The Role of Digitalization in Reducing Energy Poverty in Europe: Insights on Affordability and Thermal Comfort

Teresa Magina, Inês Carrilho-Nunes, Margarida Catalão-Lopes

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More than **2 billion people** lack access to clean fuels and technologies for cooking (IEA, 2022).

Source: https://www.iea.org/news/low-cost-solutions-can-give-billions-access-to-modern-cooking-by-2030-but-the-world-is-failing-to-deliver

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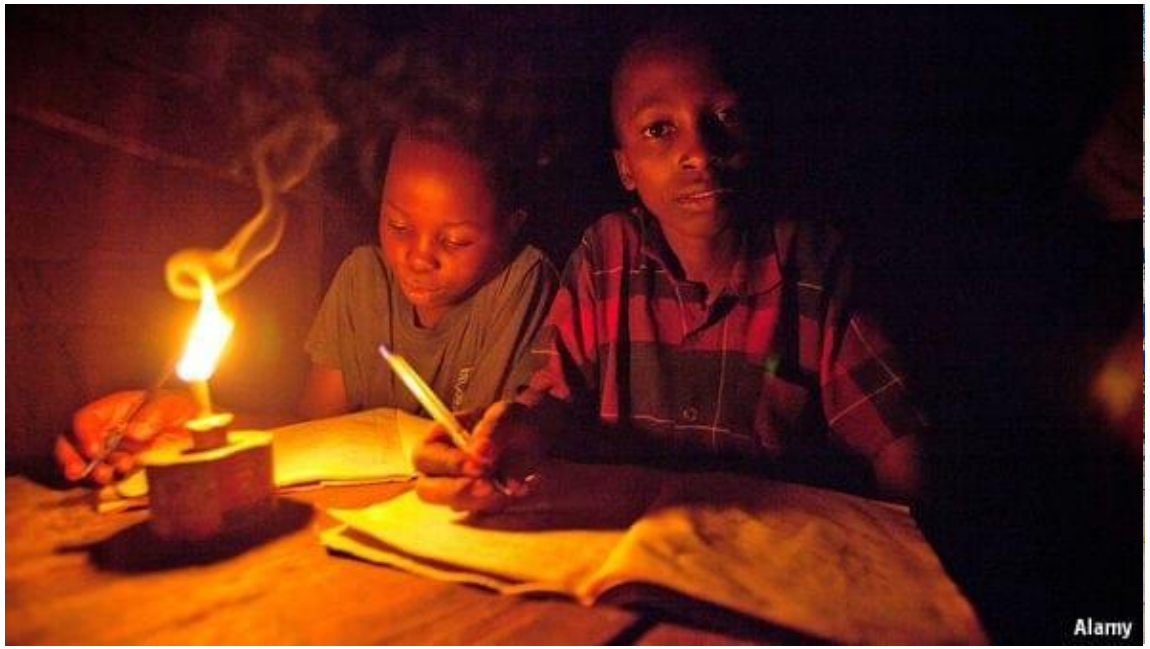

Source: https://www.economist.com/international/2016/02/27/power-to-the-powerless

