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Energy retrofitting of firms after a natural disaster: A '*build back better*' strategy

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ABSTRACT

In 2012, an earthquake struck one of Italy's most productive and dynamic areas, the Emilia-Romagna region. Just as policy makers are today considering green and climate-conscious investments to recover from the COVID-19 pandemic, in 2012, the regional government granted specific energy retrofitting contributions to manufacturing and service firms affected by the seismic event. Through a panel data analysis, we evaluate the impact of such energy policy measures on firm-level labour productivity to assess the presence of non-zero multipliers. We find that energy retrofitting through regional aids positively affected firms' labour productivity. We discuss the energy and economic policy implications of such intervention in the current framework of fiscal recovery packages.

1. Introduction

On May 20, 2012, at 4:03 a.m., an earthquake with a local magnitude of 5.9 on the Richter scale struck the Po Plain. The epicentre was in the province of Modena, in the northern region of Emilia-Romagna. Nine days later, on May 29, 2012, a 5.8 shock struck the Modena plain again. The earthquake hugely marked the region: 59 municipalities with a total of 550,000 inhabitants were affected, with severe damage to private homes (approximately 31,000 of which were left uninhabitable), historical and cultural buildings, health and social services facilities, and commercial and industrial structures, the reconstruction of which was necessary to ensure the recovery of economic and social activities. Thousands of firms affected by the natural disaster turned to their private insurance and to the regional government for assistance. The regional government intervened with substantial aids, leveraging the private insurance compensation, and explicitly included an extra energy efficiency contribution for those firms in need to reconstruct, relocate, and recover assets under different modes of intervention (Regione Emilia-Romagna, 2021).[2]

As a result, the earthquake represented an –unwelcome – opportunity to deeply renovate and improve the energy performance and endowments of businesses, consistent with the Europe 2030 energy efficiency target.[3] In addition, the kick-off of the so-called 'Agenda 2030'[4] included energy as a theme in the sustainable development goals (SDGs), specifically to 'ensure access to affordable, reliable, sustainable, and modern energy for all' (SDG 7). Among other things, SDG 7 establishes the need to prioritise energy-efficient practices and, specifically, to double the global rate of improvement in energy efficiency by 2030 (Target 7.3).[5]

In this study, we examine whether regional government contributions targeting energy retrofit affected firms' economic performance, specifically in terms of improvements in labour productivity. Drawing

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[3] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency (Text with EEA relevance.).

[4] 'Agenda 2030' is a plan of action divided into 17 sustainable development goals (SDGs) set forth by the United Nations in 2015 to define the global development agenda until 2030. It follows the previous launching of eight objectives (the so-called millennium development goals, MDGs) by the United Nations in 2000. Unlike the MDGs, SDGs are universal (goals and targets apply to every country in the world), integrated (the goals should be interconnected), and based on country ownership (the process is not top-down).

[5] https://sdgs.un.org/goals/goal7.

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on the literature on the effects of energy retrofit on firms' performance and on the effects of natural disasters on factor productivity and economic growth, we investigate whether an exogenous shock, such as an earthquake, triggers solutions capable of reactivating the economic processes and improve existing conditions. What we observe after the earthquake is the result of different forces interacting, as in a natural experiment: the efforts made by the public and private sectors, with direct contributions to support the recovery, together with the natural dynamics of changes in productivity stemming from the reallocation of capital, labour, and the (forced) adoption of new technologies and organisational solutions.

We use a unique and original dataset of firm-level observations on energy retrofit contributions obtained by the regional reconstruction agency, matched with balance sheet data. This very special dataset allows for the direct investigation of the impact of energy retrofit contributions on estimated labour productivity with respect to those firms not obtaining/requiring the extra public contribution, enabling an evaluation of the policy actions undertaken. This study contributes to the relatively scarce literature on the firm-level impact of energy retrofit measures on factor productivity and, secondarily, on the impact of the reconstruction efforts after natural disasters on overall GDP and economic performance in general. The use of firm-level data on funds received for energy retrofit, matched with financial variables, adds to the evidence of energy retrofit effects on firms' performance. It is relatively rare to be able to access this type of data, as overall amounts of external interventions for energy retrofit – if any – are usually considered at the local or sectoral level (Filippini et al., 2020; Liang et al., 2018), so it is usually difficult to correlate individual firms' investments in energy retrofit with subsequent performance. This limitation also applies to studies over the impact of natural disasters on economic performance: very few studies have been able to use microeconomic data (Noth and Rehbein, 2019; Lai et al., 2022).

The article is structured as follows. Section 2 summarises the most relevant themes for our study from the literature on the relationship between energy efficiency and firms' performance and the effects of natural disasters on economic growth. Based on this summary, research questions are formulated. Section 3 describes the case study and the data used. Section 4 presents the methodology and embeds the research hypotheses in the empirical formulation. Section 5 presents the results of the empirical estimates, section 6 discusses the findings and section 7 concludes and draws the policy implications.

2. Background literature and research questions

2.1. The energy efficiency gap, firms' behaviour and public intervention

Energy efficiency is among the most intensely discussed and widely implemented targets in energy and environmental policy. It refers, in essence, to an output-to-input ratio – obtaining the same level of service/output or, more contentiously, an equivalent quality-adjusted level of service/output, from a smaller quantity of energy consumed (Patterson, 1996).

The key problem with investments in energy retrofit is that the ideally optimal amount of current investments lies below the socially desirable threshold, since the benefits will only be reaped in the future or come in the form of positive externalities not immediately valuable by the individuals. The issue, for both consumers and firms, is known as energy efficiency gap (Koomey and Sanstad, 1994; Gillingham and Palmer, 2006): the way individuals make decisions about energy efficiency leads to a slower diffusion of energy-efficient products than would be expected if consumers made all positive net present value investments. According to this hypothesis, the inability to correctly consider the by-products on energy retrofit and the net present value of energy efficiency investments brings about a sub-optimal level of actual investments.

A sub-optimal level of investment comes with various interpretations in the literature, ranging from imperfect information, credit constraints and moral hazard (Giraudet et al., 2018), (market failures) to non-standard preferences (see Della Valle and Bertoldi, 2022, for an extended overview).

Information failures prevent businesses and individuals from understanding the long-term costs of their production and consumption choices and the cost saving of opting for resource-efficient solutions (Harris et al., 2000; Gillingham et al., 2006). A number of studies revealed that people use extremely high discount rates in their consumption behaviour when making purchases of energy savings appliances (Hausman, 1979; Ruderman et al., 1987).

Unrewarded positive externalities also contribute to an insufficient level of investment, as more responsible approaches towards energy consumption would benefit everyone by reducing power failures, decreasing air pollution, reducing dependence from energy imports, and so on (Sovacool et al., 2021).

When focussing on the optimization problem of the firm, energy efficiency investments are internalised in the optimality decisions. Loss aversion and hyperbolic discounting are instances of behavioural failures entering the firm's utility function and leading to under-investing in energy saving technologies as a result of the profit maximization (Della Valle and Bertoldi, 2021).

Some authors (Singh et al., 2016) find that environmental expenditure has a negative effect on economic performance through pollution prevention capability but a positive effect through product stewardship capability.

