ASSESSING THE EFFECTIVENESS OF ENERGY EFFICIENCY MEASURES IN THE RESIDENTIAL SECTOR THROUGH DYNAMIC TREATMENT EFFECTS: EVIDENCE FOR THE UNITED KINGDOM

Cristina Peñasco, Department of Politics and International Studies, University of Cambridge, +44 01223 767242, cp633@cam.ac.uk
Laura Diaz Anadon, Department of Land Economy, University of Cambridge, +44 01223 337156, lda24@cam.ac.uk

Overview

Improving energy efficiency (EE) is vital to ensure a sustainable, affordable, and secure energy system. The residential sector represents, on average, 18.6% of the total final energy consumption in the OECD countries in 2018, reaching one of the highest percentages of Europe in the UK, with 29.5% of total final energy consumption (IEA, 2020). The aim of this paper is to shed light on the extent to which technical energy efficiency improvements, specifically the installation of loft insulation and cavity walls, are associated by changes in residential gas consumption in the UK. More importantly, this paper analyses the dynamic effects of the installation of such measures and the lasting effect of the gas consumption reductions Recently several studies have aimed to estimate the impact of household EE technical improvements on energy consumption using different techniques including general equilibrium models (Lecca et al., 2014; Bye et al., 2018; Figus et al., 2017; Wei and Liu, 2017; Kulmer and Seebauer, 2019), microeconomic demand systems (Tovar and Wolfing, 2018) and input-output models (Thomas and Azevedo, 2013; Freire-González et al., 2017). One of the last contributions regarding the potential of energy savings in the household sector in the UK has been Rosenow et al. (2018) who estimate the lifetime energy savings associated to different levels of deployment of energy efficiency technologies up to 2035. There is a wide range of ex ante assessments in the literature. With a few notable exceptions (Trotta, 2018; Elsharkawy and Rutherford, 2018; Adan and Fuerst, 2016; Webber et al., 2015), there is a gap in the literature in terms of ex-post evaluations of the changes in residential energy consumption that follow the implementation of different EE technical improvements. The evaluation of actual energy savings in the UK and the factors that may influence residential energy consumption or the impact of different EE technical measures, is timely, particularly given the perceived policy failures in the residential EE space (See, e.g. Kjaerbye et al., 2011; Sovacool et al., 2017; DBEIS, 2016). This paper contributes to the current literature in the following ways. First, to the best of our knowledge, this is the first study analysing the gas consumption patterns in the UK at the micro level for a large panel of households of more than 50,000 dwellings and 700,000 observations. Second, we apply a novel approach based on a staggered differences-in-differences (DiD) methodology considering dynamic treatment effects. As per our knowledge this is the first study aiming at disentangling the long lasting effects of EE technical improvements in residential buildings with observational and ex-post data, through an event study.

Methods

Using a staggered DiD approach with dynamic treatment effects, we analyse changes in residential gas consumption before and after the adoption of energy efficiency measures in an event study design. The analysis includes households' technical energy efficiency interventions subjected to energy efficiency programmes in England and Wales between 2005 and 2017 using a total of 717,002 observations corresponding to a panel of 55,154 households from the National Energy Efficiency Data-Framework (NEED). The EE measures installed corresponds to EE improvements carried out under National EE support schemes. The technical energy efficiency measures covered in this paper are loft insulation and cavity wall installation. We will focus on gas consumption as 85% of the dwellings in the UK by 2018 relied on gas central heating systems (Ministry of Housing, Communities and Local Government, 2019). We identify and estimate the effect of the treatment using a generalization of the DiD approach with multiple time periods, variations in the treatment timing and the parallel trend assumption holding after controlling for possible confounding covariates. Cerulli and Ventura (2019) have developed an estimation methodology to the case of binary time-varying treatment with pre and post intervention periods. We use their development to analyse the differences in energy consumption of households 5 years before and after the implementation of EE improvements. With this approach, we can not only analyse the effect of the EE improvements but also if there are some anticipatory or delay effects. An analysis of the energy savings inequality using percentile shares is also included. Robustness checks are performed using Propensity Score Matching (PSM).

