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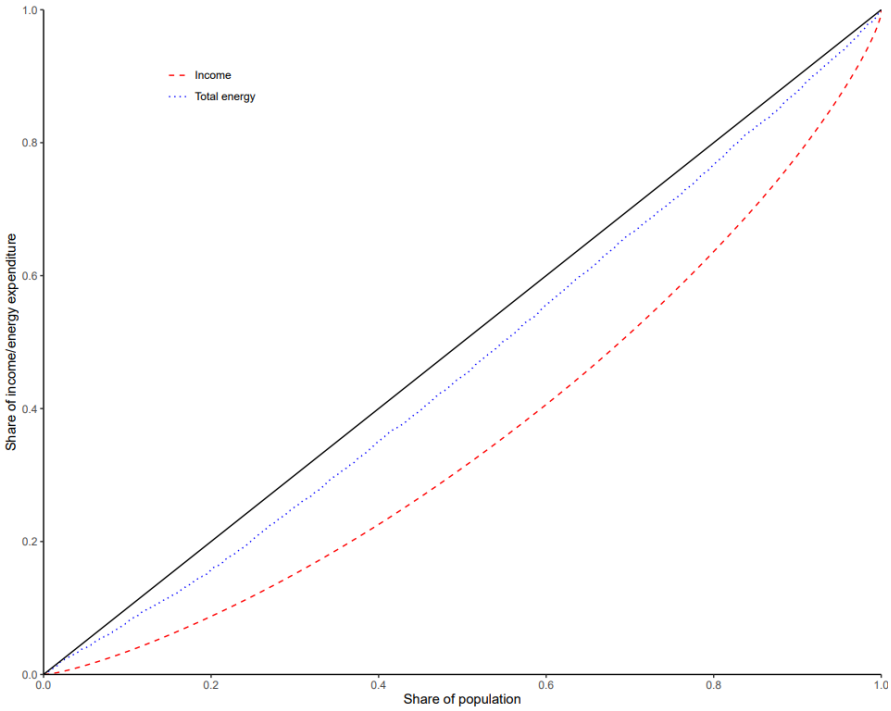
Federal Department of the Environment,
Transport, Energy and Communications DETEC

Swiss Federal Office of Energy
Energy Research and Cleantech

Interim report from 7 November 2024

Energy Burdens Unveiled

A Comparative Study of Household Energy Expenditure Inequality in Switzerland and EU Countries



Source: Authors calculation. The Lorenz curves illustrate the energy expenditure and income inequalities. On the x axis households are ordered by income levels from low to high. The y axis depicts the cumulative share of total energy expenditures or income in Switzerland. Therefore, the higher the degree of convexity, the higher the respective inequality. Total equality is represented by the 45-degree line. If the distribution of income is more concentrated than energy expenditures (as in the graph above), energy expenditures are regressive.

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Publisher:
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Berne
www.energy-research.ch

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SFOE contract number: SI/50502524-01

The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Summary

During the second year of the project, we focused on the empirical analysis of the distribution of housing-related energy expenditures based on data retrieved from the Swiss and European household budget surveys. The primary objective was to quantify the regressive nature of energy expenditures with different measures. This analysis spanned various European countries, enabling cross-country comparisons. Additionally, we decomposed energy expenditure concentrations by various socio-economic covariates and simulated the effect of price increases triggered by the Ukraine conflict on housing related energy expenditures for different income quintiles. The initial results, presented at different academic conference and published as a CESifo working paper, highlight that the regressivity of energy expenditures in Europe, as measured by the Kakwani index, ranged from -0.26 (Luxembourg) to -0.07 (Bulgaria). Switzerland, with a Kakwani index of -0.20, is among the European countries with a relatively higher degree of regressivity. The degree of regressivity of housing related energy expenditures remained constant during the analysed time period between 2006 and 2017.

In contrast, compared to other European countries, Switzerland exhibits the lowest shares of income spent on energy across all income quintiles. Households in the lowest income quintile allocated 2017 8.6% of their income to energy expenses, while those in the highest quintile allocated 2.6%. Hence, in terms of energy poverty—defined as the share of the population spending more than 10% of their income on energy—Switzerland ranks lowest at 7.9%, alongside Luxembourg. Between 2006 and 2017, the share of income spent on energy slightly decreased. However, our simulations reveal an increase in these shares for all income quintiles following the onset of the Ukrainian conflict.

A decomposition of energy expenditure concentration indicates that income represents the primary factor driving the concentration of energy expenditures. However, variables such as household size feature a negative contribution to the concentration, thus counteracting the effect of other factors and hence resulting in a more uniform distribution of energy expenditures across income quintiles.

