\boldsymbol{D^{(b)}}) = \frac{1}{n_1} \sum_{i=1}^{n_1} \hat{\tau}_i(\boldsymbol{D^{(b)}}) \tag{5}$$

Finally, one can compute p-values as the frequencies across iterations of the value of $\hat{T}(\boldsymbol{D^{(b)}})$ more extreme than $\hat{T}(\boldsymbol{D^{obs}})$. This one-sided test writes as follows:

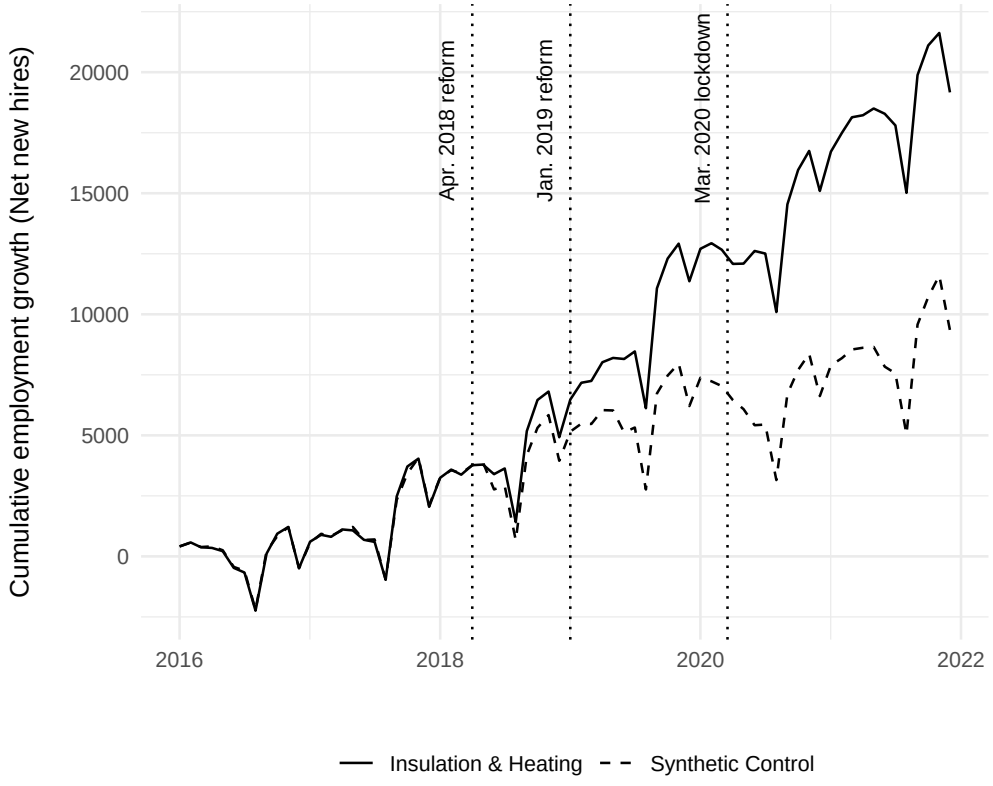
$$\hat{p} = \frac{1}{B+1} \left(1 + \sum_{b=1}^{B} \mathbf{1}\{\hat{T}(\boldsymbol{D^{(b)}}) \geq \hat{T}(\boldsymbol{D^{obs}})\} \right) \tag{6}$$

5 Results

5.1 Total employment growth

Our main results are provided in Figure 4, which compares the evolution of cumulative employment growth in the energy retrofit sectors versus its synthetic control group.

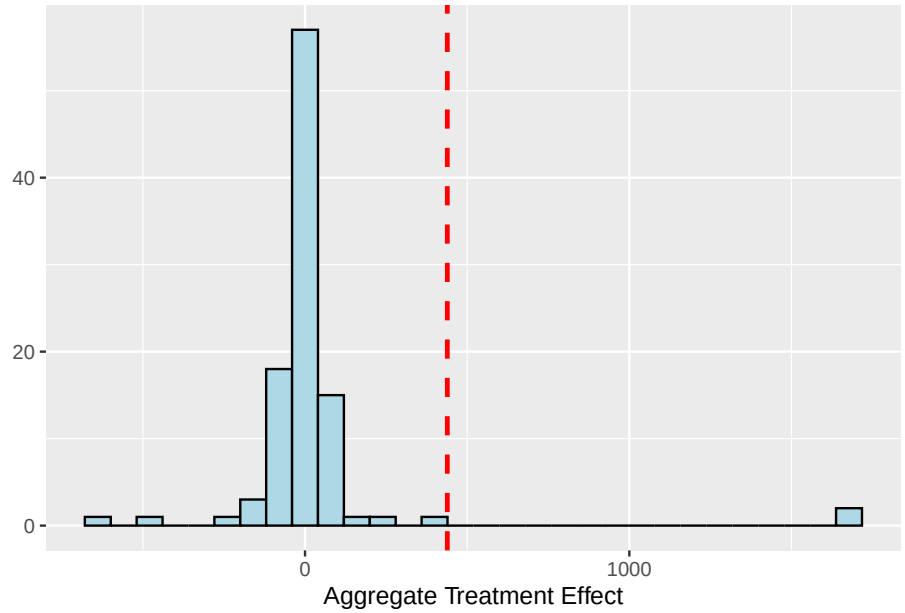
Figure 4: Employment growth in energy renovation vs its penalized synthetic control



Before the introduction of the first change in policy in April 2018, the evolution of workforce in the energy retrofit sectors is very similar to the evolution in the synthetic control group. This implies that the model is reliable to assess the impact of the policy reforms on employment. Between April 2018 and December 2018, there is barely any effect, suggesting that the first policy change had a way lower impact on employment as compared with the second one. These findings are consistent with Figures 1 and 2 since more than half of the increase in the value of certified works occurred from 2019 onwards. Moreover, we infer variations in employment by looking at the number of days a worker is under contract with a firm of the retrofitting industry. Hence, it is possible that for small increases in the demand for energy efficiency services, part of the activity surplus is borne by workers already employed in the industry. Conversely, we find that the second policy change, which led to the most drastic change in policy design, also led to a strong increase in the growth of employment, equivalent to +5,703 additional jobs as compared to what would have happened without the policy shock, by February 2020 (before the first lockdown in France due to the COVID-19 pandemic). Over the same period, cumulative employment growth increased by 9,350 in the sector, according to Table A1. Thus, our estimates attribute to the policy around 60% of the rise in employment between February 2018 and February 2020.

To ensure that the results of Figure 4 can be attributed to the policy, we follow the inference framework depicted in Section 4.3. Figure 5 displays the results of permutation tests for an estimator with the optimal penalization parameter $\lambda^* = 0.01$. The observed treatment assignment ranks second against the 100 alternative random permutations, with a test statistic equal to 438.75. This value corresponds to the average effect of the policy shock on regional-level employment in the retrofitting sector. The corresponding p-value for the one-sided test is 0.0297, which allows us to confidently interpret the additional $5,700$ jobs as the effect of the change in the policy.

Figure 5: Permutation test for the effect of the policy



Note: Results are obtained for 100 permutations, using the optimal value $\lambda^* = 0.01$. The figure displays the histogram of the aggregate treatment effect. The red doted line is the value of the statistics for the observed assignment. p-value for the one-sided test is 0.0297.