Aflaki et al. (2012) propose a conceptual framework linking energy efficiency to sustainable operations and briefly discuss how myopia, excessively high discount rates, complexity, and ambiguity contribute to lower adoption of energy efficiency projects than expected.

Muthulingam et al. (2013) investigate the importance of ranking suggestions when considering the efficiency measures undertaken by businesses, stating that energy efficiency is closely aligned with firms' operations management because energy constitutes a significant share of manufacturing inputs and because improving energy efficiency in manufacturing typically involves process improvements, such as modification or replacement of equipment, improved management of existing systems, and minimisation of waste or resource usage.

Very few academic studies analyse the direct relationship between energy efficiency and productivity at the firm level, although it is of the utmost importance in policymaking. The discussion of the impact of energy efficiency on productivity at the firm level has mainly focused on the so-called 'Porter hypothesis'. Porter (1991) and Porter and van der Linde (1995) state that more stringent but properly designed environmental regulations might incentivise firms to innovate, increase efficiency, and consequently boost their performance. The literature includes 'weak' and 'strong' versions of the Porter hypothesis. The weak version states that environmental regulation may lead to innovation; the strong version adds that regulation can improve firms' competitiveness and productivity (Jaffe and Palmer, 1997). Studies to date do not support a consensus on support for the strong version of the Porter hypothesis. Some studies conclude that environmental regulation policy has led to a fall in productivity due to the higher costs that firms may have to bear (Gray and Shadbegian, 1995, 2003; Becker, 2011; Dechezleprêtre and Sato, 2014) or that environmental regulation has had a negative or insignificant effect on productivity growth (Cohen and Tubb, 2018; Kozluk and Zipperer, 2014; Hille and Möbius, 2019). Others highlight the positive effects of this kind of regulation on productivity (Hamamoto, 2006; Yang. Tseng and Chen, 2012; Jorge et al., 2015; Qiu. Zhou and Wei, 2018). The differences in these outcomes probably result from these studies suffering from a lack of generality since very specific regulations or industries in a single country setting are usually analysed (Albrizio et al., 2017) and since there is not a uniform standard for measuring performance (Zeng et al., 2010). Positive effects on total factor productivity (TFP) growth have been assessed from energy efficiency programs for iron and steel firms in China (Filippini et al., 2020).

A recent contribution by Montalbano et al. (2022), extending a previous work by Montalbano and Nenci (2019), uses firm-level survey data for a large sample of mainly developing countries, including different measures for energy efficiency, to find a positive relationship between alternative measures of energy efficiency and firm-level productivity for the period of 2006–2018.

Whenever regulation alone is not sufficient to spur innovation and energy retrofit at firm level, a targeted public intervention could help to bridge the energy efficiency gap. The initiatives aimed at improving buildings' efficiency through increased tax expenditures are a clear instance of such initiatives.

Government interventions could reduce market failures (as in the case of underpriced energy cost, that lead firms not to take into account the full costs of supply and consumption) and reduce transaction costs, (as for the acquisition of information or the risks and benefits associated with investments in new efficient technologies, that could be facilitated through institutional arrangements and regulations; Golove and Eto, 1996). A number of instruments, as carbon taxes, tradable green certificates and subsidies or incentives to R&D in cleaner technologies are available to the policy maker to address barriers and failures in the energy efficiency quest (Copenhagen Economics, 2013; Linares and Labandeira, 2010).

Given the assessment of the energy efficiency gap in the literature, the sub-optimal level of retrofit investments undertaken by firms and the role of the government in bridging the gap and addressing market failures, we draw the following research question to be tackled by our empirical case study:

RQ1. *Do energy retrofit contributions by the policy maker after an earthquake affect firm-level factor productivity?*

2.2. Energy efficiency and macroeconomic variables

Although there are several potential channels through which energy efficiency policies could spur

Competitiveness and growth (Deichmann and Zhang, 2013), few empirical studies adopt a macroeconomic perspective of the direct relationship between energy efficiency and GDP levels or growth.

Using a panel vector autoregression approach for 56 developing countries, Rajbhandari and Zhang (2017) find evidence of a long-run Granger causality from economic growth to lower energy intensity for all countries, as higher energy prices provide incentives for increasing energy efficiency, while economic development and demand growth provide opportunities for achieving efficiency gains by replacing old plants and technologies with new ones.

According to Batini et al. (2021), the estimated multipliers associated with "green spending" are approximately 2–7 times larger than those associated with non-eco-friendly spending, depending on the sector, technology, and time horizon. In macroeconomic terms, investment in energy renovation spurs additional demand and represents an opportunity for domestic producers to increase economic activity. This relates directly to suppliers of goods or services for energy renewal, i.e., entrepreneurs engaged in construction, process and project design, and/or construction supervision. Together with these direct effects, indirect effects for suppliers of goods and services used as intermediate consumption, such as construction materials, transport, craft services, and similar goods and services, also benefit from the implementation of energy renovation programs.

A positive macroeconomic impact can be potentially derived from increased investment in energy efficiency (of buildings). These effects encompass benefits to GDP and public finances from increased employment through inter alia increased income tax revenue, corporate tax revenue, VAT revenue and reduced unemployment benefits (Copenhagen Economics, 2012). Multiple benefits for the industry encompass operational benefits, such as reduced maintenance, saved process time and increased production capacity and product-related benefits such as quality improvements – a by-product of implementing energy efficiency investment in energy intensive industries (European Commission, 2017).

In the case of Italy, the potential impact on employment of the adoption of energy-efficient technologies has been investigated by Dell'Anna (2021), who points to a large unexploited potential (likely the basis for intervention as the '110% bonus' for restructuring in the construction sector).[6] Therefore, energy retrofit incentive policies spread on the supply side of the economy because of direct funding or through facilitated access to credit envisaged in the normative context. Energy savings also induce more consumption possibilities, although a rebound effect is possible. The rebound effect[7] reflects the increase in demand for energy that is a result of the implementation of energy efficiency measures and policies or certain technological interventions (Maxwell, Owen, McAndrew, Muehmel, and Neubauer, 2011). Some studies highlight how the rebound effect might have been underestimated and have threatened global energy efficiency directly, as for instance, cost-effective energy efficiency improvements reduce the effective price of energy services, and hence encourage increased consumption of those services, which in turn will partly offset the energy savings per unit of the energy service, or indirectly, as energy saving triggers changes in the consumption of other commodities, owing, for instance, to the increase in real income stimulated by the energy efficiency improvement (income effect), or owing to an increase in effective price relative to the energy service (holding utility constant; Brockway et al., 2021; Sorrell et al., 2009). The direct and indirect rebound effects are partial-equilibrium effects, since they are usually measured by holding prices fixed, while there exist macroeconomic rebound effects that concern the economy as a whole: a fall in the real price of energy services may reduce the price of intermediate and final goods throughout the economy, leading to a series of price and quantity adjustments, with energy-intensive goods and sectors likely to gain at the expense of less energy-intensive ones (Sorrell and Dimitropoulos, 2008).