Preliminary findings from the second research project related to the likelihood of exposure to air pollution and its association with socio-economic variables support the results from the established literature: income is negatively associated with pollution exposure, while tenancy and urban residency are positively correlated with higher pollution levels. For instance, we compute that in Switzerland, the probability to live in areas subject to pollution and grime amounts to 16.7% for the lowest income decile and to 12.4% for the 10th income decile. For comparison, the numbers are higher are higher across all income deciles in Germany, where we compute a probability of 23% and 20.6% for the first and tenth income decile respectively. Further analysis will investigate whether these patterns are consistent when using satellite air pollution data, which we plan to integrate with survey data. This additional analysis will help determine if any discrepancies can be attributed to (missing) information on air quality.

Zusammenfassung

Im zweiten Jahr des Projektes haben wir die Verteilung der haushaltsbezogenen Energieausgaben. empirisch untersucht. Dazu wurden Daten aus der schweizerischen und europäischen Haushaltsbudgeterhebung verwendet. Das Hauptziel bestand darin, den regressiven Charakter der Energieausgaben mit verschiedenen Maßen zu quantifizieren. Diese Analyse erstreckte sich auf verschiedene europäische Länder und ermöglichte so länderübergreifende Vergleiche. Darüber hinaus haben wir die Energieausgabenkonzentrationen nach verschiedenen sozioökonomischen Kovariaten aufgeschlüsselt und die Auswirkung der Energiepreiserhöhungen infolge des Ukraine Konfliktes auf die Energieausgaben simuliert. Die ersten Ergebnisse, die auf verschiedenen wissenschaftlichen Konferenzen vorgestellt und als CESifo-Arbeitspapier veröffentlicht wurden, zeigen, dass die Regressivität der Energieausgaben in Europa, gemessen am Kakwani-Index, zwischen -0,26 (Luxemburg) und -0,07 (Bulgarien) liegt. Die Schweiz liegt mit einem Kakwani-Index von -0,20 unter den Ländern mit einer relativ höheren Regressivität. Diese Regressivität blieb über den betrachteten Zeitraum zwischen 2006 und 2017 konstant.

Allerdings weist die Schweiz über alle Einkommensquintile hinweg die niedrigsten Einkommensanteile für Energieausgaben im europäischen Vergleich auf. Die Haushalte im untersten Einkommensquintil wenden 8,6 % ihres Einkommens für Energiekosten auf, während es im obersten Quintil 2,6 % sind. Das widerspiegelt sich auch wenn man die Energiearmut betrachtet - definiert als der Anteil der Bevölkerung, der mehr als 10 % seines Einkommens für Energie ausgibt. Hier weist die Schweiz mit 7,9 % neben Luxemburg den niedrigsten Wert auf. Zwischen 2006 und 2017 ist der Anteil des Einkommens, der für Energie ausgegeben wird, leicht zurückgegangen, obwohl er nach dem Ausbruch des Ukraine-Konflikts gestiegen ist, wie unsere Simulationen zeigen.

Eine Aufschlüsselung der Energieausgabenkonzentration zeigt, dass das Einkommen der wichtigste Faktor für die Konzentration der Energieausgaben ist. Variablen wie die Haushaltsgröße tragen jedoch negativ zur Konzentration bei, was der Wirkung anderer Faktoren entgegenwirkt und zu einer gleichmäßigeren Verteilung der Energieausgaben über die Einkommensklassen hinweg führt.

Die vorläufigen Ergebnisse unserer Analyse zwischen dem Zusammenhang sozioökonomischer Variablen und der Wahrscheinlichkeit von Luftverschmutzung betroffen zu sein unterstützen die gängige Literatur: Das Einkommen steht in negativem Zusammenhang mit der Luftverschmutzung, während Mietverhältnisse und der Wohnort in der Stadt positiv mit einer höheren Luftverschmutzung korreliert sind. Wir berechnen mit Hilfe der Umfragedaten, dass die Wahrscheinlichkeit am Wohnort von Umweltverschmutzung betroffen zu sein in der Schweiz für das niedrigste Einkommensdezil 16.7% und für das höchste Einkommensdezil 12.4% beträgt. Deutschland weist beispielsweise höhere Werte auf, da hier die Wahrscheinlichkeiten 23% respektive 20.6% für das niedrigste und höchste Einkommensdezil betragen. In weiteren Analysen werden wir untersuchen, ob diese Muster auch bei der Verwendung von Satellitenluftverschmutzungsdaten, die wir in die Erhebungsdaten integrieren wollen, übereinstimmen. Diese zusätzliche Analyse wird dazu beitragen, Erkenntnisse zu gewinnen, ob etwaige Diskrepanzen auf (fehlende) Informationen zur Luftqualität zurückgeführt werden können.

Résumé

Au cours de la deuxième année du projet, notre enquête empirique s'est concentrée sur la répartition des dépenses énergétiques liées au logement. Nous avons utilisé les données des enquêtes suisses et européennes sur le budget des ménages. L'objectif principal était de quantifier la nature régressive des dépenses énergétiques avec différentes mesures. Cette analyse a porté sur plusieurs pays européens, ce qui a permis des comparaisons entre pays. En outre, nous avons décomposé les concentrations de dépenses énergétiques en fonction de diverses covariables socio-économiques et simulé les dépenses énergétiques après le début de la guerre en Ukraine. Les premiers résultats, présentés lors de différentes conférences universitaires et publiés dans un document de travail CESifo, soulignent que la régressivité des dépenses énergétiques en Europe, mesurée par l'indice de Kakwani, varie de -0,26 (Luxembourg) à -0,07 (Bulgarie). La Suisse, avec un indice de Kakwani de -0,20, présente une régressivité élevée par rapport aux pays européens. Cette régressivité est restée constante entre 2006 et 2017.