Moreover, we perform two robustness checks to substantiate the attribution of the surge in employment to the policy change. First, we simulate a treatment in January 2018, when the EEOs entered its fourth period. At this point, the overall obligation nearly doubled from $1,166$ cumulative TWh for the third period (2014-2017) to $2,133$ cumulative TWh over 2018-2021. Hence, one could think that our synthetic control approach wrongly attributes the effect of the revised obligation to the *Coup de Pouce* bonusing mechanism, which was designed to direct investment towards specific works. However, this falsification test illustrated in Figure A1, Appendix C.1, shows no divergence with our baseline analysis. The wedge in cumulative employment growth occurs after April 2018, as in Figure 4, and the overall effect is also very similar with $5,391.17$ additional workers (p-value of 0.0297). The second anticipation test defines a treatment date way earlier, in June 2017, when the certificate price increased to 3 EUR. Figure A2, Appendix C.2 illustrates this anticipation test. A wedge in cumulative employment growth appears way before April 2018, but it is of very limited magnitude ($< +2,000$ jobs). Moreover, the effect of the February 2018 policy change is clearly identified with an effect on job creation comparable to our baseline estimates.

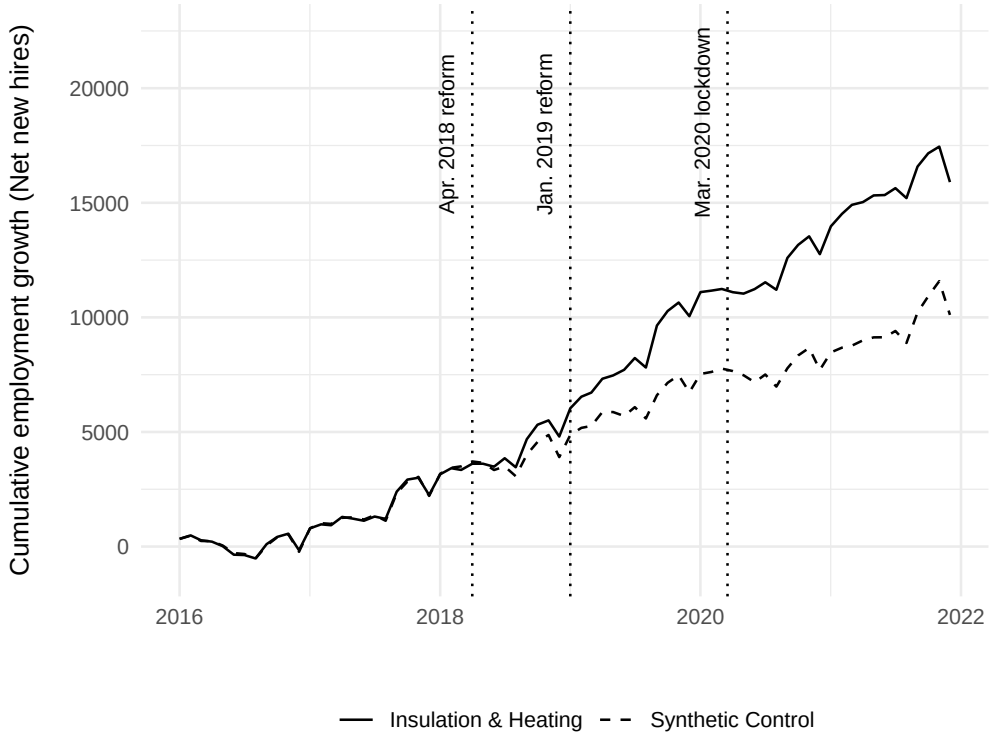
As we further seek to understand the firm's hiring behavior, we refine the analysis of this aggregate effect by looking separately at different contract types. More specifically, we apply the exact same procedure to build two separate synthetic controls for permanent and fixed-term contracts, respectively.

5.2 Permanent versus fixed-term employment growth

The motivation for this decomposition is based on a key unknown in retrofitting firms' hiring behavior when they face the sudden policy-induced positive demand shock. As shown in Table A1, permanent contracts already accounted for the vast majority of hiring before the April 2018. This wasn't the case for the rest of the economy, but a trend reversal occurred over 2019 and 2020, when the share of permanent contracts rose to 60% of new hires in non-renovation sectors (Aldama, Cochard, and Ouvrard 2020). We thus rely on the synthetic control method to define a counterfactual for the permanent versus fixed-term divide in the employment growth of the retrofitting sector after April 2018.

The first estimation compares permanent contracts within versus outside the retrofitting sector at the regional level. Applying the methodology described in Section 4.2, we get an optimal penalization parameter equal to $\lambda^* = 0$, such that pairwise discrepancies do not seem to be a main concern in this analysis. The resulting estimated effect aggregated at a national level, illustrated in Figure 6, induces a surplus in cumulative permanent employment growth by $+3,548.86$, equivalent to around 60% of the excess growth in total employment imputed to the policy change (p-value of 0.0297). The remaining of the employment growth is attributed to fixed-term contracts by another, dedicated estimation comparing fixed-term contracts within versus outside the retrofitting industry. According to this estimation, the policy shock led to $1,274$ additional fixed-term contracts as compared to what would have occurred otherwise: this comparison is depicted in Figure A3. The penalization parameter of this second robustness check is optimized at $\lambda^* = 0.35$, hence this estimation relies more heavily on direct matches to avoid extrapolation biases. Notice, however, that the pre-treatment fit is really good given the constraints imposed by the cyclicality of fixed-term employment across months. We clearly identify two distinct waves of contract terminations, one in July-August and the other in December. Still, the inference reveals only a weakly significant effect as the test statistics ranks 9^{th} out of 101, yielding a p-value of 0.0891.

Figure 6: Permanent employment growth in energy renovation vs its penalized synthetic control

