# Determinants, Persistence and Dynamics of Energy Poverty: An Empirical Assessment Using German Household Survey Data

Benedikt Janzen, University of Bern, benedikt.janzen@kpm.unibe.ch
Katharina Drescher, Statistics Austria, katharina.drescher@statistik.gv.at

## Overview

Energy affordability receives increasing attention in developed countries. It refers to a state of experiencing difficulties to reach adequate levels of domestic energy services, related to high energy expenditures, low income and inefficient energy use. To pursue energy poverty reduction policies, policy maker need a correct identification of the determinants and dynamics of energy poverty. In this paper we employ a dynamic random-effects probit model on three waves of panel data from Germany to identify socio-economic and socio-demographic characteristics as well as housing conditions and household preferences that influence the probability of being energy poor. The longitudinal data structure allows us to examine the persistence and dynamics of energy poverty. Our findings suggest that households that are energy poor in one period are between 6.1 and 19.9 percent more likely to be energy poor in the subsequent period depending on the indicator chosen. Furthermore, we employ multinomial logistic regression to establish differences between chronic and transient energy poverty. Our results show that differences between chronic and transient energy poverty can be mainly attributed to household composition, labor force status, energy efficiency measures and in particular the heating system in place.

## Methods

For this study we resort to the German Socio-Economic Panel (GSOEP), which is a nationally representative household panel study for Germany that started in 1984. The survey is conducted annually, with the latest available data being from 2018. To assess energy poverty, we use both an expenditure-based energy poverty measure and a consensual approach. The expenditure-based approach is based on monthly household expenditures on domestic energy services relative to household income, with a household considered energy poor if the share of income spent on energy is greater than twice the national median. The subjective (or consensual) indicator labels households as energy poor if they self-report difficulties keeping their home comfortably warm in the colder months due to financial reasons. Since a survey question on consensual energy poverty was only introduced in 2016 (wave 33) we restrict our sample to the period covering 2016 and each year thereafter (i.e., waves 33 to 35).
To identify the driving factors and the persistence of energy poverty, we employ a dynamic panel data model with random effects. The model can be summarised as follows:

$$\boldsymbol{y_{it}} = \mathbf{1}[\boldsymbol{y_{it}^*} > \mathbf{0}]$$

$$\boldsymbol{y_{it}^*} = \gamma \boldsymbol{y_{it-1}} + x'_{it}\beta + u_i + \epsilon_{it}, \qquad i = 1, \ldots, N; t = 1, \ldots, T,$$

where $\boldsymbol{y_{it}^*}$ is the latent dependent variable, $\boldsymbol{y_{it-1}}$ is the energy poverty state in period $t-1$, $x'$ is a vector of covariates and the error term $\epsilon_{it}$ follows a normal distribution. As suggested by Wooldridge (2005) the individual specific term can be modelled as $u_i = \alpha_0 + \alpha_1 y_{i0} + \bar{x}'_i \alpha_2 + v_i$ with $\bar{x}'_i = T^{-1} \sum_{t=1}^{T} x'_{it}$ and $v_i \sim N(0, \sigma^2)$.
In a second step, we follow the literature on income poverty dynamics and distinguish between chronic and transient energy poverty based on the count of periods that households live in energy poverty (Foster, 2009; Foster, 2012). For the identification of energy poverty duration states we employ an identification function $\psi_T(y_i; z)$ which determines if household $i$ with measure $y$ (i.e. share of energy expenditures in income) is chronic, transient or never energy poor given poverty line z. We define a duration line $\tau \in (0, 1]$, which represents the threshold for chronic energy poverty. Let $d_i$ be the fraction of periods t where $y_{it} < z$ relative to all periods T. Then

$$\psi_T(y_i; z) = \begin{cases} 2, & if\ d_i \geq \tau, \\ 1, & if\ 0 < d_i < \tau, \\ 0, & if\ d_i = 0. \end{cases}$$

We employ a simple multinomial classification model to explore the differences between households that are never $(\psi = 0)$, transient $(\psi = 1)$ and chronic $(\psi = 2)$ energy poor. The response probability of the multinomial logit model is given by:

$$\Pr\left(y_{ij} = \psi \,\middle|\, x_i'\right) = \frac{e^{x_i \beta_\psi}}{1 + \sum_{k=1}^{2} e^{x_i \beta_\psi}}, \qquad \psi = 0,1,2,$$

where never energy poor is used as the base category. ${x'}_i$ is the same vector of covariates employed in the previous model.