En comparaison européenne, la Suisse affiche les parts de revenus les plus faibles consacrées à l'énergie pour tous les quintiles de revenus. Les ménages du quintile de revenu le plus bas consacrent 8,6 % de leur revenu aux dépenses énergétiques, tandis que ceux du quintile le plus élevé y consacrent 2,6 %. Cette tendance est également évidente dans la mesure de la pauvreté énergétique - définie comme la part de la population dépensant plus de 10 % de son revenu pour l'énergie - où la Suisse enregistre avec 7,9 % une des plus faibles valeurs, aux côtés du Luxembourg. Entre 2006 et 2017, la part du revenu consacrée à l'énergie a légèrement diminué, bien qu'elle ait augmenté après le début du conflit Ukrainien, comme le montrent nos simulations.

Une décomposition de la concentration des dépenses énergétiques indique que le revenu est le principal facteur de concentration. Toutefois, des variables telles que la taille du ménage contribuent

négativement à la concentration, contrebalançant d'autres facteurs et entraînant une répartition plus uniforme des dépenses énergétiques entre les niveaux de revenus.

Les résultats préliminaires de notre analyse sur la probabilité d'exposition à la pollution de l'air et son association avec les variables socio-économiques confirment la littérature établie : le revenu est négativement associé à l'exposition à la pollution, tandis que la location et la résidence urbaine sont positivement corrélées avec des niveaux de pollution plus élevés. Une analyse plus poussée permettra de déterminer si ces modèles sont cohérents lorsque l'on utilise des données satellitaires sur la pollution de l'air, que nous prévoyons d'intégrer aux données d'enquête. Cette analyse supplémentaire permettra de déterminer si les divergences peuvent être attribuées à des informations (manquantes) sur la qualité de l'air.

Contents

1 Introduction

1.1 Context and motivation

The transformation of energy systems has economic, social, and environmental impacts. Transition pathways must be designed to ensure energy policies do not disproportionately burden certain population groups. While governments globally prioritize income redistribution and environmental concerns, practical challenges arise in addressing both simultaneously. Policies targeting environmental externalities, like carbon pricing, often increase electricity or heating costs, exacerbating income inequality. For instance, in 2018, the lowest-income EU households spent an average of 8.3% of their expenditures on energy (excluding transport), reaching 22% in Slovakia. Nearly 19% of lower-middle-income households in the EU struggled to keep their homes adequately warm. In Switzerland, households with monthly incomes below 4,530 CHF allocated about 3.4% of their expenditures to energy between 2015 and 2017. Rising energy prices have heightened these concerns; for example, heating oil in Switzerland nearly doubled in price between January 2021 and April 2022, while gas costs increased by 40%. This project examines the distributional impacts of energy policies across Europe using household survey data and empirical methods. The data enables analysis of variations in household energy expenditures across socio-demographic factors like income, age, household size, and urbanity.

Additionally, we explore which households suffer from pollution in their living environments, as air pollution has been shown to harm health outcomes and even increase mortality. Understanding the factors that influence a household's exposure to pollution can reveal who stands to benefit from a cleaner energy transition. Further, we aim to explore the discrepancy of findings described above between perceived and actual measured pollution levels. Previous research highlights several correlations and distinctions that warrant further investigation. For instance, studies indicate that measured air pollution at an individual's residence does not necessarily reflect their true exposure, as people spend much of their time in other locations (e.g., workplaces, recreational areas). Moreover, research shows that individuals often base their behaviour on perceived pollution rather than on actual measurements. For health-conscious behaviour to be effective, it is crucial that perceived and actual pollution levels align closely. Therefore, in the final phase of our project, we intend to examine how information about air quality—such as coal plant closures, smog alerts, and similar public advisories—affects the gap between perceived and actual air pollution levels.

Our findings aim to inform policymakers about the trade-offs involved in achieving both environmental and equity objectives in energy policy.

1.2 Project objectives

Energy policies commonly aim to achieve multiple objectives, including emissions reduction, the promotion of renewable energy, and the enhancement of energy efficiency. However, the implementation of these diverse policies often encounters resistance, primarily due to concerns within the population regarding potential equity consequences. Therefore, this project is designed to gain a better understanding of how the costs associated with energy policies are distributed in the population. To achieve this, we quantify the distribution of living expenditures related to energy among households across various income quintiles. Additionally, we quantify the degree of regressivity of energy expenditures by various measures. This comprehensive analysis seeks to provide valuable insights into the social and economic implications of energy policy measures and address concerns related to equity and distributional impacts.