Results

Our results indicate that the adoption of EE measures is associated with significant reductions in household residential gas consumption one year after their implementation. The coefficient of the EE installation (EEMit) is statistically significant across estimations confirming that the introduction of an EE improvement generates a decrease in the gas consumption of the households analysed. The coefficients accompany the introduction of an EE improvement varies between -0.061 (reduction of 6.1%) for the installation of loft insulations to -0.113 (reduction in gas consumption of around 11.3%) for cavity walls installations. We conclude therefore, that the installation of cavity walls almost doubles the energy saved, i.e. gas, in comparison to loft insulation installations. However, the effect does not last in the long run and energy savings disappear four years after retrofitting for cavity wall insulation measures and after one-two years for loft insulations. The segmentation of the sample confirms that, this negative result could be explained by either the rebound effect and/or by concurrent residential projects and renovations that can increase energy consumption. Overall, the effect of those installations in the gas consumption is smaller in households with conservatories (~5% only in the first year after the installation), than in those dweelings without conservatories (~7% one year after the installation plus additional reductions in gas consumption of around 3% during the second year). However, as we have seen for the whole sample, the effect in this case disappear in two years. This seems to correspond approximately with the payback time of an installation. For our prefer estimation, i.e. ols staggered diff-in-diff with dynamic treatment effects controlling for covariates, anticipatory effects cannot be detected. Using percentile share analysis, we can observe unequal distributions in energy savings. For households in deprived areas the installation of technological interventions does not deliver energy savings. These results confirm the existence of backfire effects and the magnitude of energy efficiency rebounds show potential to completely offset any energy savings for certain groups. The particular lack of effect on the poorest segments of the population may provide a rationale to focus the attention on the barriers that may prevent those households to get potential energy savings derived from the adoption of EE measures. However, it must be highlighted that the introduction of EE technical improvements measures makes households on deprived areas more responsive to changes in energy prices. This represents a positive outcome as EE measures may be acting as tools for the flexibility of the energy demand in the residential sector. They also reduce inequalities between groups of consumers allowing households at the bottom of the gas consumption distribution to increase their gas consumption in absolute and relative terms regarding their peers at the top of the distribution. This result implies positive impacts of EE measures in reducing fuel poverty in deprived areas of the UK geography.

Conclusions

The results show that the adoption of EE measures in households lead to a decrease in the demand of gas consumption right after the adoption. However, the energy gains generated from the installation of those technical measures, i.e. loft insulation and cavity walls, do not long last. Energy savings dissolve two to four years after the adoption for cavity wall installations. Loft insulation effect only lasts one to two years. Attention must be paid to the fact that the impact of the adoption of these measures varies considerably depending on the level of deprivation of the areas in which households are located and the existence of conservatories in the households.

Several implications derive from this research. First, our paper shows that energy efficiency gains derived from the technical installation of energy efficiency measures are only effective in the short-term. Further research is therefore needed in understanding the reasons behind the lack of long-lasting effects. We hypothesize that the implementation of energy efficiency schemes consisting of a mix of regulatory instruments, i.e. tighter standards for newly constructed dwellings and for renovations, financial incentives, i.e. grant, loans or subsidies, and soft instruments is needed. Soft instruments influencing behaviour might be key to get long-term efficiency gains. Second, energy efficiency gains vary widely among households located in areas with different levels of deprivation. Considering the domains of the Index of Multiple Deprivation (IMD) of the UK Government, we assume that those households in the lowest quintile of the IMD represent households with low-income levels, low education attainment and that are more likely to be hit by unemployment. Our results determine that households in the first and second quintile of the IMD do not experience the same levels of energy efficiency gains after the installation of technical efficiency improvements. This conclusion is reinforced by the result obtained with the analysis of percentile shares of the total gas consumption distribution where we see that the bottom 20% of the distribution increases their gas consumption after the installation of EE measures. While energy efficiency policies therefore may be having a positive impact on reducing fuel poverty, e.g. those households become more sensitive to changes in energy prices and they reduces the inequality gap with their peers at the top of the distribution; the energy efficiency schemes are not effective in this segment of the population and they do not get the expected energy savings. This result is relevant for the design of measures that may need to be targeted differently depending on the group and the intended objective, e.g. reduction of fuel poverty vs. energy efficiency savings. Finally, our results highlight the specific difficulties of the British housing stock associated to the very high natural gas penetration and the traditional existence of conservatories in households that may be counteracting the positive effects of the energy efficiency technical improvements. UK with a 62.7%, is the second country in Europe, after The Netherlands (70.9%) with the highest share of gas in the final energy consumption in the residential sector (Eurostat, 2017). Our results call for the urgent need to fully incorporate human behaviour into ex-ante modelling of energy use and to complement energy efficiency policies oriented to support the adoption of measures from a financial point of view with soft instruments that allow to integrate behaviours into the new ambience of households with EE improvements.