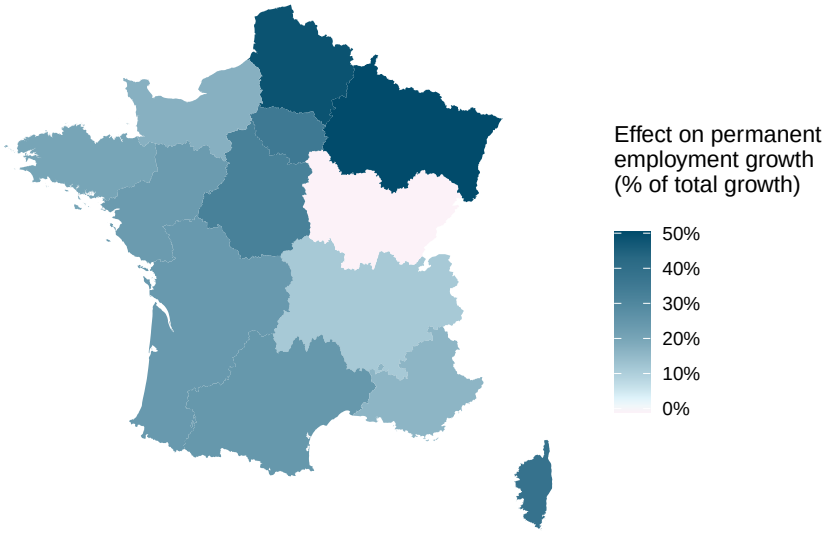


5.3 Regional heterogeneity in employment growth dynamics

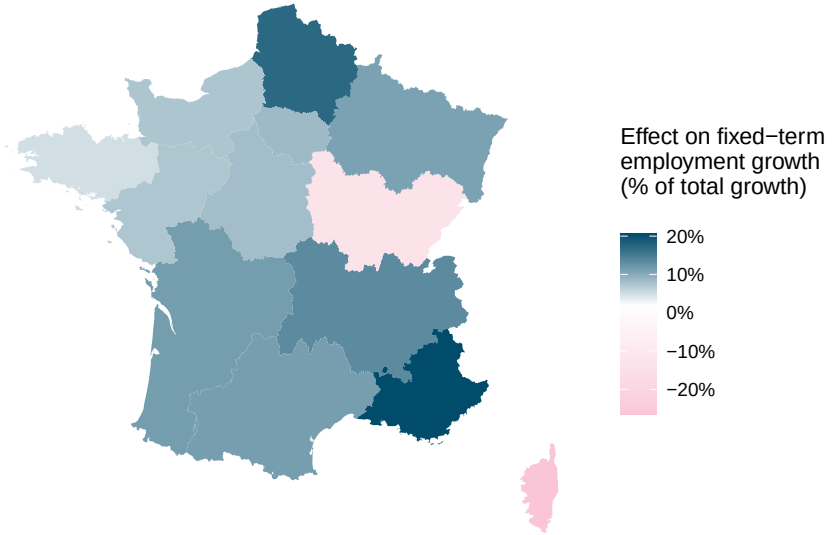
One key advantage of the penalized synthetic controls method is the ability to define treatment effects that are different for each treated group. In our case, these groups consist in retrofitting sectors at the regional level. These disaggregated results are as significant as the nationwide ones, because they rely on the very same methodology described in Section 4. Hence, one can plot the estimates and compare the magnitude of the policy effect across regions, to refine our understanding of the employment growth dynamics. We first look at the absolute value of employment growth (p-value 0.0297), i.e., the number of new contracts in each regional sector. As shown in Figure A4a, Île de France ranks first in terms of job creations over the period under study, with around $+2,068$ net hires. This makes more than one third of all new jobs. Other winners are the Grand Est (+688) in the North-East, Occitanie (+565) in the South-West and Auvergne-Rhône-Alpes (+538) in the Center-East. These regions are also among the most populous parts of France; hence they easily win in terms of job creations. To account for such cross-region differences, we compare our estimates to the total employment growth of the sector observed in each region (Figure A4b).

In Grand Est, where winter temperatures are colder and households rely more heavily on polluting residential heating sources[16], the policy-induced surplus represented 86% of all job creations; in Hauts-de-France, this share equated 75%. Moreover, the regional industries' growth does not rely on the same type of contracts.

Figure 7: Effect of the policy on permanent employment



(a) Effect on fixed-term employment in number of workers



(b) Effect on total employment as a share of total growth

[16]In the Grand Est region, fuel oil is still the main heating source for around 10% of households (INSEE 2020)

Figure 7a and 7b show the effect of the policy on permanent and fixed-term contract as a share of total regional employment growth in the retrofitting industry. The effect on permanent employment growth (p-value 0.0297) resembles a lot that for total employment. Indeed, the policy mostly resulted in permanent job creations, as shown in Section 5. Near the Belgian and German borders, in Hauts-de-France and Grand Est, around 50% of all new hires are permanent contract induced by the policy. This share is way lower along the Italian border, with only 16% of all new hires for Provence-Alpes-Côte d'Azur (in the South-Eastern corner), and 11% in Auvergne-Rhône-Alpes. On the contrary, we identify a higher policy-induced growth in fixed-term contracts for Provence-Alpes-Côte d'Azur (21%), as compared to what would have happened without any change in the EEOs rules; the same applies to Auvergne-Rhône-Alpes (13%). Thus, in these two regions, employment growth relies more heavily on fixed-term contracts, which is clearly at odds with the rest of France.

6 Discussion

All in all, we can conclude from our analysis that under the Coup de Pouce stimulus, the French EEO program led to an increase in employment in the most affected sectors. According to official records made available by the French Ministry of Ecological Transition, the monthly average market value of certified energy efficiency works was 36.593 million EUR between January 2016 and March 2018. After the first reform, investment steadily increased, reaching an average monthly market value of 175.420 million EUR. This induces a rise by 139 million EUR each month. At the same time, the surplus in employment growth in the retrofitting industry equated to +248 workers a month, as compared with what would have happened without the surge in investment. Therefore, the policy sustained 1.8 direct jobs for each additional million euro invested[17].

We can compare this estimate with other studies exploring the relation between green investments and jobs. Our results are way below ex ante estimations. BPIE 2020 provides a literature review of 35 of such studies assessing the link between refurbishment and jobs. The review argues that energy renovation might provide a range of 13 to 28 direct and indirect jobs per EUR million invested, of which one third (this is 4.29–9.24) would be direct jobs. In the US, Garrett-Peltier 2017

[17] 248/139 = 1.78 additional worker for each million EUR invested in a month.

use an input-output model and find that 4.55 direct jobs were created by USD million invested in energy retrofits. Other similar studies find higher results: 10 direct jobs per million euros invested in Pikas et al. 2015, and 11 direct jobs in Mikulić, Bakarić, and Slijepčević 2016. Considering both direct and indirect jobs, the European Commission has used 8.52 Full-Time-Equivalent (FTE) per EUR million invested as the reference job multiplier for energy renovation (European Commission 2019a). Overall, our results imply that we should not expect post-pandemic stimulus packages to have such an impact on job creation in the energy retrofit sector.

Our estimate of a weak effect on employment as compared to ex ante projections rather fits with other ex-post studies, such as Popp et al. 2022, who find 2 to 4 jobs in the construction sector, or Fabra et al. 2023 who find 0.8-1.1 jobs in the solar industry. This suggests that energy retrofits could have a similar potential for job creation as compared with other types of green investments. Note, however, that the evaluation by Popp et al. 2022 is more likely to capture both indirect and direct jobs, because it is done at a wider scale of analysis and provides estimates at a larger level of aggregation, e.g. for the construction sector as a whole. In this paper, we have only analyzed direct job creation, while the policy could have employment effects outside of the sectors considered. Especially, we do not assess the potential impacts on the rest of the energy retrofit value chain (on manufacturers, salespeople, etc.). On the other hand, Fabra et al. 2023 only consider direct local job creation at a sub-regional scale, hence their scope is even narrower than ours. However, if we consider that most energy retrofits are performed by SMEs locally, then our estimates and those of Fabra et al. 2023 can be closely compared. Our results are also aligned with recent insights published in a note by the French Economic Analysis Council (CAE 2023) looking at the effect of the energy transition on employment. Authors indeed carefully discarded the common thought that the transition would massively create so-called green jobs. They acknowledge the existence of a clear development potential for retrofitting activities, but with only a limited effect on total employment. These jobs require a wider array of technical skills as compared with *non-green* jobs, a human capital investment not reflected by any wage premium to the date. Hence, more than a question of quantity, it is rather on qualitative grounds that we should evaluate the sector's response to the policy-induced demand increase.