After analyzing the distribution of housing related energy expenditures in the first project, we focus in the second project on the distribution of pollution related exposure among households. Specifically, we examine the likelihood that households are subject to pollution and grime in their living conditions, and how this likelihood varies according to socio-demographic characteristics. Here, it is essential that we distinguish between actual and perceived air pollution. This analysis enables a better understanding of

which population groups would benefit from improved environmental quality resulting from the energy transition.

2 Approach, method, results and discussion

For this project, we rely on cross national longitudinal household-level survey microdata methods, to assess the distributional impact of energy policy. Having access to data from a large number of countries (including Switzerland) and years, allows us to leverage variation in energy related housing expenditures. Countries differ with respect to their power generation mix or levy higher or lower energy taxes or use different energy sources for heating and all of these translate into different energy prices and hence energy related housing expenditures (electricity, heating). Thus, we identify socio-demographic and housing conditions that influence the distribution of energy related housing expenditures across the income distribution, but also according to the degree of urbanisation, tenure and dwelling type. Furthermore, for the case of Switzerland, we also assess how these vary according to the language region or between rural and urban areas. The Swiss Household Budget Survey (HBS) contains information on energy related housing expenditures, income, household appliances and many socio-demographic characteristics for the years 2006-2008, 2009-2011, 2012-2014 and 2015-2017.

We scrutinize the degree of regressivity of energy expenditures by computing “Housing Energy Expenditures Concentration and Kakwani” indices (Kakwani, 2005) and depict the corresponding Lorenz curves. These indicators are computed for European countries for different years. The indicators reflect the housing related energy expenditure inequality by showing the distribution of energy expenditures in the population for different countries (including Switzerland) and years and comparing the energy expenditure concentration with the concentration of income to quantify the regressivity of energy expenditures.

Such energy/electricity related Kakwani coefficients have not been computed in this form for Switzerland yet. We decompose these coefficients and show how these indicators vary between the seven administrative regions as well as between the French and the German speaking part of the country. In addition, we also compute measures of energy poverty such as the ten per cent rule or twice the median criterion. Furthermore, as an alternative to the Kakwani index, we also measure the degree of convexity of the distribution of the share of income spent on energy. Lastly, we decompose the concentration of energy expenditures by various covariates.

Furthermore, in order to be able to assess the benefits of increased environmental quality from a clean energy transition, we first need to have a better understanding of the environmental quality of living conditions across households of different types. We employ data from the Statistics on Income and Living Conditions (SILC) to analyse this question. Hence, we assess the proportion of households whose living conditions are affected by pollution or grime across countries and years and empirically estimate the probability of being affected by poor environmental quality by means of logistic regression. For Switzerland, if data quality allows, the analysis can be also performed at the NUTS2 level (the 7 regions – Genfersee, Espace Mittelland, Nordwestschweiz, Zurich, Ostschweiz, Zentralschweiz and Ticino). In a next step we intend to merge actual air pollution satellite data to the survey data from the socio-economic panel (SOEP) in Germany which has the same question about air pollution perception as in the SILC data. This allows us to do the same regressions as with the perceived air pollution and compare the relationships with the socio-economic variables.

Subject to being able to merge the SILC data with data to regional variation in information on air quality like the closing or building of a coal fired power plant or Smog-alarm, we identify the effect of information on the discrepancy between actual and perceived air pollution.

For the first research project we find that in 2017, the poorest and richest households in the survey spent 8.6% and 2.6% of their equivalent disposable income on household energy expenditures. These

numbers do not vary much between administrative regions, with slightly higher shares for the French and Italian speaking regions. Furthermore, the difference of 6 percentage points between the burden for the poorest and richest households in the survey is among the smallest compared to the analysed EU countries where the difference can even reach 19 percentage points (Croatia). One possible explanation for these marked differences, can be the influence of heating type. For instance in Croatia, the share of coal heating is almost 5 percentage points higher in Q1 than in Q5 in 2020, whereas in Belgium, one of the countries with the lowest difference in the burden, heating systems of all types are very evenly distributed among income groups. Furthermore, we compute the average cost associated with each heating type for each country in 2020. Thus, Croatian households using coal heating in 2020 face an average expenditure share of 23.4%, which is the highest among all heating types. Hence, this descriptive evidence suggests that low-income households are more likely to employ heating systems that command higher expenditure shares.