From a social perspective, the fiscal and environmental impacts should be considered together with the gross value added and employment impact. Taxes included in investment costs are actually a redistribution of funds from investors to government, and more tax revenues can be expected to result from enhanced economic activity. In addition, lower CO_2 emissions from energy savings contribute to economic sustainability, according to the EU and national climate and environmental strategies (Mikulić et al., 2016).

Estimates of the unrealised country-level energy efficiency potential range from 15 to 25% (Jackson, 2010). From a broader perspective, global energy efficiency investments are approximately half the size of upstream oil and gas investments and are distributed unevenly across countries and energy-consuming sectors (OECD/IEA, 2014). The more investment is made in renewable energy technologies, the more energy savings revenues can be expected in return. However, investment in energy-saving projects is risky since efficiency investments are often capital-intensive and have long payback times during which energy market conditions may change (Abadie et al., 2012; Deng et al., 2014). The related uncertainties include but are not limited to the performance of energy conservation measures, fluctuation of energy market prices (Cortazar and Schwartz, 2003), weather conditions, varied human operations, and random occupancies (Lü et al., 2014; Chou and Ongkowijoyo, 2014).

The stage of economic development of a region or country also affects the attainable benefits of energy retrofit (Esen and Bayrak, 2017). Economies that complete the transition from agriculture to industry experience a shift to services that require relatively fewer resource-intensive activities (Stern and Cleveland, 2004; Mehrara,

[6] https://www.theguardian.com/world/2022/apr/13/italys-superbonus-110-scheme-prompts-surge-of-green-home-renovations.

[7] This is known as 'Jevons paradox' (Saunders, 1992).

2007), as service-producing economic activities require less energy and more labour than other economic activities. It is expected that the relative share of services in economic growth will increase as development increases while the relative shares of agriculture and industry will decrease. If we were to extend the results of our case study to a larger economic scale in terms of economic growth and/or employment, we could formulate a second research question:

RQ2. *Is it possible to infer from our case study a potential macroeconomic impact of energy retrofit incentives in terms of growth and employment?*

2.3. Natural disasters and economic growth

In the economic literature, the usually accepted view is that in a manufacturing economy, an exogenous shock such as a natural disaster brings solutions that reactivate economic processes and improve conditions (Albala-Bertrand, 1993a, 1993b; Tol and Leek, 1999; Okuyama and Chang, 2004; Benson and Clay, 2004; Strömberg, 2007; UNISDR, 2009; Cuaresma, 2009; Cavallo and Noy, 2009; Cavallo et al., 2010; The United Nations and The World Bank, 2010). In particular, the focus is on the effects that the replacement of capital assets has on industrial production, benefitting from the possibility of purchasing cutting-edge technologies and techniques, as well as the multiplying effects of investments in the construction industry and other public works, which generate income from work and the demand for goods and services by families, businesses, and the public administration. Our examination of the effects of public and private interventions in helping to restore businesses in the Modena area affected by the 2012 earthquake lies in this context.

Other studies have examined medium- and long-term economic effects, indicating how the path followed is not necessarily that which the affected territory would have been able to follow if it had not suffered a natural disaster (Geipel, 2012; DuPont and Noy, 2015). Skidmore and Toya (2002) investigate the long-run relationships among disasters, capital accumulation, total factor productivity, and economic growth. Their cross-country analysis finds that although disaster risk reduces the expected rate of return to physical capital, risk also serves to increase the relative return to human capital.

To understand whether, in the medium term, disasters can become opportunities for the improvement of the affected areas, local development factors and the interrelationships between territories need to be considered, as well as the interrelationships between the different administrative levels involved in the reconstruction processes. The fact that the amount of resources for reconstruction is not the only variable at stake is also demonstrated by Barone and Mocetti (2014), who compared the growth paths of two Italian areas affected by earthquakes, Friuli in 1976 and Irpinia in 1980. The latter area received considerable resources for decades to address the damage that occurred, but the area has not seen the transformation that one would expect, considering the resources invested. For example, flood events in Germany have been associated with significantly higher turnover, lower leverage, and higher cash (Noth and Rehbein, 2019). Floods in urban areas in China have been associated with firms obtaining access to additional trade credit and significant performance increases (Shaojie et al., 2018).

However, other studies report negative effects of natural disasters. For example, Po-Hsuan et al. (2018) report that firms with plants exclusively found in areas affected by natural disasters have lower returns on assets. Gunessee et al. (2018) report that supply chain disruption occurred after a tsunami event in Japan. When physical capital is affected, GDP may also decrease after a negative shock: according to Strulik and Trimborn (2019), GDP is driven above its pre-shock level when natural disasters destroy predominantly durable consumption goods (cars, furniture, etc.). In contrast, disasters that destroy mainly productive capital are predicted to reduce GDP.

A comprehensive survey of the studies over direct and indirect effects of natural disasters is found in Wouter Botzen, Deschenes, and Sanders (2019): models aimed at measuring the macroeconomic impact of disasters are based on CGE, GIS systems, I–O matrixes. Potentially, further research could extend our study as to evaluate the earthquake macroeconomic effects in the short, medium and long run perspective.

3. Case study: Emilia Romagna

The Emilia-Romagna region is one of Italy's most productive and export-oriented areas, contributing to almost 2.5% of the national gross domestic product (GDP) and representing 16.6% of regional value added (Provincia di Modena, 2012). The 2012 earthquake caused damage to both private housing and business facilities. The damages in the housing sector required approximately one billion Euro in funds for reconstruction works. The funds for reconstruction covered the costs of reconstruction and partially seismic improvement works and energy efficiency enhancement. This has produced a leverage effect on the affected area: it is estimated that for each Euro of public funding, there were only slightly fewer private resources (0.90 Euro).

The supply chain was struck as well: damages to the agricultural and agri-industrial sector were estimated to be approximately 2.3 billion Euro, the majority of which were in the province of Modena. This damage sum refers not only to crops but also to agricultural machinery and equipment on farms, as well as stocks, which particularly affected the Parmigiano-Reggiano supply chain (Fanfani and Pieri, 2013).

Manufacturing activities' damage estimates can be obtained from the 'Sfinge' platform (https://sfingesisma.regione.emilia-romagna.it/sfinge_si/aziende/WebLogin/), which highlights applications for 1.9 billion EUR (Regione Emilia-Romagna, 2021), mostly for buildings (75%) and the replacement and repair of instrumental goods, stocks, together with relocation. These investments have a distinguishing feature: they were associated with incentives offered by regional laws for energy retrofit, so specific chapters of funding were devised to support energy retrofit in all possible instances: to restore, refurbish, or reconstruct old buildings and for new buildings.

More than 5000 firms affected by the natural disaster applied for contributions to reconstruct, relocate, and recover assets under different chapters of interventions (Regione Emilia-Romagna, 2021). Among these, approximately 3500 were given consideration, and 350 firms included explicitly in their application the specific energy retrofit public contribution. The public energy retrofit contribution amounted to an increase of 15% of the total costs to be covered through the public intervention.