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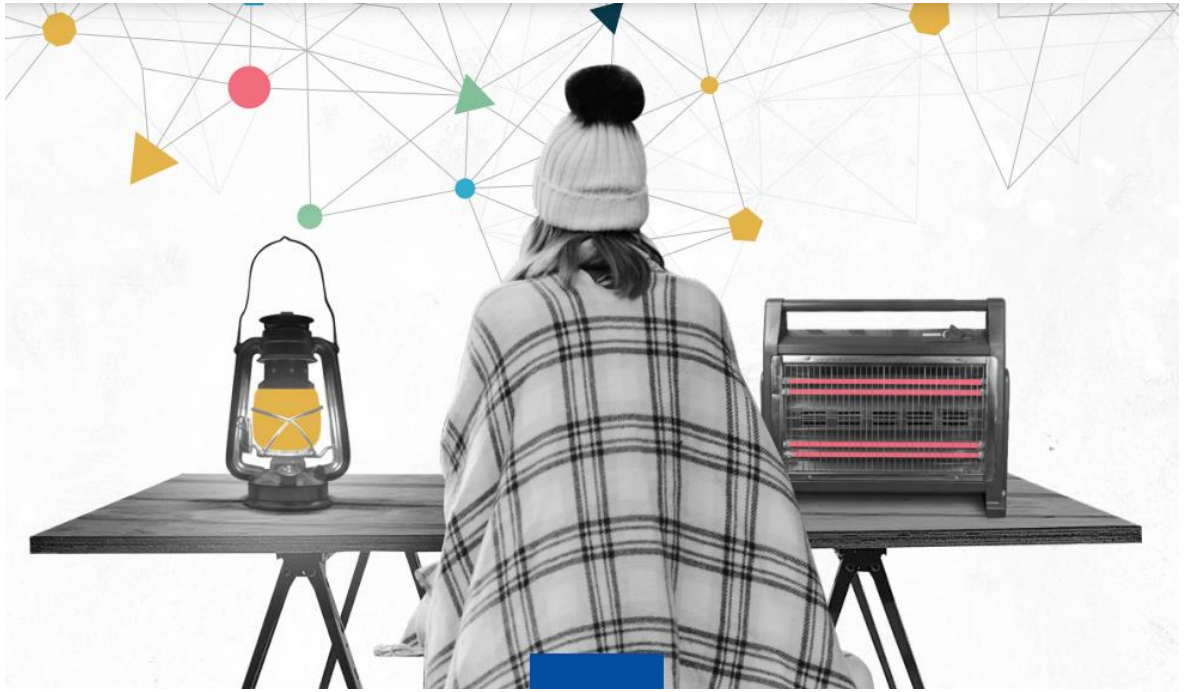

Source: Introduction to the Energy Poverty Advisory Hub (EPAH) Handbooks: A Guide to Understanding and Addressing Energy Poverty Published by the Energy Poverty Advisory Hub (2022)