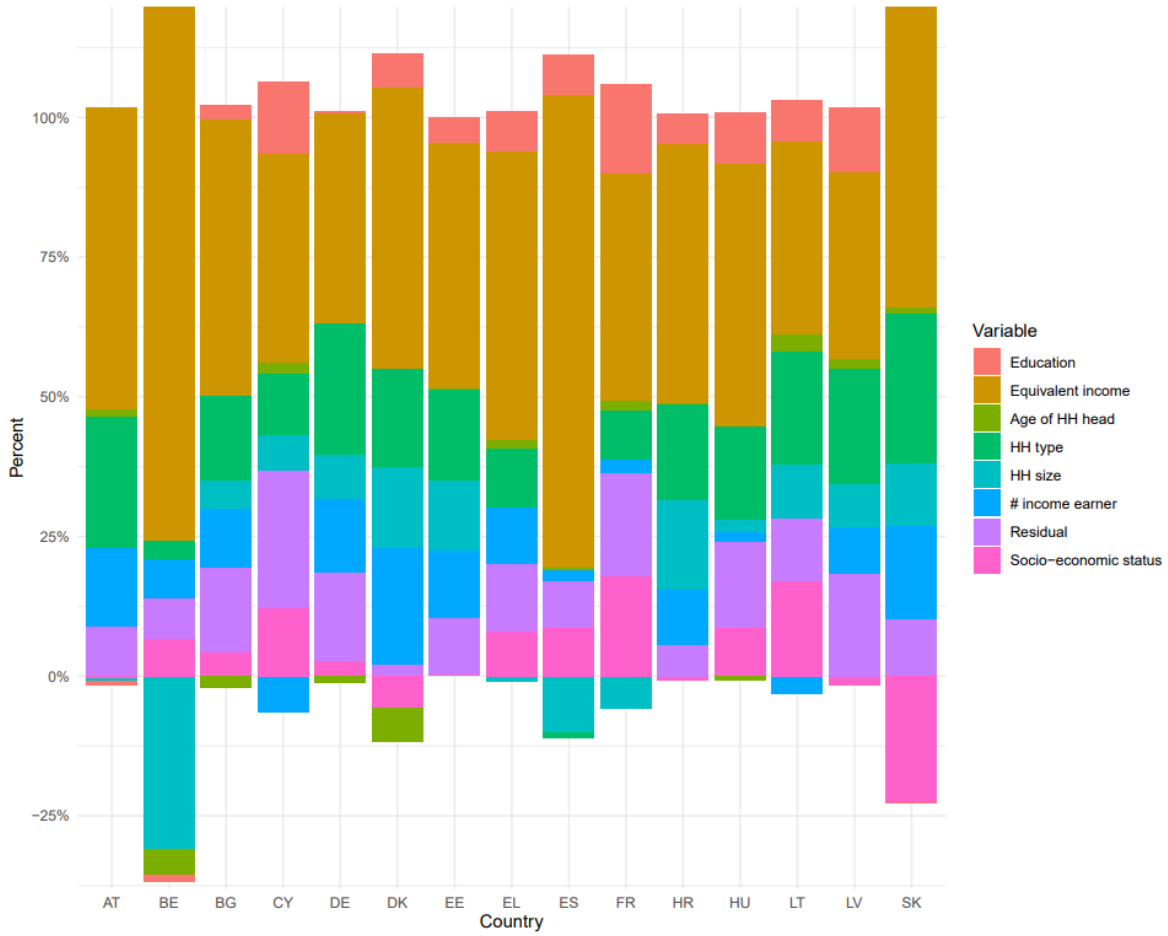
The effect of recent price spikes is projected to be rather small in Switzerland in comparison to some EU countries. Thus, even assuming the highest price increases for electricity recorded among municipalities in 2023, our projections imply an increase in the burden for the lowest and highest income quintile to only 11% or 3.8% respectively. The corresponding values are much higher for the 19 EU countries where, for instance in Greece we project shares of 34.4% and 14.8% for the lowest and highest income quintile respectively.

In terms of energy poverty measured by the TPR (Ten Percent Rule), Switzerland and Luxembourg feature the smallest proportion of households with energy expenditures exceeding 10% of their income. However, when applying the 2M criterion (twice the median), 17% of households in Switzerland report energy expenditures that are more than double the national median, a rate higher than in most analysed EU countries. This discrepancy is explained by the fact that many surveyed households in these countries report high energy expenditures, which raises the national median and consequently results in a smaller proportion of households surpassing the twice-median threshold.

Furthermore, we document a considerable variation in the degree of regressivity among the studied countries, with Luxembourg, Spain, and Switzerland exhibiting the most pronounced regressivity (-0.20 in 2020 and 2017 respectively in Spain and Switzerland, -0.26 in Luxembourg in 2020) and Bulgaria displaying the least degree of regressivity (-0.07 in 2020). A crucial aspect emphasized in our analysis is that assessing inequality in the distribution of the energy expenditure burden among households requires a more nuanced approach than solely focusing on the fraction of income spent on energy. As illustrated, the countries with the lowest or highest share of equivalent disposable income spent on energy differ from those with the lowest or highest degree of regressivity, underscoring the importance of a comprehensive examination of these dynamics. Additionally, while we observe a significant impact of price spikes on various energy poverty measures, the effect on the degree of regressivity is minimal. This outcome, however, depends heavily on the assumptions made regarding energy price elasticities across different income levels.