After the event, the governor of the Emilia-Romagna region was selected as the Commissioner for reconstruction. The normative instruments adopted to manage the aid and support the reconstruction process were the so-called '*Ordinanze*', administrative provisions detailing the sectors, amounts of funding, and procedures to be implemented to access the financial aid. The Sfinge online platform had to be used to apply for financial aid. This online system keeps track not only of the contributions granted in the framework of the Ordinanze system on behalf of the Commissioner[8] but also of the economic assessments representing the baseline for the computation of the contributions themselves, that is, the amounts of funds necessary for renovation/reconstruction projects, the parametric conventional costs estimated on the basis of damages and areas, and the amounts of insurance refunds. The contribution that could be granted was computed as the lesser of the project amount and the parametric conventional cost, less the insurance refund.

The specific chapter on energy efficiency improvement for industrial and production-related assets acknowledged an increase in the contribution granted to the selected businesses of 15%, provided the buildings to be reconstructed or renovated went through an energy retrofit to

[8] The Commissioner for the earthquake is formally appointed by the First Minister.

reach an energy performance indicator 30% lower than a standard equivalent building, according to the energy efficiency laws and provisions. Fig. 1 illustrates the distribution of the industrial macrosectors and municipalities of businesses eventually granted energy retrofit contributions.

The Sfinge database, containing detailed data on the public contributions granted and on the applying entities, was merged with the AIDA database, containing financial variables for the whole Emilia-Romagna region (please see the Methodology section below). Therefore, we can analyse the differences in the economic indicators of the Modena province businesses according to their status: 1) businesses that did not apply for financial assistance (presumably, therefore, not damaged by the earthquake); 2) businesses that did apply for financial assistance but not for the specific energy efficiency contribution (firms 'with Sfinge basic contribution'); and 3) businesses that did apply for financial assistance and for the energy efficiency contribution (firms 'with Energy Efficiency contribution'). Of the total of 16,968 businesses,[9] 389 received financial assistance without the specific energy retrofit contribution, and 87 received the additional energy retrofit contribution. Key indicators for the three groups are reported in Table 1.

Firms in the three groups differ with respect to all of the variables: the basic Sfinge contribution was obtained by older, larger, more foreign-owned firms, those reporting higher valued-added growth rates in the decade 2010–2019, and those with higher returns on investment. These trends are even more evident for firms applying for the specific energy retrofit contribution, except for the ROI, which is lower. This divide between small and large firms suggests that smaller firms might have been less ready or less prepared to initiate the process of applying for the contribution; larger firms were probably better endowed in terms of organisation, resources, and financial capabilities to manage the bureaucratic process and eventually obtain the contribution. Larger firms might also have had better opportunities to relocate the personnel and production sites while rebuilding/renovating damaged assets, while smaller firms might have had to pause their activity and face tighter financial constraints. Nonetheless, the statistics are probably affected by the very different sizes of the three groups.

4. Methodology

To compare the economic performance of firms that obtained the energy efficiency contribution with the economic performance of those that did not, we use data from the AIDA dataset merged with the Sfinge data. The AIDA dataset from Bureau Van Dijk offers comprehensive information on the balance sheets of almost all Italian corporations operating in the private sector, except in the agricultural and financial industries. More specifically, this dataset contains variables such as labour costs, revenues, value added, net profits, the book value of physical capital, and raw-material expenditures taken from the balance sheets. By exploiting this detailed information, we can calculate approximate indicators of labour productivity (value added per employee), fixed capital (the total amount of physical assets per employee), and many other parameters. The time span considered covers 10 years, from 2010 to 2019, for 16.968 firms in 79 industries (Table 2).

To keep prices constant, we deflated all monetary variables using the GDP deflator provided by OECD (2021). Underlying the empirical specification, our main reference for the theoretical model is a standard macroeconomic production function:

$$Y = f(K, L, C, D)$$

where K is Capital, L is Labour, C are firm-level control variables and context-related control variables, and D are dummy variables capturing specific events and the energy retrofit contribution. We partially follow Brockway et al. (2021) and (Stucki, 2019) in setting up the empirical model with the firm-level production function in per capita terms, in terms of log per capita value added:

$$ln\left(\frac{Value\ added_{i,t}}{L_{i,t}}\right) = \alpha\, ln\left(\frac{Capital_{i,t}}{L_{i,t}}\right) + \beta\, ln\left(\frac{Total\ Investment_{i,t}}{L_{i,t}}\right) + \gamma \ln(Province\ V.A._{t}) + \delta\, ln(Unemployment_t) + \vartheta \ln(DistanceVAPr - IT_t) + \sigma(Size) + \eta + \vartheta + \tau + \varepsilon_{i,t}$$

where the dependent variable is an approximation for the ith firm's labour productivity observed at time t, expressed as log valued added over employees; capital represents fixed assets; total investment is the yearly change in total assets (both of the latter two are in terms of employees). As context control variables, we include the Modena province's value added, the yearly province unemployment rate, and the difference between the province's valued-added yearly growth rate and the whole country's growth rate as a relative performance indicator. *Size* is a categorical variable for firm size.[10] We include dummy variables to capture η, the presence of a foreign global ultimate owner (detecting a multinational firm local unit[11]); ϑ, a recipient firm of the 15% energy retrofit contribution; τ, the year of the earthquake, 2012; and $\varepsilon_{i,t}$, is an error term. Our first research question can be investigated through the specific ϑ parameter; it captures the policy contribution effect in determining the firms' performance and therefore a positive and statistically significant coefficient would confirm the hypothesis of efficacy of the policy actions undertaken in spurring productivity.

Firms obtaining the 15% energy retrofit contribution were also awarded the general Sfinge not-energy-specific reconstruction contribution. As addressed by Hille and Möbius (Hille and Möbius, 2019)) in evaluating the impact of environmental regulation on productivity, significant positive overall effects of environmental regulation on productivity growth are estimated when the models do not account for simultaneity, whereas, after controlling for simultaneity, significantly negative effects are estimated. We therefore include the lagged value of log value added per capita to correct for potential endogeneity, and we adopt a panel data econometric approach, comparing the performance in labour productivity in the three groups of businesses to provide an estimate of the impact of energy retrofit. We estimate the equation with generalized-least-square random effects[12] in four model specifications, where model (1) represents the baseline, (2) includes sector dummies (described in Table 2 above), (3) includes firms' age, and (4) includes municipalities dummies. The random-effects assumption is that the individual-specific effects are uncorrelated with the independent variables. In order to take into account for potential heteroskedasticity or within-panel serial correlation in the idiosyncratic error term ε_{it}, we required robust standard errors in the estimation. Correlation matrixes are reported in the annex.[13] Estimates can partially address our second research question: since we can link the overall amounts of the

[9] In the process of merging the Sfinge database with the AIDA database, we lose some information from the two databases and are left with several firms representing a sample of the Modena province firms' population larger than those located in the areas affected by the earthquake. See below for details.

[10] Size can be measured by turnover or employees. The size variable measured by turnover was highly correlated with the lagged dependent variable, therefore we opted for size as measured by number of employees (Table 3).

[11] The minimum percentage that must characterize the path from a subject company up to its ultimate owner was set at 25.01%.

[12] The large number of dummy variables does not suggest the use of a fixed-effect estimator, a collinearity would lead to dropping a number of indicators. GLS estimators are the best linear unbiased estimators in presence of heteroskedasticity and/or autocorrelation of the error term (Aitken's Theorem).