## Results

The dynamic random effects model shows that expenditure-based (column (2) in Table 1) energy poor households are 19.9 percent more likely to be energy poor in the subsequent period. However, applying the consensual energy poverty approach (column (4) in Table 1), state dependence is lower with only 6.1 percent. We identify household type, educational attainment, labor force status, thermal insulation and heating system as important drivers of expenditure-based energy poverty. Households that use electricity as their main heating source are 4.9 percent more likely to have a high share of energy expenditures in income than households that use gas. Households that use oil are 2 percent more likely to experience energy poverty.

Looking at expenditure-based metrics, the share of households that experience energy poverty at least once in our sample period (14.6 percent) is significantly higher than the share of the chronic energy poor (4.7 percent). The same applies to consensual energy poverty. While 3.7 percent of all households are transitory energy poor, only 0.4 percent are energy poor all three periods. The results of our multinomial logit model (Table 2) suggest that an important factor of chronic energy poverty is the heating system in place. Our raw data show that 6.3 percent of the transient energy poor households use electricity as their main heating type, while the share is twice as high for chronic energy poor households. We identify single parents and one-person households as most vulnerable to chronic energy poverty. The results imply that environmental preferences also play a role for energy poverty. Households that have serious climate change concerns have a lower chance of being chronic energy poor, whereas the effect is non-existent for transient energy poverty.

## Conclusion

This paper contributes to the rather limited literature on energy poverty dynamics in a developed country. While we do find evidence of state dependencies, energy poverty is mostly a transitory state. Understanding the nature of energy poverty is imperative for policy makers, since alleviating transient and chronic energy poverty requires different policy responses. Short-term measures like direct subsidies for energy costs might reduce entries into energy poverty. However, for reducing chronic energy poverty long-term measures like improving energy performance of housing is the most appropriate response.