Finally, we examine the contribution of various socio-demographic variables to the overall concentration index of energy expenditures (see Figure 1). Equivalent income emerges as the main contributor to explaining the concentration of overall household energy expenditures, however its contribution varies to a large extent. In Switzerland equivalent income alone explains more than 50% of the overall energy expenditure concentration index, but only 33% in Latvia or even 85% in Spain. However, we also find that variables such as household size may even feature a negative contribution to the concentration of energy expenditures, thus counteracting the effect of the other variables and yielding a more uniform distribution of energy expenditures along the income distribution. Understanding the contribution of these drivers is important in view of potential appropriate policy instruments that can be employed to address the potential adverse effects of higher energy prices.

Figure 1: Decomposition of energy expenditure concentration by socio-demographic variable



Source: Authors calculation. With this decomposition we calculate the share of the energy expenditure concentration that is explained by the respective socio-demographic variables. For methodological background, see Ackermann and Radulescu (2024) CESifo working paper.

With respect to the second research project, first results of the empirical analysis of the probability of being subject to air pollution based on the SILC data and its correlation with socio-economic variables, suggest that income is negatively and urbanisation and tenant status is positively correlated with the probability of being affected by air pollution which is in line with the literature. These results hold for Switzerland as well as for the considered European countries.

First results indicate that higher income is associated with a lower probability of being subject to air pollution (see Table1).

Table 1 Probability of living in areas subject to air pollution by income quintile

	Switzerland	Germany
Income decile 1	16.7	23.0
Income decile 2	15.9	22.7
Income decile 3	15.4	22.5
Income decile 4	15.0	22.4

Income decile 5	14.6	22.2
Income decile 6	14.3	22.0
Income decile 7	13.9	21.9
Income decile 8	13.5	21.6
Income decile 9	13.0	21.3
Income decile 10	12.4	20.6

Source: Authors' calculation. This calculation is based on a logistic regression using EU-SILC survey data for Germany and Switzerland.

3 Conclusions and outlook

In the initial part of our analysis, we observe that the proportion of income allocated to energy expenditures is relatively low for both low- and high-income groups in Switzerland compared to other European countries. In 2017, households in the lowest income quintile spent an average of 8.6% of their income on energy, whereas this figure was 2.6% for the highest income group. Energy poverty, defined as the share of the population spending more than 10% of their income on energy, stood at 7.9%, representing one of the lowest shares among European countries along Luxembourg. However, the regressivity of energy expenditures—assessed by the Kakwani index—is slightly higher in comparison to other European countries. Between 2006 and 2017, the degree of regressivity remained constant, although the share of income spent on energy slightly declined.

The surge in energy prices following the onset of the war in Ukraine led to an increase in the share of income spent on energy. According to the simulations, this is more pronounced among lower-income households, since they feature a lower price elasticity of energy demand in absolute terms and hence they have less room for reaction in response to the price increases.

In the next year, we plan to examine the relationship between socio-economic factors and the likelihood of perceived and actual air pollution exposure. To achieve this, we intend to collect relevant air pollution data and obtain access to geolocated survey data. Additionally, suitable proxy data representing public information on air pollution must be identified. We will then proceed with the empirical analysis. Upon completion, the results will be compiled into a working paper and presented at both national and international academic conferences. Combined with the findings from the initial project phase, these results will be synthesized and documented in the final report which will also be presented in person.

4 National and international cooperation

Not applicable

5 Publications and other communications

The findings of the first part of the project have been presented at the SURED conference, the Annual Conference of the Swiss Society of Economics and Statistics, the Annual Conference of EAERE and the Annual Conference of IIPF between June and August of 2024.

A modified version was published as a CESifo working paper.

6 References

Project 1:

Auffhammer, M., & Rubin, E. (2018). Natural gas price elasticities and optimal cost recovery under consumer heterogeneity: Evidence from 300 million natural gas bills (Tech. Rep.).National Bureau of Economic Research.

Boardman, B. (1991). Fuel poverty. from cold homes to affordable warmth. Belhaven Press,London.

Boardman, B. (2009). Fixing fuel poverty. Earthscan, London.

Borenstein, S. (2012). The redistributional impact of nonlinear electricity pricing. American Economic Journal: Economic Policy, 4 (3), 56–90.

Bouzarovski, S., & Tirado Herrero, S. (2017). The energy divide: Integrating energy transitions, regional inequalities and poverty trends in the European Union. European Urban and Regional Studies, 24 (1), 69–86.

Burtraw, D., Sweeney, R., & Walls, M. (2009). The incidence of us climate policy: alternative uses of revenues from a cap-and-trade auction. National Tax Journal , 62 (3), 497–518.

Churchill, S. A., Smyth, R., & Farrell, L. (2020). Fuel poverty and subjective wellbeing. Energy economics, 86 , 104650.

Drescher, K., & Janzen, B. (2021). Determinants, persistence, and dynamics of energy poverty: An empirical assessment using german household survey data. Energy Economics, 102 , 105433.

Feger, F., Pavanini, N., & Radulescu, D. (2022). Welfare and redistribution in residential electricity markets with solar power. The Review of Economic Studies, 89 (6), 3267–3302.