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41 million EU citizens can not warm their homes properly (Eurostat, 2023).

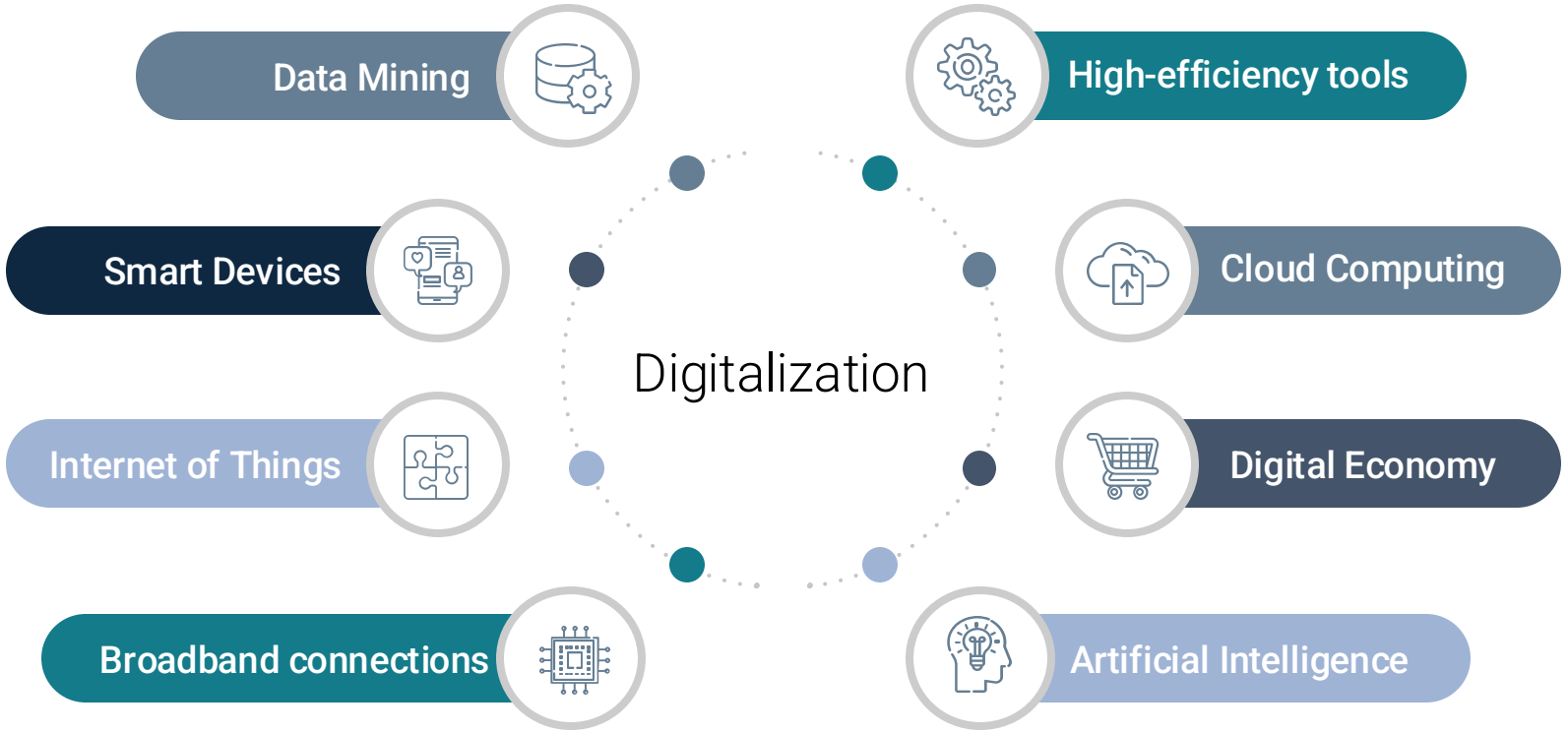
30 million EU citizens have arrears on utility bills (Eurostat, 2023).