Indeed, our estimates of firms' reaction to the positive demand shock connects to an important strand in the labor economics literature. The effect of uncertainty on employment decisions is key to define appropriate policies, especially as governments seek long-term effects structuring the

retrofitting industry. The positive effect on aggregate employment (+5,700 additional jobs) can be interpreted as an effect of the massive rise in demand, which has considerably reduced uncertainty for local SMEs over dozens of months. This is fully in line with the theoretical insights provided by Schaal 2017, who shows the central role played by time-varying risk to account for the magnitude of fluctuations in aggregate unemployment in the case of the U.S. However, the distribution between permanent and fixed term hiring remains uncertain without a separate analysis of the two phenomena. The Fixed-Term (FTC) vs Indeterminate Term Contract (ITC) divide in France has been analyzed by Goux, Maurin, and Pauchet 2001, who highlight important cost advantages for firms to adjust their number of FTC rather than their number of ITC. This has implications for the interpretation of our estimated 60% share of permanent contracts. At the very least, the use of ITC in an unstable institutional framework[18] implies that firms did not perceive the policy-induced demand shock as a purely temporary one, because they committed themselves into a long-term relationship by hiring part of their new workers on a permanent basis. We also performed a spatial heterogeneity analysis by digging into the regional differences in employment growth. The main take-away from our findings is that the geographical distribution of job creation may not be homogeneous. Richer and more populous regions see a higher growth in the number of jobs. However, the quality of job creation, which we proxy using the permanent versus fixed-term divide, can vary a lot in reaction to the same policy shock. More research is therefore needed to understand the determinant of a growth based on either permanent or fixed-term contracts.

Finally, the French EEO program has some features that make it particularly interesting to study. However, impacts may not be fully transferrable to other investment policies because of the specificities of this market-based instrument. Especially, the cost of the policy is put on energy providers, who are required to provide subsidies to households and businesses. There are little government expenditures, and the policy is much more socially acceptable than a carbon tax. However, the financial burden of the EEOs is likely to have been considerably passed on to consumers with increases in energy prices. Darmais, Glachant, and Kahn 2022 estimated that a 4-percent increase in residential energy prices would be necessary to cover the cost of the EEO program.

[18]The Journal Officiel of the French Republic (Ministère de l'Écologie, du Développement Durable et de L'Énergie 2023) reports 50 successive amendments of the decree defining standardized operations formulas between 2015 and 2022. This number only accounts for changes in the engineering projection of savings and does not affect bonus schemes such as the *Coup de Pouce*, which were passed onto the law through another decree specific to the scheme's implementation rules.

The evidence on the responsiveness of consumers to energy prices for energy-using products and home improvements is mixed. Long-term energy costs may be underestimated by consumers, even though energy price increases could still trigger improvements in energy efficiency (Cohen, Glachant, and Söderberg 2017; Schwarz et al. 2021; Houde and Myers 2021; Kiso, Chan, and Arino 2022). Therefore, the effect of the French EEOs on investments may not exclusively come from the subsidies, but also from the concomitant increase in energy costs for households, who may decide to invest in energy efficiency because of the increase in energy prices. Importantly, energy price increases due to the EEOs could only concern households and (low-consuming) businesses in the tertiary sector. This is because industrial energy consumption is exempted from the policy: obligations do not depend on the amount of energy sold in the industrial sector, and some providers, who exclusively sell energy to the industrial sector, were not covered by the EEO program. This was done to ensure that the EEOs would not lead to a contraction of economic activity in other sectors. We can therefore presume that there was no job loss in industrial sectors because of the introduction of the policy.

7 Conclusion

We exploit a sharp discontinuity in the French EEOs to estimate the impact on employment of one of the largest energy retrofit policies in Europe. Our penalized synthetic control method detects a significant, but limited increase in employment in the energy renovation following two reforms in April 2018 and January 2019, with about 1.8 jobs sustained per million euro invested in the EEOs.

To the best of our knowledge, this study constitutes the first ex-post analysis of the employment co-benefit of energy retrofits. It mitigates expectations in terms of job creation potential, which originated in ex-ante studies and serve as a theoretical ground for widely used multiplier effects of the impact of energy retrofits on employment. When compared to the other two analysis of the impact of green investments on jobs (Popp et al. 2022; and Fabra et al. 2023), our results suggest that energy retrofits might have a similar employment potential than other investment types, even though scope and methods are not fully comparable. Thus, our analysis confirms the existence of social co-benefits of energy retrofit policies, with comparable magnitude as other green investments in the energy transition.

There are a few limitations to what we do in this paper. First, we would like to further investigate the effect of the policy on the stability of employment in the retrofitting industry, by estimating its effect on the turnover rate within firms. Indeed, the flexibility lost by hiring a significant share of new workers on a permanent basis could have been compensated by posting shorter FTCs. However, our cumulative employment growth measure only accounts for the total evolution of each contract type but it remains agnostic on the average contract duration. For the exact same reason, we also plan to investigate the effect of the policy on the number of interim workers within the industry. Second, firms' initial size may have played a role in their ability to respond to the increased demand. Because EEOs-related paperwork is heavy, it is possible that only bigger firms with the appropriate administrative staff benefited from the policy, which has important implications for the structure of the industry. As highlighted by Crampes and Léautier 2023, bigger contractors would be more solvent, hence they could be subject to quality ex-post checks with sufficient fines in case of non-compliance. Finally, the analysis of employment effects for other sectors, such as energy providers, is a promising field of research which would require an improved understanding of the policy's effect on local energy prices and demand.

References

Abadie, Alberto (2021). "Using synthetic controls: Feasibility, data requirements, and methodological aspects". In: *Journal of Economic Literature* 59.2, pp. 391–425.

Abadie, Alberto, Diamond, Alexis, and Hainmueller, Jens (2010). "Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program". In: *Journal of the American statistical Association* 105.490, pp. 493–505.

— (2015). "Comparative politics and the synthetic control method". In: *American Journal of Political Science* 59.2, pp. 495–510.

Abadie, Alberto and Gardeazabal, Javier (2003). "The economic costs of conflict: A case study of the Basque Country". In: *American economic review* 93.1, pp. 113–132.

Abadie, Alberto and L'Hour, Jérémy (2021). "A penalized synthetic control estimator for disaggregated data". In: *Journal of the American Statistical Association* 116.536, pp. 1817–1834.

Aldama, Pierre, Cochard, Marion, and Ouvrard, Jean-François (2020). "Les politiques économiques ont contribué aux fortes créations d'emplois en France de 2016 à 2019". In: *Le Bulletin de la Banque de France* 231.

Allegretto, Sylvia et al. (2017). "Credible research designs for minimum wage studies: A response to Neumark, Salas, and Wascher". In: *ILR Review* 70.3, pp. 559–592.

Aydin, Erdal, Kok, Nils, and Brounen, Dirk (2017). "Energy efficiency and household behavior: the rebound effect in the residential sector". In: *The RAND Journal of Economics* 48.3, pp. 749–782.

Bohn, Sarah, Lofstrom, Magnus, and Raphael, Steven (2014). "Did the 2007 Legal Arizona Workers Act Reduce the State's Unauthorized Immigrant Population?" In: *The Review of Economics and Statistics* 96.2, pp. 258–269.

BPIE, Buildings Performance Institute Europe (2020). *Building Renovation: A Kick-Starter for the EU Economy—Renovate Europe*.

Broc, Jean-Sébastien, Stańczyk, Wojciech, and Reidlinger, Bettin (May 2020). *Snapshot of Energy Efficiency Obligation Schemes in Europe*. Report Provisional version. ENSMOV.