Feger, F., & Radulescu, D. (2020). When environmental and redistribution concerns collide: The case of electricity pricing. Energy Economics, 90 , 104828.

Fullerton, D., Heutel, G., & Metcalf, G. E. (2011). Does the indexing of government transfers make carbon pricing progressive? (Tech. Rep.). National Bureau of Economic Research.

Glaeser, E. L., Gorback, C. S., & Poterba, J. M. (2022). How regressive are mobility-related user fees and gasoline taxes? (Tech. Rep.). National Bureau of Economic Research.

Halkos, G. E., & Gkampoura, E.-C. (2021). Evaluating the effect of economic crisis on energy poverty in Europe. Renewable and Sustainable Energy Reviews, 144 , 110981.

Hassett, K. A., Mathur, A., & Metcalf, G. E. (2009). The incidence of a us carbon tax: A lifetime and regional analysis. The Energy Journal , 30 (2).

Hills, J. (2012). Getting the measure of fuel poverty. Centre for Analysis of Social Exclusion, London.

Holz, F., Kemfert, C., Engerer, H., & Sogalla, R. (2022). Europa kann die Abhängigkeit von Russlands Gaslieferungen durch Diversifikation und Energiesparen senken.

Huang, W.-H. (2022). Sources of inequality in household electricity consumption: evidence from Taiwan. Energy Sources, Part B: Economics, Planning and Policy, 17 (1), 1966133.

Jacobson, A., Milman, A. D., & Kammen, D. M. (2005). Letting the (energy) Gini out of the bottle: Lorenz curves of cumulative electricity consumption and gini coefficients as metrics of energy distribution and equity. Energy Policy, 33 (14), 1825–1832.

Kakwani, A. W., N., & van Doorslaer, E. (1997). Socioeconomic inequalities in health: Measurement, computation, and statistical inference. Journal of Econometrics, 77 (1), 87-103.

Labandeira, X., Labeaga, J. M., & L´opez-Otero, X. (2017). A meta-analysis on the price elasticity of energy demand. Energy Policy, 102 , 549–568.

Landesindex der Konsumentenpreise (No. 20984927). (2022). Neuchâtel: Bundesamt für Statistik (BFS). Retrieved from https://dam-api.bfs.admin.ch/hub/api/dam/assets/20984927/master

Landis, F. (2019). Cost distribution and equity of climate policy in Switzerland. Swiss Journal of Economics and Statistics, 155 (1), 1–28.

Levinson, A., & Silva, E. (2022). The electric gini: income redistribution through energy prices. American Economic Journal: Economic Policy, 14 (2), 341–65.

Lohnrunde 2023: Was ist zu erwarten? (2022). Credit Suisse.

Menyhert, B., et al. (2022). The effect of rising energy and consumer prices on household finances, poverty and social exclusion in the eu. Publications Office of the European Union, Luxembourg.

Oswald, Y., Owen, A., & Steinberger, J. K. (2020). Large inequality in international and intranational energy footprints between income groups and across consumption categories. Nature Energy, 5 (3), 231–239.

Peersman, G., & Wauters, J. (2022). Heterogeneous household responses to energy price shocks. CESifo Working Paper No. 10157 . Trotta, G., Hansen, A. R., & Sommer, S. (2022). The price elasticity of residential district heating demand: New evidence from a dynamic panel approach. Energy Economics, 112 , 106163.

Vona, F. (2021). Managing the distributional effects of environmental and climate policies: The narrow path for a triple dividend.

Wadud, Z., Noland, R. B., & Graham, D. J. (2010). A semiparametric model of household gasoline demand. Energy Economics, 32 (1), 93–101.

Wagstaff, A., & van Doorslaer, E. (1994). Measuring inequalities in health in the presence of multiple-category morbidity indicators. Health Economics, 3 (4), 281-291.

Wagstaff, E. v. D., A., & P.Paci. (1989). Equity in the finance and delivery of health care: Some tentative cross-country comparisons. Oxford Review of Economic Policy, 5 (1), 89-112.

Wagstaff, E. v. D., A., & Watanabe, N. (2003). On decomposing the causes of health sector inequalities with an application to malnutrition inequalities in Vietnam. Journal of Econometrics, 112 (1), 207-223.

Wu, D., Zeng, G., Meng, L., Zhou, W., & Li, L. (2017). Gini coefficient-based task allocation for multi-robot systems with limited energy resources. IEEE/CAA Journal of Automatica Sinica, 5 (1), 155–168.

Project 2:

Banzhaf, H. S. (2012). The political economy of environmental justice. Stanford Economics and Finance.

Barwick, P. J., Li, S., Lin, L., & Zou, E. Y. (2024). From fog to smog: The value of pollution information. American Economic Review , 114 (5), 1338–1381.

Bickerstaff, K. (2004). Risk perception research: socio-cultural perspectives on the public experience of air pollution. Environment international , 30 (6), 827–840.

Chiarini, B., D'Agostino, A., Marzano, E., & Regoli, A. (2020). The perception of air pollution and noise in urban environments: A subjective indicator across European countries. Journal of environmental management, 263 , 110272.