Energy Poverty

The "inability of households to ensure their energy needs", through reliable and modern energy
(European Commission, 2023).

- Multidimensional problem
- The definition varies with the context and countries where is the focus of the study
- Evaluated with different indicators
- Consequences for society and the environment

Problem Contextualization



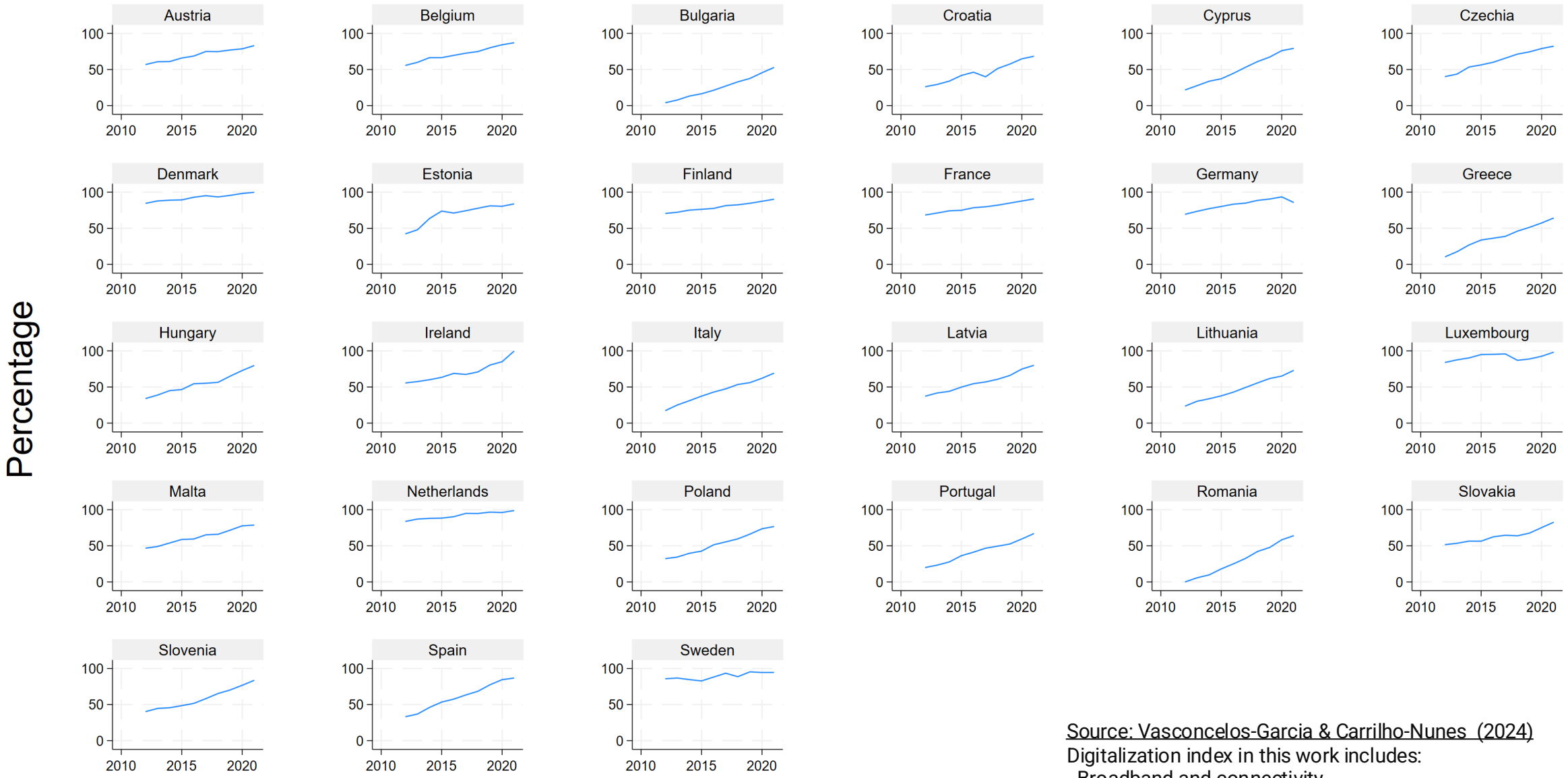
Digitalization can enhance the energy network, eco-innovations, and contribute to and accelerate the energy transition

↓

TWIN TRANSITION

(IEA, 2022; Bianchini et al., 2023; Chatzistamoulou, 2023; Fouquet & Hippe, 2022; Mäkitie et al., 2023; Vasconcelos-Garcia & Carrilho-Nunes, 2024).

Digitalisation Index (2013-2022)



Source: Vasconcelos-Garcia & Carrilho-Nunes (2024)

Digitalization index in this work includes:

- Broadband and connectivity
- Digital Inclusion
- Digital Single Market – promoting e-commerce for individuals

Literature Review

Literature Review

Topics per existing literature:

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- Digital Technologies and Cleaner Energy
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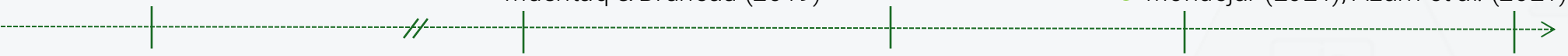

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Gap: Understanding the potential of digitalization in alleviating energy poverty

RQ1: Can digitalization reduce energy poverty concerning energy affordability in the EU?

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Gap: Understanding the potential of digitalization in alleviating energy poverty

RQ1: Can digitalization reduce energy poverty concerning energy affordability in the EU?

RQ2: Can digitalization reduce energy poverty concerning thermal comfort in the EU?

RQ3: How does the impact of digitalization vary across different income thresholds?

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Gap: Understanding the potential of digitalization in alleviating energy poverty

Can digital knowledge/literacy be an indirect tool to alleviate household energy poverty?