CAE, Conseil d'Analyse Economique (Nov. 2023). "Transition énergétique: faut-il craindre pour l'emploi ?" In: *Les notes du conseil d'analyse économique* 80.

Cohen, François, Glachant, Matthieu, and Söderberg, Magnus (2017). "The cost of adapting to climate change: evidence from the US residential sector". In: *Centre for Climate Change Economics and Policy Working Paper* 297.

Crampes, Claude and Léautier, Thomas-Olivier (2023). "Les certificats d'économie d'énergie entre économie et politique". In: *Revue économique* 74.1, pp. 51–80.

DARES, Direction de l'Animation de la Recherche, des Etudes et des Statistiques au sein du Ministère du Travail (2018). *Reconstitution des mouvements de main-d'œuvre (MMO) depuis 1993 : guide méthodologique*. Tech. rep.

— (2023). *Les mouvements de main-d'œuvre (MMO)*. URL: `https://dares.travail-emploi.gouv.fr/donnees/les-mouvements-de-main-doeuvre`.

Darmais, Amélie, Glachant, Matthieu, and Kahn, Victor (2022). "Distributive Impacts of Energy Efficiency Obligations Schemes: an ex-post analysis in France". In: *Working Paper*.

Davis, Lucas W, Fuchs, Alan, and Gertler, Paul (2014). "Cash for coolers: evaluating a large-scale appliance replacement program in Mexico". In: *American Economic Journal: Economic Policy* 6.4, pp. 207–238.

Dell'Anna, Federico (2021). "Green jobs and energy efficiency as strategies for economic growth and the reduction of environmental impacts". In: *Energy Policy* 149, p. 112031.

Direction Générale de l'Energie et du Climat, GDEC (2022). *Outil de calcul des Certificats d'Économies d'Énergie (CEE)*. URL: `https://calculateur-cee.ademe.fr/user/fiches/BAR`.

European Commission (2019a). *Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU – Final report*. Publications Office. DOI: `doi/10.2833/14675`.

— (2019b). *Internationalisation of SMEs from the European construction sector in third markets – Drivers, challenges and policy examples – Final report, Figure 6, p 20.*

— (2020a). *A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives.* Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.

— (2020b). *Europe's moment: Repair and Prepare for the Next Generation.* Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.

European Commission (2021). *The EU's 2021-2027 long-term budget and NextGenerationEU : facts and figures*. Directorate-General for Budget, Publications Office of the European Union. DOI: 10.2761/808559.

Fabra, Natalia et al. (2023). "Do Renewable Energies Create Local Jobs?" In: *Available at SSRN 4579987*.

Falkenhall, Björn, Månsson, Jonas, and Tano, Sofia (2020). "Impact of VAT reform on Swedish restaurants: A synthetic control group approach". In: *The Scandinavian Journal of Economics* 122.2, pp. 824–850.

Fowlie, Meredith, Greenstone, Michael, and Wolfram, Catherine (2018). "Do energy efficiency investments deliver? Evidence from the weatherization assistance program". In: *The Quarterly Journal of Economics* 133.3, pp. 1597–1644.

Garrett-Peltier, Heidi (2017). "Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model". In: *Economic Modelling* 61, pp. 439–447.

Giraudet, Louis-Gaëtan, Houde, Sébastien, and Maher, Joseph (2018). "Moral hazard and the energy efficiency gap: Theory and evidence". In: *Journal of the Association of Environmental and Resource Economists* 5.4, pp. 755–790.

Goux, Dominique, Maurin, Eric, and Pauchet, Marianne (2001). "Fixed-term contracts and the dynamics of labour demand". In: *European Economic Review* 45.3, pp. 533–552.

Hafstead, Marc and Williams, Roberton C (2018). "Unemployment and environmental regulation in general equilibrium". In: *Journal of Public Economics* 160, pp. 50–65.

Houde, Sébastien and Myers, Erica (2021). "Are consumers attentive to local energy costs? Evidence from the appliance market". In: *Journal of Public Economics* 201, p. 104480.

Howden-Chapman, Philippa et al. (2007). "Effect of insulating existing houses on health inequality: cluster randomised study in the community". In: *Bmj* 334.7591, p. 460.

IEA, International Energy Agency (2020). *Global energy use and energy-related CO2 emissions by sector*. URL: https://www.iea.org/data-and-statistics/charts/global-energy-use-and-energy-related-co2-emissions-by-sector-2020.

INSEE, Institut National de la Statistique et des Études Économiques (2020). *French Population Census, Housing, individuals, activity, educational and professional mobility, residential migration in 2019*. URL: https://www.insee.fr/fr/statistiques/6456104.

Jardim, Ekaterina et al. (May 2022). "Minimum-Wage Increases and Low-Wage Employment: Evidence from Seattle". In: *American Economic Journal: Economic Policy* 14.2, pp. 263–314. DOI: 10.1257/pol.20180578. URL: https://www.aeaweb.org/articles?id=10.1257/pol.20180578.

Kiso, Takahiko, Chan, H Ron, and Arino, Yosuke (2022). "Contrasting effects of electricity prices on retrofit and new-build installations of solar PV: Fukushima as a natural experiment". In: *Journal of Environmental Economics and Management* 115, p. 102685.

Lang, Ghislaine and Lanz, Bruno (2022). "Climate policy without a price signal: Evidence on the implicit carbon price of energy efficiency in buildings". In: *Journal of Environmental Economics and Management* 111, p. 102560.

Liang, Jing et al. (2018). "Do energy retrofits work? Evidence from commercial and residential buildings in Phoenix". In: *Journal of Environmental Economics and Management* 92, pp. 726–743.

Marin, Giovanni and Vona, Francesco (2019). "Climate policies and skill-biased employment dynamics: Evidence from EU countries". In: *Journal of Environmental Economics and Management* 98, p. 102253.

— (2021). "The impact of energy prices on socioeconomic and environmental performance: Evidence from French manufacturing establishments, 1997–2015". In: *European Economic Review* 135, p. 103739.

Markandya, Anil et al. (2016). "Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union". In: *Applied energy* 179, pp. 1342–1350.

Metcalf, Gilbert E and Stock, James H (2020). "Measuring the macroeconomic impact of carbon taxes". In: *AEA papers and Proceedings*. Vol. 110. American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203, pp. 101–106.

Mikulić, Davor, Bakarić, Ivana Rašić, and Slijepčević, Sunčana (2016). "The economic impact of energy saving retrofits of residential and public buildings in Croatia". In: *Energy Policy* 96, pp. 630–644.

Ministère de l'Écologie, du Développement Durable et de L'Énergie (2023). *Arrêté du 22 décembre 2014 définissant les opérations standardisées d'économies d'énergie*. Journal Officiel de la République Française.

O'Callaghan, B et al. (2021). "Global recovery observatory". In: *Draft Methodology Document. Available online: https://recovery. smithschool. ox. ac. uk/global-recovery-observatory-draft-methodology-document/(accessed on 10 September 2021)*.

Office of the Federal Register, National Archives and Records Administration. (Mar. 2021). *Public Law 117 - 2 - American Rescue Plan Act of 2021*. Government. U.S. Government Publishing Office.

Peñasco, Cristina and Anadón, Laura Díaz (2023). "Assessing the effectiveness of energy efficiency measures in the residential sector gas consumption through dynamic treatment effects: Evidence from England and Wales". In: *Energy Economics* 117, p. 106435. ISSN: 0140-9883. DOI: https://doi.org/10.1016/j.eneco.2022.106435.