Chiarini, B., D'Agostino, A., Marzano, E., & Regoli, A. (2021). Air quality in urban areas: Comparing objective and subjective indicators in european countries. Ecological Indicators, 121 , 107144.

Colmer, J., Hardman, I., Shimshack, J., & Voorheis, J. (2020). Disparities in pm2. 5 air pollution in the United States. Science, 369 (6503), 575–578.

Cori, L., Donzelli, G., Gorini, F., Bianchi, F., & Curzio, O. (2020). Risk perception of air pollution: A systematic review focused on particulate matter exposure. International Journal of Environmental Research and Public Health, 17 (17), 6424.

Currie, J., Voorheis, J., & Walker, R. (2023). What caused racial disparities in particulate exposure to fall? new evidence from the clean air act and satellite-based measures of air quality. American Economic Review , 113 (1), 71–97.

Evans, G. W., & Kantrowitz, E. (2002). Socioeconomic status and health: the potential role of environmental risk exposure. Annual review of public health, 23 (1), 303–331.

Fehr, R., Yam, K. C., He, W., Chiang, J. T.-J., & Wei, W. (2017). Polluted work: A self-control perspective on air pollution appraisals, organizational citizenship, and counterproductive work behaviour. Organizational Behaviour and Human Decision Processes, 143 , 98–110.

Graff Zivin, J., & Neidell, M. (2013). Environment, health, and human capital. Journal of economic literature, 51 (3), 689–730.

Gray, S. C., Edwards, S. E., & Miranda, M. L. (2013). Race, socioeconomic status, and air pollution exposure in North Carolina. Environmental research, 126 , 152–158.

Hajat, A., Diez-Roux, A. V., Adar, S. D., Auchincloss, A. H., Lovasi, G. S., O'Neill, M. S., Kaufman, J. D. (2013). Air pollution and individual and neighbourhood socioeconomic status: evidence from the multi-ethnic study of atherosclerosis (mesa). Environmental health perspectives, 121 (11-12), 1325–1333.

Hajat, A., Hsia, C., & O'Neill, M. S. (2015). Socioeconomic disparities and air pollution exposure: a global review. Current environmental health reports, 2 , 440–450.

Hsiang, S., Oliva, P., & Walker, R. (2019). The distribution of environmental damages. Review of Environmental Economics and Policy.

Kim, J., & Kwan, M.-P. (2021). How neighbourhood effect averaging might affect assessment of individual exposures to air pollution: A study of ozone exposures in Los Angeles. Annals of the American Association of Geographers, 111 (1), 121–140.

Kwan, M.-P. (2018). The neighbourhood effect averaging problem (neap): An elusive confounder of the neighbourhood effect. International journal of environmental research and public health, 15 (9), 1841.

Lu, J. G. (2020). Air pollution: A systematic review of its psychological, economic, and social effects. Current opinion in psychology, 32 , 52–65.

Neidell, M. (2009). Information, avoidance behaviour, and health: the effect of ozone on asthma hospitalizations. Journal of Human resources, 44 (2), 450–478.

Peng, M., Zhang, H., Evans, R. D., Zhong, X., & Yang, K. (2019). Actual air pollution, environmental transparency, and the perception of air pollution in China. The Journal of Environment & Development, 28 (1), 78–105.

Perlin, S. A., Wong, D., & Sexton, K. (2001). Residential proximity to industrial sources of air pollution: interrelationships among race, poverty, and age. Journal of the Air & Waste Management Association, 51 (3), 406–421.

Pratt, G. C., Vadali, M. L., Kvale, D. L., & Ellickson, K. M. (2015). Traffic, air pollution, minority and socio-economic status: addressing inequities in exposure and risk. International journal of environmental research and public health, 12 (5), 5355–5372.

Samoli, E., Stergiopoulou, A., Santana, P., Rodopoulou, S., Mitsakou, C., Dimitroulopoulou,C., . . . others (2019). Spatial variability in air pollution exposure in relation to socioeconomic indicators in nine European metropolitan areas: A study on environmental inequality. Environmental Pollution, 249 , 345–353.

Semenza, J. C., Wilson, D. J., Parra, J., Bontempo, B. D., Hart, M., Sailor, D. J., & George, L. A. (2008). Public perception and behaviour change in relationship to hot weather and air pollution. Environmental research, 107 (3), 401–411.

Song, W., & Kwan, M.-P. (2023). Air pollution perception bias: Mismatch between air pollution exposure and perception of air quality in real-time contexts. Health & Place, 84 , 103129.

Walker, G., Simmons, P., Irwin, A., & Wynne, B. (1998). Public perception of risks associated with major accident hazards. HSE Books.

Wang, Y., Wang, Y., Xu, H., Zhao, Y., & Marshall, J. D. (2022). Ambient air pollution and socioeconomic status in China. Environmental health perspectives, 130 (6), 067001.

7 Appendix

Not yet applicable