[13] In order to test our model specification, we also ran pooled OLS estimates with robust standard errors. Results were similar to the GLS estimates in terms of signs and statistical significance. Fixed-effects estimates were not applicable because of collinearity with the dummy and categorical variables in the model.

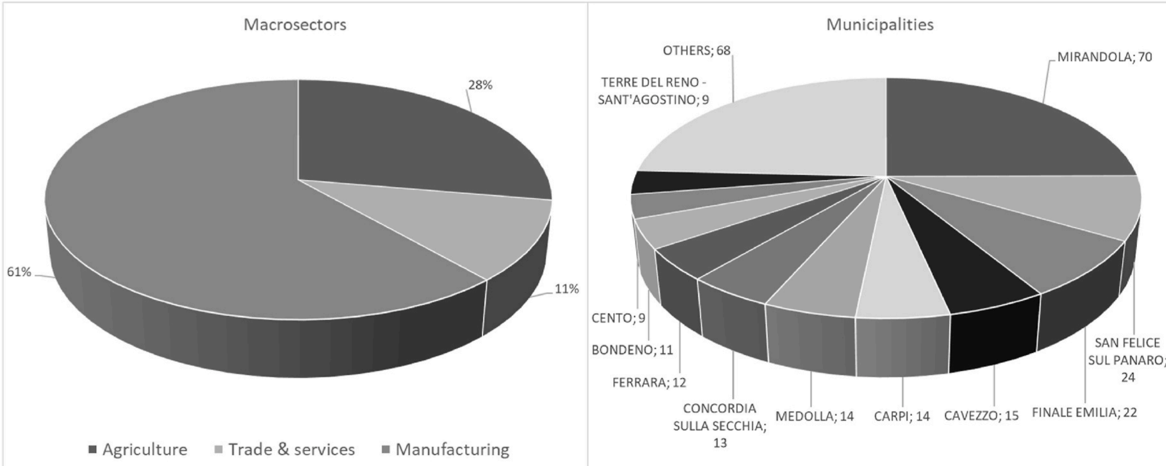

Fig. 1. Firms granted energy retrofit contribution, macrosectors, and municipalities
Source: own elaboration from Sfinge data.

Table 1
Sfinge-AIDA dataset key indicators (mean values, 2019).

Variable	No contribution	With Sfinge basic contribution	With Energy Efficiency contribution
Age in 2021	16	28	31
Foreign-owned	0.046	0.051	0.087
Value added (Euros)	789,454	2,463,762	7,702,589
Employees	11	31	87
ROI	6.78	6.91	5.23
Value added CAGR 2010–2019	2.30	2.66	3.42
N	16492	389	87

Source: own elaboration of AIDA and Sfinge data

Table 2
Industries by NACE Rev. 2 codes.

NACE Rev.2 Industries	n	%
Real estate activities	2721	16.04%
Wholesale trade, except of motor vehicles and motorcycles	1723	10.15%
Construction of buildings	1317	7.76%
Specialised construction activities	977	5.76%
Manufacture of fabricated metal products, except machinery and equipment	807	4.76%
Retail trade, except of motor vehicles and motorcycles	787	4.64%
Food and beverage service activities	738	4.35%
Manufacture of machinery and equipment n.e.c.	569	3.35%
Activities of head offices; management consultancy activities	545	3.21%
Wholesale and retail trade and repair of motor vehicles and motorcycles	444	2.62%
Manufacture of food products	321	1.89%
Computer programming, consultancy, and related activities	316	1.86%
Other professional, scientific, and technical activities	309	1.82%
Manufacture of wearing apparel	288	1.70%
Land transport and transport via pipelines	276	1.63%
Financial service activities, except insurance and pension funding	261	1.54%
Office administrative, office support and other business support activities	257	1.51%
Other sectors[a]	4312	25.41%
Total	**16,968**	**100%**

[a] The category Other sectors contains the remaining 62 sectors, including for instance “Repair and installation of machinery and equipment”, “Manufacture of textiles”, Manufacture of furniture”, etc., each representing about 1% of the sample.

reconstruction contributions to estimated productivity, we can generally infer a macroeconomic impact stemming from energy retrofit measures. Table 3 contains the main descriptive statistics of the variables used in the analysis.

5. Results

Results (Table 4) are consistent with emerging empirical evidence on the impact of energy efficiency retrofit on individual firms’ performance (Filippini et al., 2020; Montalbano et al., 2022). All coefficients in models (1)–(3) and most coefficients in model (4) have the expected signs and are statistically significant at the 95% or 99% level. The overall R^2 values of the estimates range between 49% and 55%. The lagged dependent variable has a positive sign, hinting at the importance of past performance in explaining labour productivity and controlling for endogeneity, as the best-performing firms might also have had better organisational structures and efficient processes, leading them to turn to the authorities for support soon after they were hit by the earthquake. Differences in productivity levels may also be caused by economies of scale and scope, which are better exploited by larger firms. Capital and investment affect labour productivity positively, as do firms’ age and belonging to a multinational group (Piscitello and Rabbiosi, 2005; De Kok, Fries, Brouwer, 2006). The Modena province’s value added and the difference in growth performance compared to the Italian average also have positive signs, while an increase in unemployment rates in the area negatively affects labour productivity. Businesses in our sample follow the overall business cycle, and when the province performs better than the Italian average, this is evident in our data. Dummies for two-digit NACE[14] sectors (model 3) are significant in 9 cases out of 71, with somewhat large positive coefficients for sector 35 (Electricity, gas, steam, and air conditioning supply) and 64 (Financial service activities, except insurance and pension funding). In our Modena province sample of businesses, however, the most frequent sectors for businesses are 68 (Real estate activities), 46 (Wholesale trade, except motor vehicles and motorcycles), and 41 (Construction of buildings), while among the firms being granted the Sfinge overall contribution, the most frequent sectors are 25 (Manufacture of fabricated metal products, except machinery and equipment), 28 (Manufacture of machinery and equipment n.e.c.), and 41 (Construction of buildings). Dummies for the municipalities (model 4) are almost never significant. The size categorical variable is negative

[14] In the correlation matrixes, NACE sectors are reported as ATECO, which are the Italian equivalent of NACE classification (https://www.istat.it/it/files//2022/03/Corrispondenza-Ateco-2022-vs-NACE-Rev.-2.xlsx).

Table 3
Descriptive statistics.