References

Adan, H., Fuerst, F. (2016). Do energy efficiency measures really reduce household energy consumption? A difference-in-difference analysis. Energy Efficiency 9: 1207–1219. https://doi.org/10.1007/s12053-015-9418-3

Bye, B., Faehn, T., Rosnes, O. (2018) Residential energy efficiency policies: Costs, emissions and rebound effects. Energy, 143: 191:201.

Cerulli, G. and Ventura, M. (2019) 'Estimation of pre- and posttreatment average treatment effects with binary time-varying treatment using Stata', The Stata Journal, 19(3), pp. 551–565. doi: 10.1177/1536867X19874224.

DBEIS (2016). Smart Meter Rollout, Cost-Benefit Analysis. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567167/OFFSEN_2016_smart_meters_cost-benefit-update_Part_I_FINAL_VERSION.PDF.

Elsharkawy, H., Rutherford, P. (2018). Energy-efficient retrofit of social housing in the UK: Lessons learned from a Community Energy Saving Programme (CESP) in Nottingham. Energy and Buildings, 172: Pages 295-306

EUROSTAT (2017). Energy Statistics, 2017. Eurostat. https://ec.europa.eu/eurostat/data/database Last access 30th August 2018

Figus, G., Turner, K., McGregor, P., Katris, A. (2017). Making the case for supporting broad energy efficiency programmes: Impacts on household incomes and other economic benefits. Energy Policy, 111: 157-165.

Freire-Gonzalez, J., Font Vivanco, D., Puig-Ventosa, I. (2017). Economic structure and energy savings from energy efficiency in households. Ecological Economics, 131: 12-20.

IEA (2020). World Energy Balances: Overview, IEA,/OECD, Paris https://www.iea.org/reports/world-energy-balances-overview

Kjaerbye, V.H., Larsen, A.E., Togeby, M. (2011). Do changes in regulatory requirements for energy efficiency in single-family houses result in the expected energy savings? ECEEE 2011 Summer study. Energy efficiency first: The foundation of a low carbon society. Rome.

Kulmer, V. and Seebauer, S. (2019). How robust are estimates of the rebound effect of energy efficiency improvements? A sensitivity analysis of consumer heterogeneity and elasticities'. Energy Policy, 132: 1–14. doi: https://doi.org/10.1016/j.enpol.2019.05.001.

Lecca, P., McGregor, P. G., Swales, J. K., & Turner, K. (2014). The added value from a general equilibrium analysis of increased efficiency in household energy use. Ecological Economics, 100: 51-62.

Ministry of Housing, Communities and Local Governments (2019). English Housing Survey Energy efficiency, 2018-19. UK Government.

Rosenow, J., Guertler, P., Sorrell, S., Eyre, N. (2018): Remaining potential for energy efficiency in UK homes. Energy Policy, 121: 542-552

Sovacool, B.K., Kivimaa, P., Hielscher, S., Jenkins, K. (2017). Vulnerability and resistance in the United Kingdom's smart meter transition. Energy Policy, 109: 767-781.

Thomas, B. A. and Azevedo, I. L. (2013). Estimating direct and indirect rebound effects for U.S. households with input–output analysis. Part 2: Simulation. Ecological Economics, 86: 188–198. doi: https://doi.org/10.1016/j.ecolecon.2012.12.002.

Tovar M.A., Wolfing, N.M. (2018). Household energy prices and inequality: Evidence from German microdata based on the EASI demand system. Energy Economics, 70: 84-97.

Trotta, G. (2018). Factors affecting energy-saving behaviours and energy efficiency investments in British households. Energy Policy, 114: 529-539.

Webber, P., Gouldson, A., Kerr, N. (2015). The impacts of household retrofit and domestic energy efficiency schemes: A large scale, ex post evaluation. Energy Policy, 84: 35-43

Wei, T. and Liu, Y. (2017). Estimation of global rebound effect caused by energy efficiency improvement. Energy Economics, 66: 27–34. doi: https://doi.org/10.1016/j.eneco.2017.05.030.