Methodology

Methodology

Econometric Static (OLS-FE) Model

Period

10 years (2013-2022)

Cross-country panel data set
(28) European Countries

Austria	Italy
Belgium	Latvia
Bulgaria	Lithuania
Croatia	Luxembourg
Cyprus	Malta
Czech Republic	The Netherlands
Denmark	Norway
Estonia	Poland
Finland	Portugal
France	Romania
Germany	Slovak Republic
Greece	Slovenia
Hungary	Spain
Ireland	Sweden

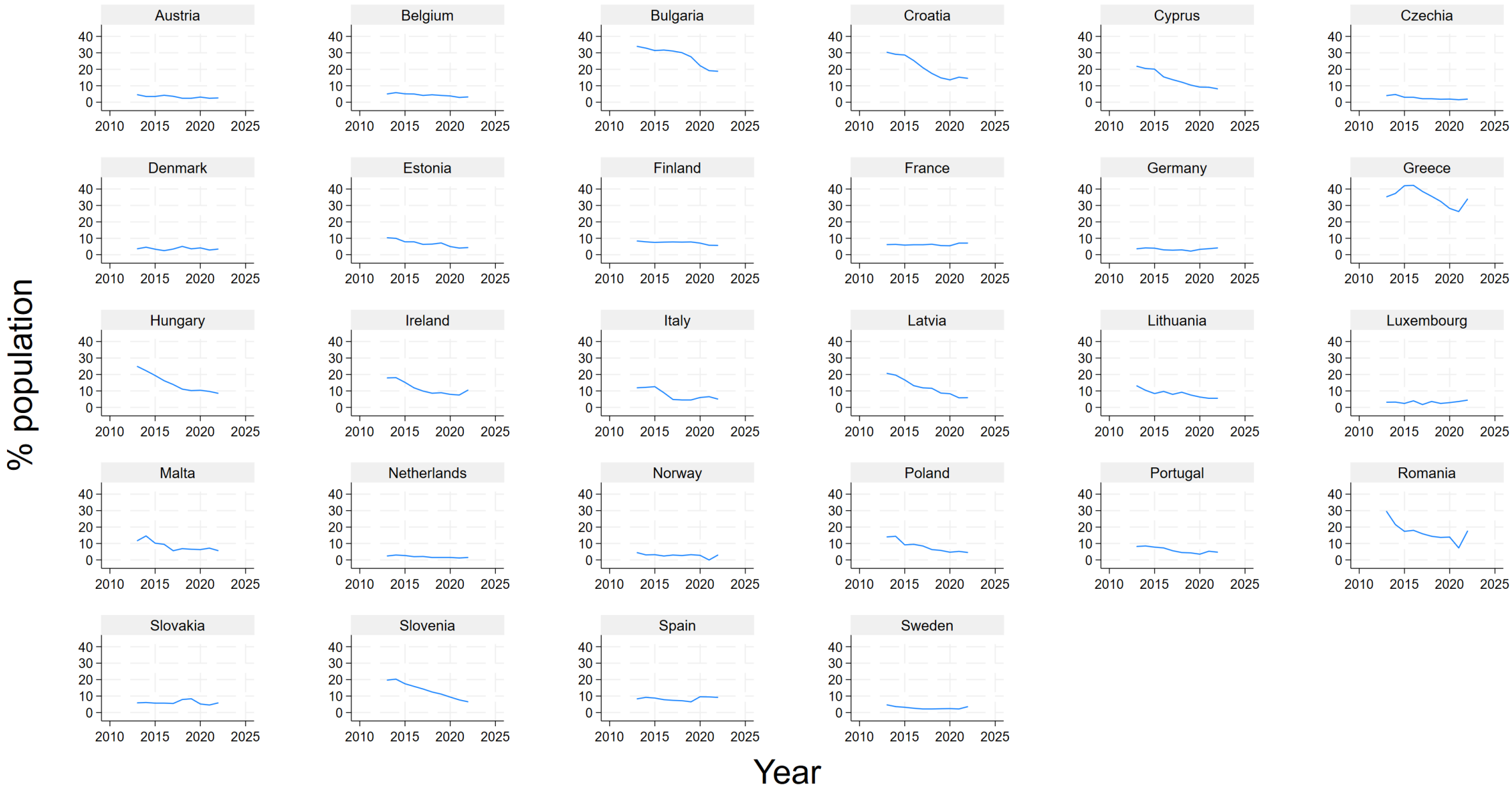
Methodology

1. Variables selection: Dependent Variables

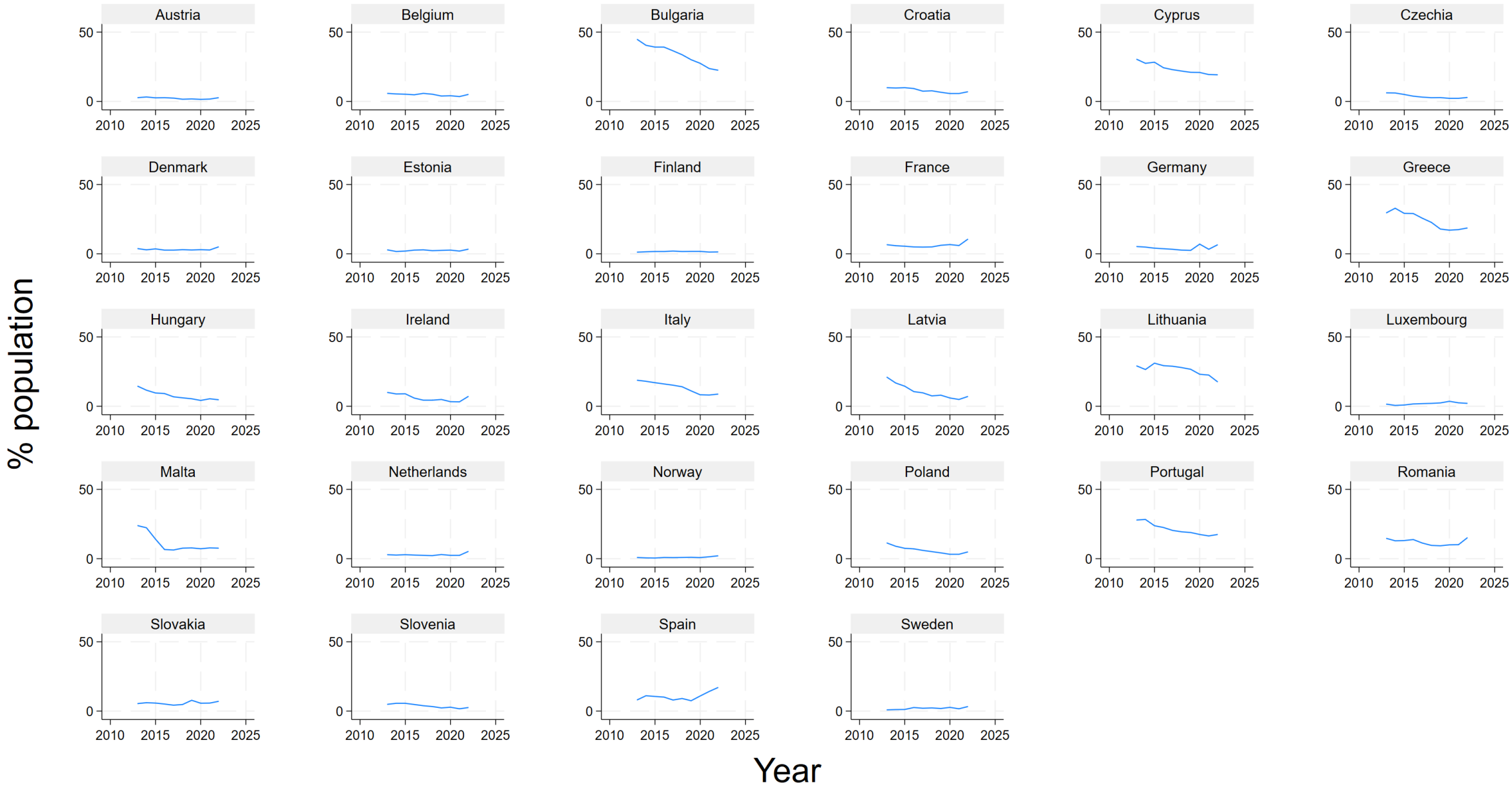
Indicator	Description	Label	Sample	Source	
1. Arrears on utility bills (% households)	Share of the population unable to pay utility bills (heat, electricity, gas, water) on time in 12 months.	$EPArrears$	% households total	Eurostat	Affordability Dimension of Energy Poverty
		$EPArrears\_A60$	% households above poverty line of 60% income		
		$EPArrears\_B60$	% households below poverty line of 60% income		
2. Inability to keep home adequately warm (% households)	Share of the population who declare they cannot maintain their homes in an adequate temperature.	$EPThermal$	% households total		Thermal Comfort Dimension of Energy Poverty
		$EPThermal\_A60$	% households above poverty line of 60% income		
		$EPThermal\_B60$	% households below poverty line 60% income		