Variable name	Description	Mean	Std. dev.	Observations	Years
ln(Value added per capita)	value added per capita at firm level (deflated, in logs)	10.615	0.881	10702	6
ln(Capital per capita)	fixed assets per capita at firm level (deflated, in logs)	9.486	1.986	10482	6.1
ln(Investment)	change in the logs of capital per capita as a proxy of fixed investment	0.006	0.807	9207	5.9
Firm age	years from incorporation on January 1st, 2021	15.987	13.551	16944	10
Foreign owned	dummy variable = 1 if the firm has a foreign global ultimate owner	0.046	0.210	14044	10
ln(Modena province value added)	value added of the Modena province, in logs, deflated	10.027	0.038	16968	9
Modena unemployment rate	unemployment rate of the Modena province	6.679	0.801	16968	10
Earthquake	dummy variable, = 1 in 2012, year of the earthquake	0.100	0.300	16968	10
Modena - Italy V.A. growth rate	difference between the growth rate of the value added of the Modena province and Italy's one	0.008	0.016	16968	9
Energy Retrofit contribution	dummy variable, = 1 in the firm received the energy retrofit contribution	0.005	0.071	16968	10
Size[a]	size in terms of employees, where 0 is <10, 1 is ≥ 10 and <50, 2 is ≥ 50 and <250, 3 is ≥ 250	1.161	1.371	16968	10

[a] We use the number of employees as a measure for size since the revenue – turnover – variable is correlated (>50%) with the lagged value added variable and led to inconsistent estimates.

and significant in 3 out of 4 specifications. The dummy variable for 2012, the year of the earthquake, has a negative sign, while our key variable, the dummy variable for the energy retrofit contribution for the 87 firms in the sample, has a positive sign in all specifications.

Given the semi-log specification of our equation, we can interpret the coefficients in straightforward percentage terms: firms that received the energy retrofit contribution had labour productivity increases in the range of 10–13%, compared to firms that did not. The coefficient for the earthquake year dummy ranges from -7 to -9%, which provides another insight: given that all firms were negatively affected by the disaster, those who were given the energy retrofit contribution were helped in countering the decrease in value-added per capita by approximately 3–4%. The correlation matrix is reported in the Annex.

6. Discussion

Estimation results provide a key to address our empirical questions. ***RQ1***: we have a confirmation of the fact that government contributions had a positive effect on firms' estimated labour productivity. The contribution enters the profit function by reducing the retrofit cost of reconstruction: the positive and significant sign of the ϑ parameter in all model specifications hints for the successful policy intervention undertaken, even after correcting for the negative effect of the earthquake. It must be emphasised, however, that in the case of reconstruction interventions, regulations do not allow building anything without respecting current energy efficiency standards, so we should be cautious in assessing a straight a positive causation between EE contribution and labour productivity performance, as the reconstruction in itself might have had a positive effect. Also, we have to keep in mind a possible confounding factor, that we tried to control by means of the lagged variables, since larger firms are usually more productive than smaller ones, and larger firms were the ones more successful in applying and obtaining the contributions.

RQ2 speculated on the potential inference of the results to macroeconomic dimension. The benefits of cost-effective investments in energy efficiency and/or renewable energy can support the economy by lowering energy costs for businesses, increasing productivity, and creating jobs. The estimated effect of the policy action undertaken is suggested by Fig. 2. In terms of the total amounts of contributions granted to businesses in the Modena province, the amount of the Sfinge contribution received has a positive but decreasing effect on estimated labour productivity.

It appears that the benefit reaches a maximum at values of approximately 15 million Euros; therefore, there might be an optimal size of the contribution that spurs productivity. This may be related to a size effect, since smaller amounts of funds are not able to trigger a multiplicative effect on the performance of the firms, or it may be because the cost improvement reached is not large enough to affect the value added significantly. However, it also means that larger gains in labour productivity are likely to be observed for relatively smaller firms, for which the contribution amount is probably smaller, as the premises to retrofit are smaller or more geographically concentrated (whereas larger firms might have facilities in more locations in the province or in other provinces as well). This also emerges from the estimates, where the size variable – categorical for dimensional classes of employees – has a negative and statistically significant sign.

Positive effects over employment are also likely. The theoretical discussion of this point in the literature is inconclusive: it is often argued that high productivity growth leads to unemployment, especially in manufacturing, as a substitution effect prevails, and less specialised jobs are lost. This might be true in the short run or for specific firms or industries. However, in the longer run, macroeconomic policies can influence the number of jobs in addition to productivity growth. Although technological change can have significant impacts on a microeconomic level (depending on the bias of technological change, the prices of competing goods and services, and the price elasticity of demand), the effect on aggregate unemployment or employment is negligible in the long run (Nordhaus, 2005). Based on data for the G7 nations, Gordon (1995) shows that in the short term, a positive trade-off between productivity and unemployment may emerge. However, in the long run, adjustment processes (regarding capital accumulation or decumulation) can contribute to eliminating this trade-off. Based on data for the US economy, Nordhaus (2005) demonstrates that more rapid productivity growth leads to higher rather than lower employment in manufacturing.

Moreover, increased investment in energy retrofit of firms not only affects those production units affected by the reconstruction process but also spills over into those sectors involved in the energy efficiency business, not necessarily found in the earthquake-affected area.

Few empirical studies provide estimates of the effect of energy retrofit on employment. According to the U.S. Department of Energy (U.S. DOE), the production, installation, and servicing of energy efficiency and renewable energy resources and technologies provide a growing number of economic benefits to and employment for millions of Americans (U.S. DOE, 2017). Solar employment in the U.S. in 2016 accounted for more than 350,000 jobs, or 43% of the electric power generation workforce—the largest share of workers in the electric power generation sector. This was an increase of 25% compared to 2015. Wind employment in the U.S. in 2016 represented just over 100,000 jobs, or 12% of the electric power generation workforce, an increase of 32% compared to 2015. More than 2 million people were employed in the production or installation of energy efficiency products in 2016, a 7% increase compared to 2015. Compared to expected growth rates of 7% and 6% in the electric power generation sector and the transmission, distribution, and storage sector, respectively, solar and wind employment were expected to grow in 2017 by 7% and just under 4%, respectively, and energy efficiency was expected to grow by 9% in 2017 (U.S. DOE, 2017).

Many U.S. state and local energy efficiency and renewable energy programs and policies are sustaining and enhancing these trends,

Table 4
Random-effects GLS regression with robust standard errors.

Baseline model (1)

Value added per capita	Coefficient	Std. Err.	z	P > z	[95% Conf. Interval]	
Lagged Value added per capita	0.413	0.011	39.120	0.000	0.392	0.433
Capital	0.087	0.004	24.730	0.000	0.080	0.094
Investment	0.134	0.008	16.130	0.000	0.118	0.150
Foreign owned	0.210	0.030	7.080	0.000	0.152	0.268
Modena province value added	0.227	0.075	3.050	0.002	0.081	0.373
Unemployment	-0.019	0.004	-4.640	0.000	-0.027	-0.011
Energy Retrofit contribution	0.159	0.046	3.460	0.001	0.069	0.250
Earthquake	-0.078	0.010	-7.680	0.000	-0.097	-0.058
Modena - Italy growth rate	0.483	0.188	2.570	0.010	0.114	0.853
Size	-0.024	0.010	-2.370	0.018	-0.044	-0.004
constant	3.302	0.755	4.370	0.000	1.822	4.782
Number of obs.	35,527					
Wald chi2(9)	4821.24					
Prob > chi^2	0.0000					
R^2 overall	0.5589					

with firm age (2)