Peri, Giovanni and Yasenov, Vasil (2019). "The labor market effects of a refugee wave: Synthetic control method meets the Mariel boatlift". In: *Journal of Human Resources* 54.2, pp. 267–309.

Pikas, Ergo et al. (2015). "Quantification of economic benefits of renovation of apartment buildings as a basis for cost optimal 2030 energy efficiency strategies". In: *Energy and Buildings* 86, pp. 151–160.

Popp, David et al. (2022). "The employment impact of green fiscal push: evidence from the American Recovery Act". In: *Brookings Papers on Economic Activity* 2021.2, pp. 1–69.

Reich, Michael, Allegretto, Sylvia, and Godoey, Anna (2017). "Seattle's minimum wage experience 2015-16". In: *Available at SSRN 3043388*.

Rubin, Donald B (1974). "Estimating causal effects of treatments in randomized and nonrandomized studies." In: *Journal of educational Psychology* 66.5, p. 688.

Schaal, Edouard (2017). "Uncertainty and unemployment". In: *Econometrica* 85.6, pp. 1675–1721.

Schwarz, Peter M et al. (2021). "ENERGY STAR appliance market shares: Do they respond to electricity prices, and does it matter?" In: *Energy Journal* 42.4.

Sooriyaarachchi, Thilanka M et al. (2015). "Job creation potentials and skill requirements in, PV, CSP, wind, water-to-energy and energy efficiency value chains". In: *Renewable and Sustainable Energy Reviews* 52, pp. 653–668.

Vona, Francesco (2019). "Job losses and political acceptability of climate policies: why the 'job-killing'argument is so persistent and how to overturn it". In: *Climate Policy* 19.4, pp. 524–532.

Vona, Francesco et al. (2018). "Environmental regulation and green skills: an empirical exploration". In: *Journal of the Association of Environmental and Resource Economists* 5.4, pp. 713–753.

Walker, W. Reed (May 2011). "Environmental Regulation and Labor Reallocation: Evidence from the Clean Air Act". In: *American Economic Review* 101.3, pp. 442–47. DOI: 10.1257/aer.101.3.442. URL: https://www.aeaweb.org/articles?id=10.1257/aer.101.3.442.

Wei, Max, Patadia, Shana, and Kammen, Daniel M (2010). "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" In: *Energy policy* 38.2, pp. 919–931.

Wiltshire, Justin C (2021). "Walmart supercenters and monopsony power: How a large, low-wage employer impacts local labor markets". In: *Job market paper*.

Yip, Chi Man (2018). "On the labor market consequences of environmental taxes". In: *Journal of Environmental Economics and Management* 89, pp. 136–152.

A WDM data

The WMD disentangles between permanent and fixed-term contracts. Table A1 below shows that most of the growth in employment in the retrofitting industry occurred by new hires under a permanent contract. This striking figure holds both before and after the policy change of April 2018, with a share of permanent contracts in total employment growth higher than 80%. Such a pattern can be explained by the fast expansion of the market for energy efficiency services, with substantial needs in terms of workforce.

Table A1: Monthly cumulative employment growth by contract type (as of Jan. 2016)

	Permanent	**Fixed-term**	**Share of permanent**
		Retrofitting industry	
Jan. 2016	+337	+73.5	82.10 %
Feb. 2018	+3,418	+168	95.32 %
Feb. 2020	+11,168	+1,768	86.33 %
		All other sectors	
Jan. 2016	+27,777	+54,492	33.76 %
Feb. 2018	+89,197	+226,805	28.23 %
Feb. 2020	+273,326	+165,761	62.25 %

On the contrary, employment growth in other sectors was mostly due to new hiring under a fixed-term contract (around 70%) up until 2018. We observe a trend reversal in the second half of our period, with up to 60% of permanent jobs creation. This occurred in a general context of economic growth, with the French economy reaching its highest job creation level in 10 years according to Aldama, Cochard, and Ouvrard 2020. Thus, the growth of the retrofitting industry started way before the reform of the EEO scheme. As a result, we cannot directly compare this sector to the rest of the economy, and we need to select carefully control sectors.

B Choice of the optimal synthetic control penalization parameter

The choice of the appropriate λ relies on a data-driven process. It follows the *Leave-One-Out Cross-Validation of Post-Intervention Outcomes for the Untreated* protocol introduced by Abadie and L'Hour 2021. We first define a set of 53 candidate values: our list includes $\lambda = 0.00001; 0.01; 0.1; 0.15;$ and all increments of 0.1 up to 4.95. Second, we construct a set of k "placebo-treated" control sectors, with $k < n_0$. It consists in the union of all four-nearest neighbors of each treated sector. Third, for each value in our series of λ, we define the optimal weight vector $W^*_{i,j}(\lambda)$, which produces

a synthetic unit for the placebo-treated sector i using all other control sectors j in the donor pool $\{n_1+1,\ldots,n\}\backslash\{i\}$. Hence, for each control unit i in the set of "placebo-treated" control sectors, the estimated treatment effect writes as:

$$\hat{\tau}_i(\lambda) = Y_i - \sum_{\substack{j=n_1+1 \\ j\neq i}}^{n} W_{i,j}^{*}(\lambda) Y_j \tag{A1}$$

For each value of λ, one can finally define some measure of loss over all the placebo-treated control sectors, such as the root mean squared prediction error (RMSPE). The optimal lambda λ^* is such that:

$$\lambda^* = \min_{\lambda} \left(\sqrt{\frac{1}{k}\sum_{i=1}^{k} [\hat{\tau}_i(\lambda)]^2} \right) \tag{A2}$$