## References

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| | Expenditure-based | | Consensual | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Expenditure-based$_{t-1}$ | 0.374*** | 0.199*** | | |
| | (0.013) | (0.015) | | |
| Expenditure-based$_{t=0}$ | | 0.132*** | | |
| | | (0.013) | | |
| Consensual$_{t-1}$ | | | 0.198*** | 0.061*** |
| | | | (0.023) | (0.016) |
| Consensual$_{t=0}$ | | | | 0.066*** |
| | | | | (0.016) |
| Couple without children | Ref. | Ref. | Ref. | Ref |
| Single parent | 0.068*** | 0.070*** | 0.010** | 0.009* |
| | (0.011) | (0.011) | (0.004) | (0.004) |
| One person household | 0.067*** | 0.064*** | 0.004* | 0.004° |
| | (0.007) | (0.007) | (0.002) | (0.002) |
| Couple with children | −0.020*** | −0.019*** | −0.002 | −0.002 |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| Other | 0.010 | 0.011 | −0.002 | −0.002 |
| | (0.015) | (0.015) | (0.004) | (0.004) |
| Gender | 0.007° | 0.007° | 0.002 | 0.001 |
| | (0.004) | (0.004) | (0.001) | (0.001) |
| Migration background | 0.032*** | 0.030*** | 0.001 | 0.001 |
| | (0.008) | (0.008) | (0.002) | (0.002) |
| Care | 0.008 | 0.008 | 0.003 | 0.004 |
| | (0.008) | (0.008) | (0.004) | (0.004) |
| Region | 0.012* | 0.014** | 0.002 | 0.003 |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| No degree | 0.041** | 0.038** | 0.000 | −0.001 |
| | (0.013) | (0.013) | (0.003) | (0.003) |
| Lower secondary degree | 0.021** | 0.020** | 0.001 | 0.000 |
| | (0.007) | (0.007) | (0.002) | (0.002) |
| Upper secondary degree | Ref. | Ref. | Ref. | Ref |
| Tertiary degree | −0.018* | −0.016* | 0.000 | −0.000 |
| | (0.007) | (0.007) | (0.002) | (0.002) |
| (Self-)Employed | Ref. | Ref. | Ref. | Ref |
| Non-working | 0.101*** | 0.095*** | 0.009** | 0.008** |
| | (0.011) | (0.010) | (0.003) | (0.003) |
| Retired | 0.045*** | 0.043*** | −0.002 | −0.002 |
| | (0.005) | (0.005) | (0.002) | (0.001) |
| Owner | −0.007 | −0.007 | −0.009*** | −0.009*** |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| Double-glazed window | −0.014° | −0.012 | −0.006° | −0.006° |
| | (0.008) | (0.008) | (0.003) | (0.003) |
| Thermal insulation | −0.022*** | −0.020*** | −0.006*** | −0.005*** |
| | (0.004) | (0.004) | (0.002) | (0.001) |
| Built before 1949 | Ref. | Ref. | Ref. | Ref |
| Built between 1949 and 1979 | −0.009* | −0.007 | 0.000 | 0.001 |
| | (0.004) | (0.004) | (0.002) | (0.002) |
| Built after 1979 | −0.018*** | −0.016*** | −0.002 | −0.002 |
| | (0.004) | (0.004) | (0.002) | (0.001) |
| Detached | Ref. | Ref. | Ref. | Ref |
| Semi-detached | −0.016** | −0.015** | −0.002 | −0.002 |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| Apartment building | −0.035*** | −0.032*** | −0.002 | −0.002 |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| Gas | Ref. | Ref. | Ref. | Ref |
| Oil | 0.020*** | 0.020*** | 0.005* | 0.006** |
| | (0.005) | (0.005) | (0.002) | (0.002) |
| Electricity | 0.049*** | 0.042*** | 0.011* | 0.010* |
| | (0.012) | (0.011) | (0.005) | (0.005) |
| District heating | 0.009 | 0.009 | 0.004° | 0.003 |
| | (0.006) | (0.006) | (0.002) | (0.002) |
| Other | 0.010 | 0.011 | 0.003 | 0.003 |
| | (0.009) | (0.009) | (0.004) | (0.004) |
| Renewable energy | −0.013* | −0.012* | −0.003 | −0.003 |
| | (0.006) | (0.006) | (0.002) | (0.002) |
| Climate change concerns | −0.005 | −0.004 | 0.001 | 0.001 |
| | (0.004) | (0.004) | (0.001) | (0.001) |
| State fixed effects | Yes | Yes | Yes | Yes |
| Wave fixed effects | Yes | Yes | Yes | Yes |
| Number of obs. | 17794 | 17794 | 17794 | 17794 |