Value added per capita	Coefficient	Std. Err.	z	P > z	[95% Conf. Interval]	
Lagged Value added per capita	0.405	0.011	37.930	0.000	0.384	0.426
Capital	0.080	0.003	22.910	0.000	0.073	0.087
Investment	0.137	0.008	16.530	0.000	0.121	0.153
Firm age	0.005	0.000	10.950	0.000	0.004	0.006
Foreign owned	0.221	0.030	7.440	0.000	0.163	0.279
Modena province value added	0.318	0.075	4.230	0.000	0.171	0.465
Unemployment	-0.019	0.004	-4.590	0.000	-0.027	-0.011
Energy Retrofit contribution	0.141	0.048	2.960	0.003	0.048	0.234
Earthquake	-0.075	0.010	-7.470	0.000	-0.095	-0.056
Modena - Italy growth rate	0.427	0.188	2.280	0.023	0.059	0.795
Size	-0.042	0.010	-3.990	0.000	-0.062	-0.021
constant	2.438	0.757	3.220	0.001	0.954	3.922
Number of obs.	35,488					
Wald chi2(10)	5295.54					
Prob > chi^2	0.0000					
R^2overall	0.5531					

with sector dummies (3)

Value added per capita	Coefficient	Std. Err.	z	P > z	[95% Conf. Interval]	
Lagged Value added per capita	0.378	0.011	34.900	0.000	0.357	0.399
Capital	0.090	0.004	24.930	0.000	0.083	0.098
Investment	0.127	0.008	15.640	0.000	0.111	0.143
Foreign owned	0.178	0.028	6.320	0.000	0.123	0.233
Modena province value added	0.303	0.075	4.020	0.000	0.155	0.450
Unemployment	-0.020	0.004	-4.930	0.000	-0.028	-0.012
Energy Retrofit contribution	0.161	0.049	3.310	0.001	0.065	0.256
Earthquake	-0.075	0.010	-7.510	0.000	-0.094	-0.055
Modena - Italy growth rate	0.446	0.185	2.410	0.016	0.084	0.809
Size	-0.031	0.011	-2.880	0.004	-0.052	-0.010
Sector dummies			Yes[a]			
constant	2.240	0.845	2.650	0.008	0.585	3.896
Number of obs.	35,527					
Wald chi2(80)	-					
Prob > chi^2	-					
R^2 overall	0.5571					

with municipality dummies (4)

Value added per capita	Coefficient	Std. Err.	z	P > z	[95% Conf. Interval]	
Lagged Value added per capita	0.411	0.011	38.870	0.000	0.390	0.431
Capital	0.087	0.004	24.790	0.000	0.080	0.094
Investment	0.134	0.008	16.110	0.000	0.117	0.150
Foreign owned	0.199	0.030	6.720	0.000	0.141	0.257
Modena province value added	0.229	0.075	3.060	0.002	0.082	0.375
Unemployment	-0.019	0.004	-4.630	0.000	-0.027	-0.011
Energy Retrofit contribution	0.192	0.046	4.170	0.000	0.102	0.283
Earthquake	-0.077	0.010	-7.660	0.000	-0.097	-0.058
Modena - Italy growth rate	0.483	0.188	2.570	0.010	0.114	0.852
Size	-0.026	0.010	-2.570	0.010	-0.047	-0.006
Municipality dummies		Yes[a]				
constant	3.324	0.758	4.380	0.000	1.838	4.809
Number of obs.	35,527					
Wald chi2(56)	24347.69					
Prob > chi^2	0.0000					
R^2overall	0.5588					

[a]9 out 79 sectors are positive, statistically significant at 5%. The remaining sectors are either significant at lower levels or unsignificant. 5 out 46 municipalities are statistically significant and negative at 5%. The remaining municipalities are unsignificant.
Rˆ2 overall.
0.4926.

generating numerous economic benefits along the way.

Quantifying the economic influence of energy efficiency and renewable energy policies and programs can illustrate how the investments can spread economic value across the broader community. For example, a 2011 analysis of spending $44.4 million in a single future year on efficiency in Vermont was estimated to result in a net increase of close to 1900 jobs-years, nearly $100 million in additional personal income, approximately $350 million in output, and $220 million in gross state product over the next 20 years. Quantifying this type of information can also help analysts and decision makers identify opportunities for which meeting today's energy or environmental challenges can also serve as an economic development strategy. A simulation based on Italian data with a dynamic general equilibrium model by Garau and Mandras (Garau and Mandras, 2015) finds that.

'the increase in energy efficiency introduces a positive supply-side disturbance, whose primary effect is to raise production efficiency,

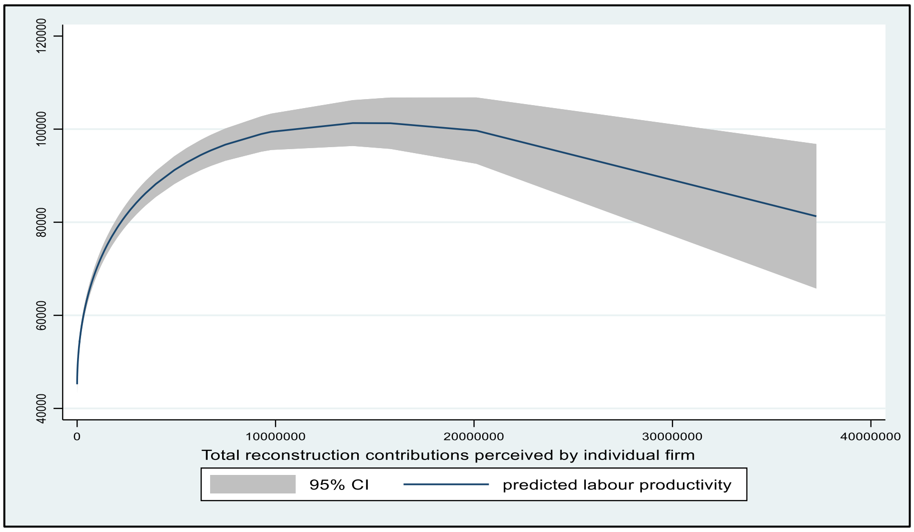

Fig. 2. Estimated labour productivity and total Sfinge contributions.
Source: own elaboration.

particularly in energy-intensive sectors. The efficiency gains stimulate economic activity through downward pressure on the prices, including the price of energy output since the energy supply sector itself is typically energy intensive. The energy efficiency improvements increase generate an increase in economic activity from the outset. GDP increases by 0.06% and 0.19% in the short and long runs, respectively. Employment rises in both periods by 0.06% and 0.13%'.

Our data are limited in that information on wages for employees is missing, so we cannot directly evaluate changes in purchasing power in the long run. In addition, we cannot observe the exact amounts of the energy retrofit contributions, as we only observe whether it has been granted within the overall package of Sfinge contributions.

Further research, coupling our data with information on wages and energy prices, could also lead, in the case of the 2012 earthquake in the Modena province, to a structured estimate of the impact of the reconstruction process in the labour market.

The negative and significant coefficient for the year of the disaster confirms the short-run negative impact of the supply shock. But, with few years available, it is difficult to draw a conclusion on a possible acceleration in economic growth in the Modena province or in the Emilia-Romagna region as a whole. When looking at regional-level data on economic performance in the considered time frame (Fig. 3, real value added province level data are not available), the impact of the 2008–2009 financial crisis, the earthquake in 2012 and the pandemic shock are all evident, but our study should be extended in order to infer an effect over macroeconomic performance in terms of gross domestic product and employment.