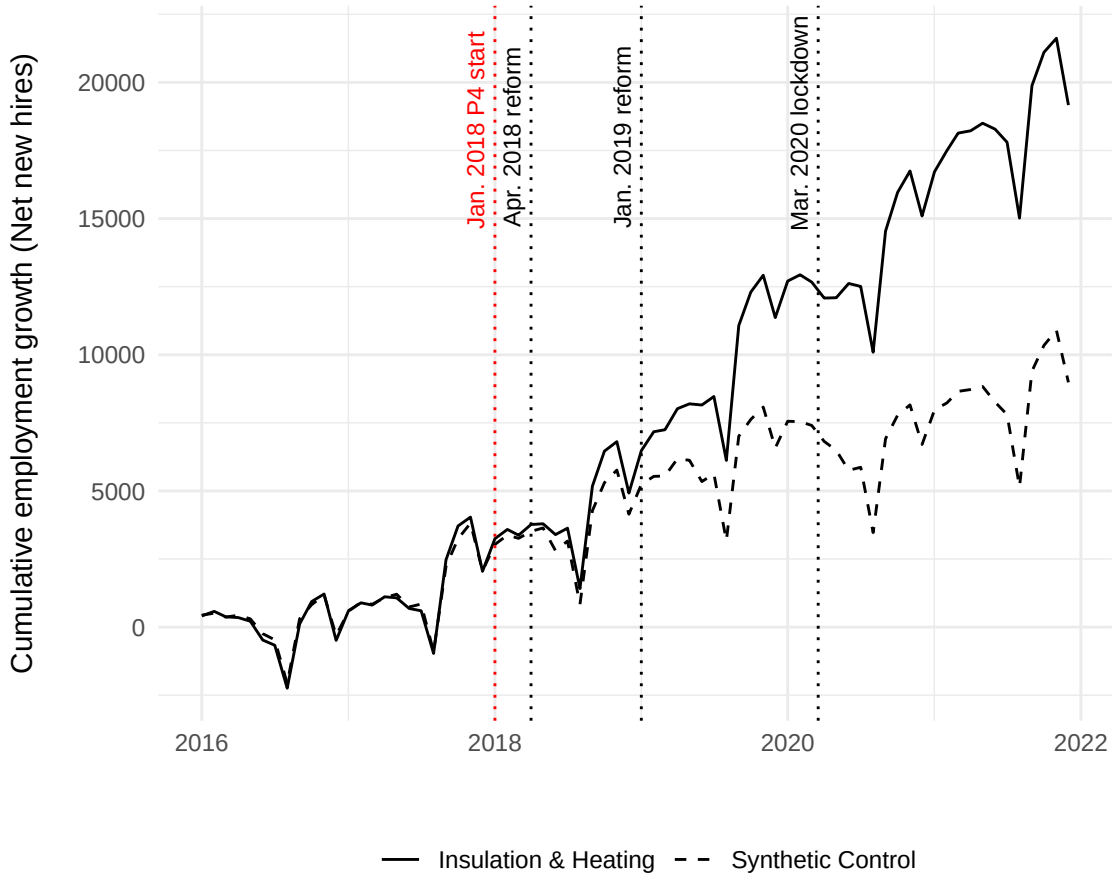
C Robustness checks

For the synthetic control method to be valid, there should be no anticipatory effect of the policy. Abadie, Diamond, and Hainmueller 2015 propose a placebo test to check this. It consists in running the same analysis, but as if the policy reform had occurred a bit earlier. If the treatment effect can already be observed during the placebo period, then the non-anticipation condition does not hold.

C.1 Anticipation test 1: treatment in January 2018

We perform a first anticipation test by assuming that the reform occurred 2 months earlier, in January 2018, at the start of the fourth obligation period. Indeed, this new period was characterized by a much higher ambition, as the overall obligation went from less than 1,166 TWh cumac to more than 2,133. In a sense, the *Coup de Pouce* reforms of April 2018 and January 2019 precisely reacted to this revised objective, by driving the increased energy suppliers' investments towards specific types of work. It is thus possible that the January 2018 obligation revision already stimulated demand for energy efficiency services before the launch of the *Coup de Pouce* bonusing mechanism.

Figure A1: Trend in employment growth in the energy renovation vs its synthetic control, assuming a policy start in January 2018

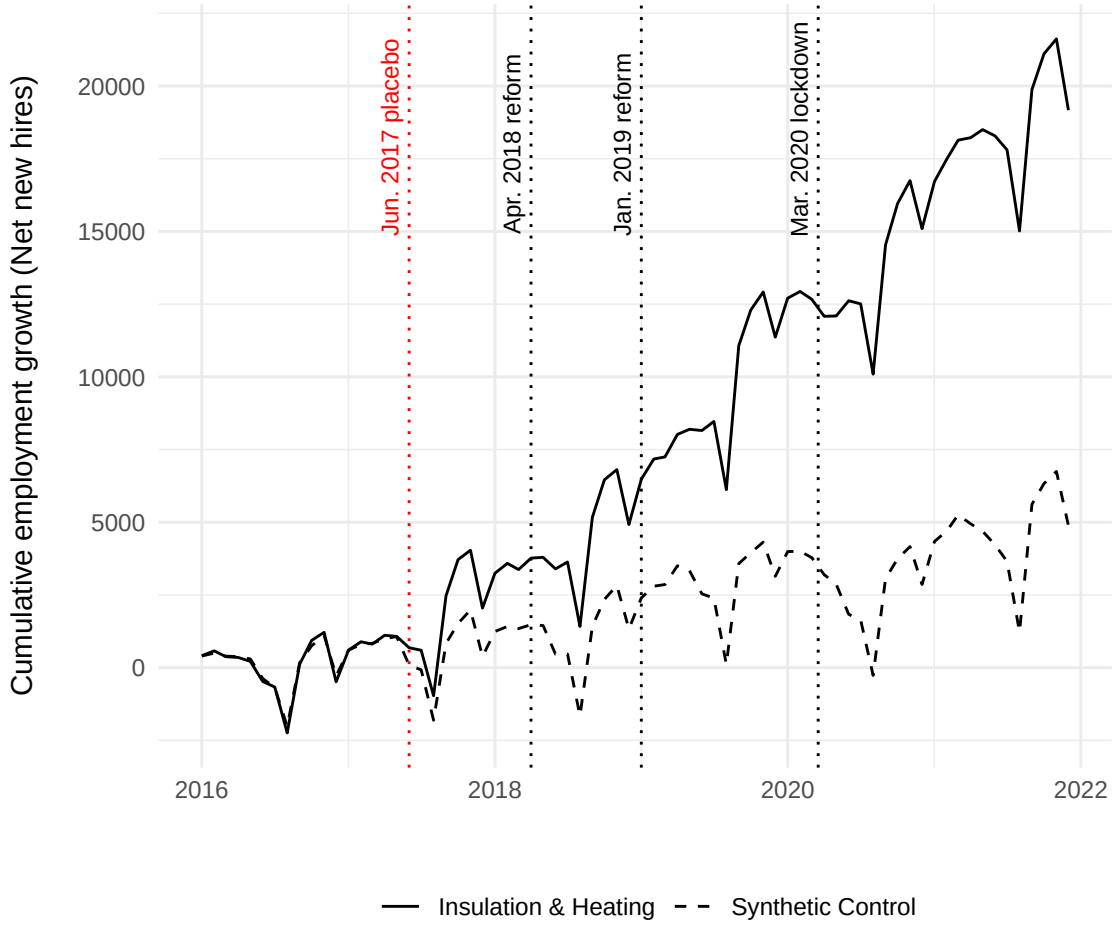


However, looking at Figure A1, we see that results do not diverge as compared with our analysis with a policy change in April 2018. The divergence between the actual retrofitting sector and its synthetic control only occurs after April 2018, with an overall effect as of February 2020 of $5,391.17$ additional workers as compared to what would have happened without the reforms. This effect, measured using a penalized synthetic control with optimal penalization parameter $\lambda^* = 0.1$, is also of the same significance as in our baseline estimation. Thus, our p-value, computed as the frequencies across 100 iterations of the values of the test statistic based on aggregate effects, reaches 0.0297. We take the result of this robustness check as additional evidence that the effects on employment were indeed driven by the policy change of April 2018 and further reinforced by the January 2019 reform, rather by the increase in the overall obligation in January 2018.

C.2 Anticipation test 2: treatment in June 2017

Our second anticipation test assumes a policy shock in June 2017, when the certificate price reached 3 EUR. This price had already been attained at the end of the third period in 2014, but it went down below 2 EUR during the first year of the fourth period, i.e., in 2015. Thus, the come-back of a price above 3 EUR was a strong signal for the market, and it could have led to new hires. Looking at Figure A2, we identify a first divergence just after our placebo treatment between the synthetic control and the treated group. However, this wedge is of limited magnitude ($< +2,000$ jobs) and remains constant across time up to the actual treatment date in April 2018. After this date, the wedge increases again, as in our baseline estimation. In February 2020, it reaches $+8,000$ jobs, roughly equating the sum of the February 2018 gap ($+2,000$ jobs) and our baseline wedge (around $+6,000$ jobs).