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; °$p < 0.1$

**Table 1: Regression Results: Dynamic Random Effects Probit Estimator**

| | *Dependent variable:* | | | |
|---|---|---|---|---|
| | *Expenditure-based* | | *Consensual* | |
| | never vs. transient | never vs. chronic | never vs. transient | never vs. chronic |
| | (1) | (2) | (3) | (4) |
| Couple without children | Ref. | Ref. | Ref. | Ref. |
| Single parent | 0.932*** | 0.906*** | 0.888*** | 1.745** |
| | (0.114) | (0.203) | (0.202) | (0.689) |
| One-person household | 0.756*** | 1.468*** | 0.633*** | 1.132* |
| | (0.088) | (0.141) | (0.174) | (0.667) |
| Couple with children | −0.471*** | −0.972*** | 0.040 | 0.232 |
| | (0.102) | (0.199) | (0.188) | (0.741) |
| Other | 0.433** | −0.396 | −0.239 | −17.588*** |
| | (0.211) | (0.462) | (0.490) | (0.000) |
| Gender | 0.143** | −0.010 | 0.080 | 0.617 |
| | (0.070) | (0.116) | (0.128) | (0.479) |
| Migration background | 0.452*** | 0.653*** | −0.017 | −0.503 |
| | (0.111) | (0.196) | (0.186) | (0.703) |
| Care | 0.274* | 0.322 | 0.142 | 0.548 |
| | (0.145) | (0.243) | (0.292) | (0.760) |
| Region | 0.183*** | 0.315*** | 0.098 | 0.400 |
| | (0.069) | (0.114) | (0.128) | (0.379) |
| No degree | 0.688*** | 1.137*** | 0.760*** | −0.991 |
| | (0.160) | (0.327) | (0.285) | (0.931) |
| Lower secondary degree | 0.307** | 0.945*** | 0.414* | −0.442 |
| | (0.123) | (0.274) | (0.236) | (0.526) |
| Upper secondary degree | Ref. | Ref. | Ref. | Ref. |
| Tertiary degree | −0.577*** | −0.223 | 0.227 | −0.227 |
| | (0.141) | (0.307) | (0.257) | (0.606) |
| (Self-)Employed | Ref. | Ref. | Ref. | Ref. |
| Non-working | 1.354*** | 2.263*** | 0.768*** | 0.792* |
| | (0.097) | (0.157) | (0.147) | (0.431) |
| Retired | 0.763*** | 0.979*** | −0.270* | −0.471 |
| | (0.080) | (0.137) | (0.164) | (0.553) |
| Owner | −0.173** | 0.130 | −0.754*** | −1.930*** |
| | (0.083) | (0.138) | (0.166) | (0.666) |
| Double-glazed window | −0.239** | −0.291 | −0.213 | −0.915** |
| | (0.118) | (0.190) | (0.184) | (0.454) |
| Thermal insulation | −0.310*** | −0.563*** | −0.580*** | −0.479 |
| | (0.068) | (0.114) | (0.124) | (0.381) |
| Built before 1949 | Ref. | Ref. | Ref. | Ref. |
| Built between 1949 and 1979 | −0.171** | −0.608*** | −0.213 | 0.121 |
| | (0.079) | (0.131) | (0.141) | (0.436) |
| Built after 1979 | −0.412*** | −0.712*** | −0.217 | 0.163 |
| | (0.082) | (0.139) | (0.147) | (0.462) |
| Isolated | Ref. | Ref. | Ref. | Ref. |
| Semi-detached | −0.396*** | −0.661*** | −0.162 | −1.662** |
| | (0.091) | (0.146) | (0.183) | (0.680) |
| Detached | −0.634*** | −1.281*** | −0.071 | −0.919* |
| | (0.101) | (0.171) | (0.184) | (0.494) |
| Gas | Ref. | Ref. | Ref. | Ref. |
| Oil | 0.311*** | 0.364*** | 0.441*** | 0.184 |
| | (0.080) | (0.135) | (0.159) | (0.502) |
| Electricity | 0.654*** | 1.362*** | 1.189*** | 0.564 |
| | (0.144) | (0.193) | (0.212) | (0.781) |
| District heating | 0.249** | 0.279 | 0.566*** | 0.628 |
| | (0.099) | (0.183) | (0.160) | (0.460) |
| Other | 0.027 | 0.042 | 0.567** | −0.091 |
| | (0.145) | (0.243) | (0.264) | (1.066) |
| Renewable energy | −0.176 | −0.728*** | −0.843** | −120.133*** |
| | (0.119) | (0.243) | (0.336) | (0.000) |
| Climate change concerns | −0.086 | −0.210* | −0.084 | −0.448 |
| | (0.070) | (0.120) | (0.127) | (0.414) |
| Constant | −1.801*** | −3.449*** | −3.427*** | −4.364*** |
| | (0.199) | (0.374) | (0.367) | (1.001) |
| Akaike Inf. Crit. | 9,077.380 | 9,077.380 | 2,963.189 | 2,963.189 |
| *Note:* | | | | *p<0.1; **p<0.05; ***p<0.01 |

**Table 2: Regression Results: Multinomial Logistic Regression**