7. Conclusions and policy implications

Case studies are not abundant in the empirical economic literature on energy retrofitting of firms. Thanks to the availability of detailed firm-level data from the Modena province in the Emilia-Romagna region in Italy for 2010–2019, we are able to evaluate the firm-level labour productivity effects of the recovery contributions specifically granted to those firms that applied for public help and funding in the aftermath of

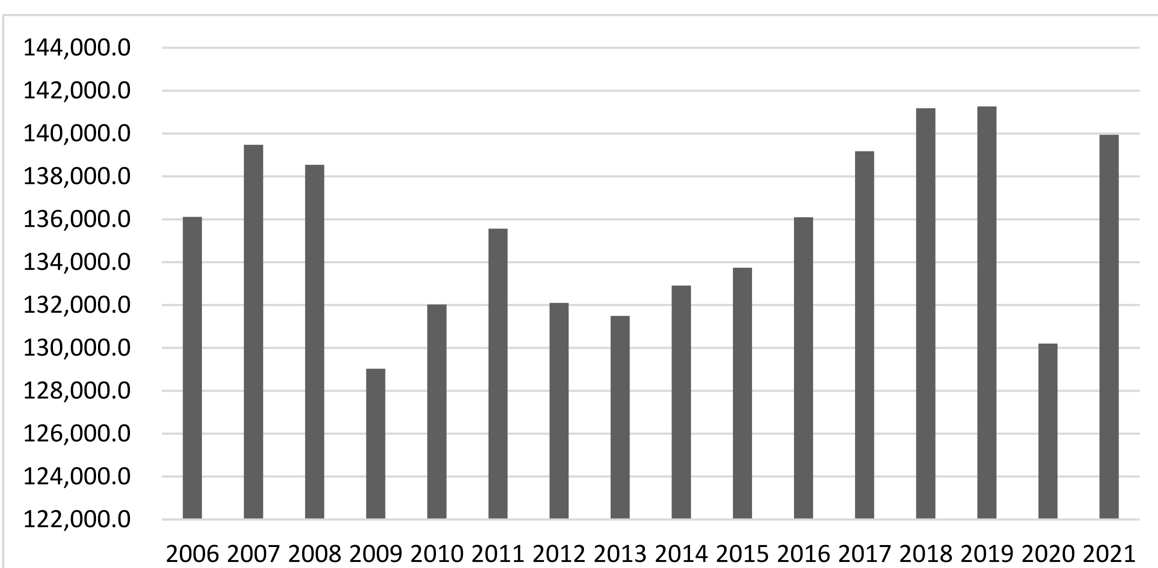

Fig. 3. Emilia Romagna real value added, 2006–2021 (base year = 2015)
Source: Istat

the 2012 earthquake. The Emilia-Romagna regional government envisaged a specific energy retrofit additional contribution for affected firms in their rebuilding and renovating their premises. Two objectives were pursued. Firms were given incentives to make greener investments, consistent with the Europe 2030 objectives of reducing greenhouse gas emissions, increasing the share of renewable energy use and improving energy efficiency. In addition, firms were helped with reconstruction after the earthquake, and since many buildings were aged, the earthquake represented an opportunity – if unwelcome –for all firms, even those not specifically applying for the energy retrofit contribution, to 'build back better'.

Our analysis illustrates that the firms that applied for the contribution were typically larger than the average, which might be because larger firms have more sophisticated organisational structures that allow them to devote resources to the application procedure. We also find that the effect of the energy efficiency contribution on labour productivity increases at a decreasing rate. Therefore, it appears that smaller interventions – likely for smaller businesses - for energy retrofitting might have a larger multiplier effect in terms of economic efficiency. Natural disasters typically set in motion a complex chain of events that can disrupt both the local economy and, in severe cases, the national economy. The economic literature on the long-term effects of natural disasters considers both the short and the long term. In the short term, the empirical findings in the literature show that GDP usually increases in the period immediately following a natural disaster since most of the damages caused by the disaster are reflected in the loss of capital and durable goods and since capital stock does not enter into GDP whereas its replacement does. In the long term, capital renovation and the adoption of new technology may provide a boost to economic growth. As a natural reaction to a disaster, governments usually adopt a fiscal expansion. Rebuilding and clean-up efforts generate temporary increases in retail sales of such items as construction materials and nonperishable items such as batteries, charcoal, and canned foodstuffs. Damaged or destroyed goods such as clothing, furniture, and other household items are replaced, and roads, bridges and other structures are repaired or rebuilt. This rebuilding activity usually generates both increased sales tax receipts and additional employment. Thus, one ironic feature of a disaster is that it spurs the pace of economic activity in the affected region.

The success of a fiscal expansion, however, also depends on the simultaneous intervention of insurance payments. For the businesses considered in our study, the average insurance payment was approximately 15% of the total recognised damages. By 2015, almost 4 billion EUR had been granted for private reconstruction, homes, and businesses, while more than 1 billion euros had been cleared by private insurance companies.

Combining all these elements – the potential for reconstruction, the public commitment, and the insurance contributions – together with economic aspects of improvement in firms' performance stemming from our empirical analysis of private firms in the Modena province, we can conclude that the earthquake triggered not only a cost-saving process from energy retrofitting but also deeper renovation and reconstruction which are likely to have both short- and long-term positive growth effects to be assessed by longer-term ex post studies in the future.

CRediT authorship contribution statement

Maria Giovanna Bosco: Conceptualization, Methodology, Software, Management, Writing – original draft, Writing – review & editing, Validation. **Elisa Valeriani:** Data curation, Conceptualization, Visualization, Investigation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table A1
Correlation matrix. The correlation matrix for the model with firm age is reported.

Model with firm age (2)												
	Value added per capita_1	Capital	Investment	Firm age	Foreign owned	Modena province value added	Unemployment	Energy Retrofit contribution	Earthquake	Modena - Italy growth rate	Size	constant
Value added per capita_1	1											
Capital	-0.3784	1										
Investment	0.1078	0.008	1									
Firm age	-0.3139	-0.06	0.0656	1								
Foreign owned	-0.1954	0.0655	0.0071	0.1122	1							
Modena province value added	-0.1201	0.0457	-0.1563	0.1235	0.0206	1						
Unemployment	0.1182	0.0247	-0.056	-0.06	-0.0426	0.1748	1					
Energy Retrofit contribution	-0.0267	-0.0423	0.0371	0.0017	-0.0248	-0.0055	-0.0411	1				
Earthquake	-0.0661	0.0537	-0.0695	0.0028	-0.0141	0.4786	0.5446	-0.0052	1			
Modena - Italy growth rate	0.0683	-0.0833	-0.1016	-0.048	-0.0054	0.1444	-0.5786	0.0067	-0.279	1		
Size	-0.0126	-0.1723	-0.3551	-0.2344	-0.205	0.045	0.0405	-0.1677	0.0791	0.097	1	
constant	-0.0133	-0.0316	0.1422	-0.0829	0.0059	-0.9896	-0.2282	0.0131	-0.4902	-0.1312	-0.0399	1

Data availability

The authors do not have permission to share data.

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