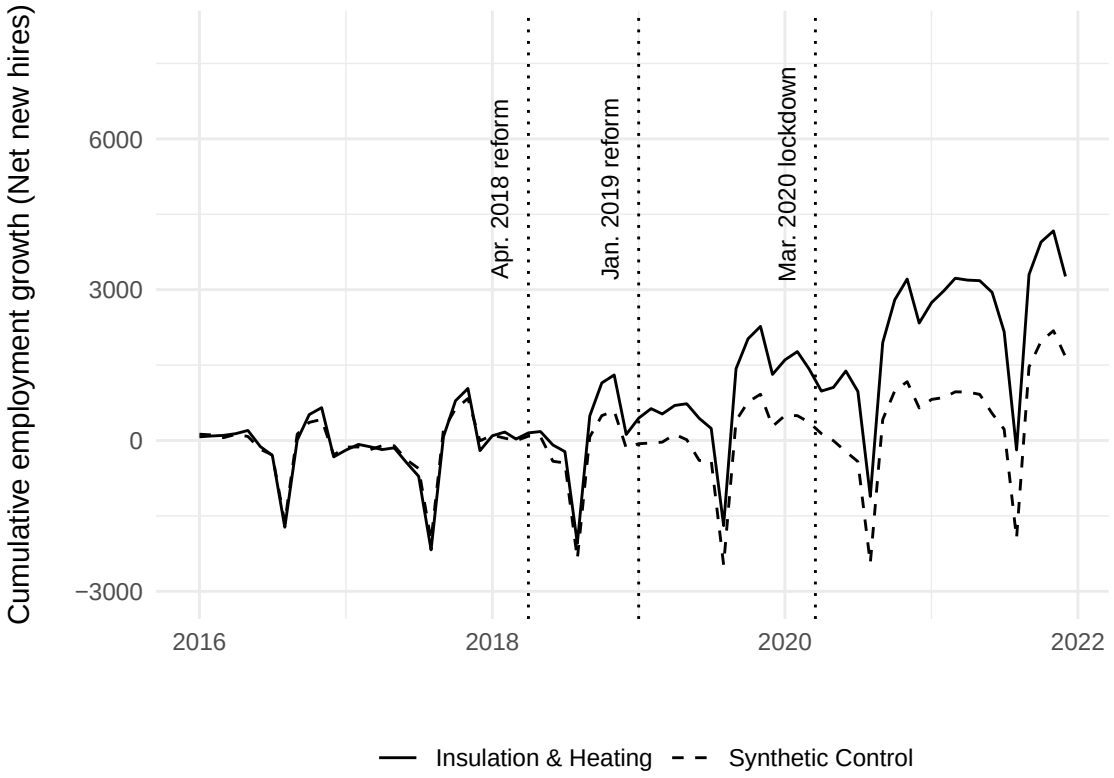
Figure A2: Trend in employment growth in the energy renovation vs its synthetic control, assuming a policy start in January 2018



Thus, despite the difference between the trend for the energy renovation and its synthetic control group before the actual treatment date, the sensible change occurs only after April 2018. As a result, we can argue our analysis to be robust to the placebo test.

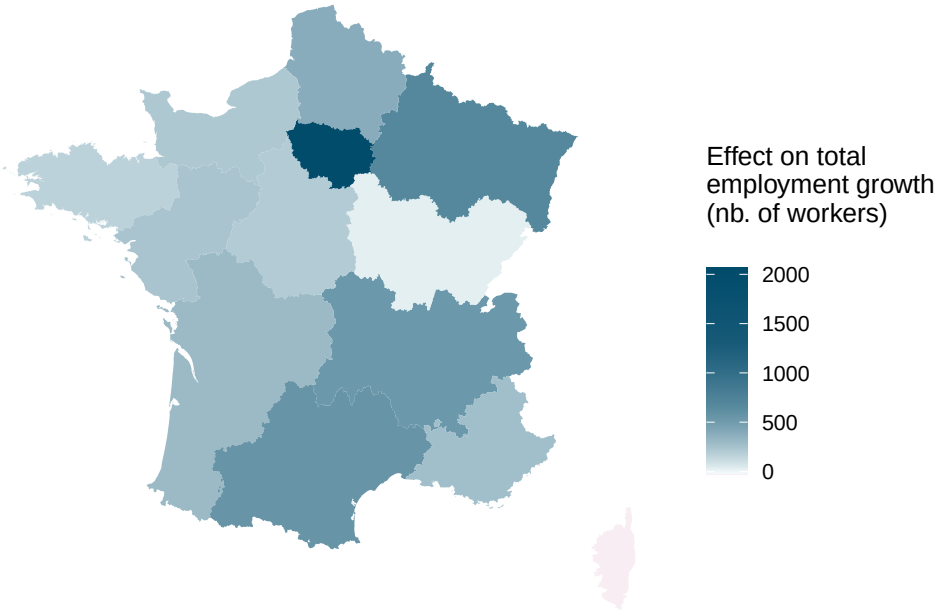
D Fixed-term employment growth in energy renovation

Figure A3: Fixed-term employment growth in energy renovation vs its penalized synthetic control

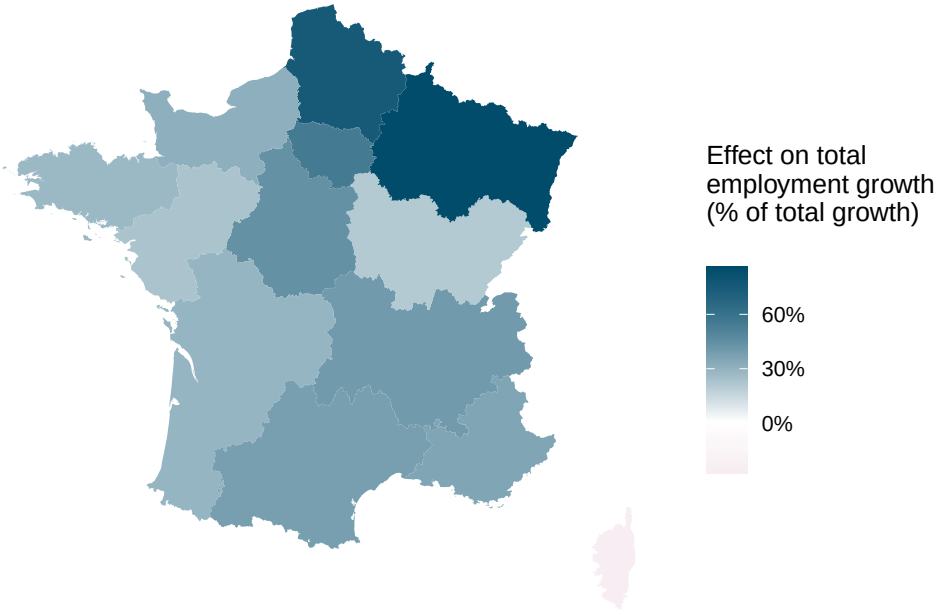


E Spatial heterogeneity

Figure A4: Effect of the policy on total employment



(a) Effect on total employment in number of workers



(b) Effect on total employment as a share of total growth