Source: [1] Eurostat. Poverty line: 60% of median equivalised household disposable income.

Arrears on utility bills (2013-2022)



Inability to keep home adequately warm (2013-2022)



Methodology

1. Variables selection: Independent variables

Digital Metrics

Individuals who ordered goods or services over the internet for private use between 3 and 12 months prior to data collection (% population) - ***ebuy***

Individuals using the Internet for information about goods and services (%population) - ***infogs***

Next-generation broadband access (%population) – ***nextgen***

Households' level of internet access (%population) – ***levelnet***

Individuals using the Internet daily (%population) – ***netdaily***

Individuals using the Internet for online banking (%population) – ***netbank***

Controls

Electricity prices from electrical energy charged to final consumers (€/kW/h) - ***electprices***
Real imported crude oil price ($/barrel) – ***oilprices***
Rural population (% population) – ***rural rate***
Unemployment rate (% labor force) – ***unemp***

Methodology

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2. Principal Components Analysis (PCA)

Creation of a Digitalization Index for each group of countries with selected digital metrics across different areas with PCA

↓

European Digitalization Index

$EDig$

Advantages:

- A single-core independent variable
- No multicollinearity
- Holistic view of the effect of Digitalization
- Retainining the principal information of the data

Kaiser-Mayer-Olkin test (KMO): 0.7064 > the 0.7 threshold, indicating the need to perform a PCA on the data.

Methodology

1. Variables selection: Independent variables – **Descriptive Statistics**

Variable	Obs	Mean	Std. dev.	Min	Max
EPArrears	280	9.601071	8.427253	0	42.2
EPArrears_A60	280	7.564286	7.253461	.7	36.6
EPArrears_B60	280	19.59464	13.10565	4.6	65.4
EPThermal	280	9.319643	9.091073	.5	44.9
EPThermal_A60	280	7.222143	7.765654	.2	38.3
EPThermal_B60	280	19.23964	14.55285	2	69.7
ebuy	278	10.96468	3.421682	3.2	21.49
infogs	279	68.09362	14.46507	25.71	95.63
nextgen	280	80.96214	16.12282	20.9	100
levelnet	278	85.06259	9.539701	53.71	99.18
netdaily	279	55.44785	23.82217	4.16	96.13
netbank	279	73.81444	13.36463	32.2	96.3
EDig	278	1.56e-09	1.654336	-4.684106	2.802309
electprices	280	.1829971	.0578874	.0451	.4559
oilprices	280	75.91197	26.10305	43.12057	126.3116
ruralrate	280	26.38845	12.77352	1.847	46.668
unemp	280	8.023214	4.474547	2	27.8

Methodology

3. Stationarity tests

- Fisher-type unit-root test based on augmented Dickey-Fuller tests
- Non-stationarity at level → Logarithmic transformation

4. Model: Ordinary Least Square with Fixed Effects (OLS-FE)

For a period (t) from 2013 and 2022, $t = 1,2, \dots, 10$, time-demeaned equations are:
(Wooldridge, 2013)

$$\ddot{EPArrears}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (1)$$

$$\ddot{EPArrears\_A60}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (2)$$

$$\ddot{EPArrears\_B60}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (3)$$

$$\ddot{EPThermal}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (4)$$

$$\ddot{EPThermal\_A60}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (5)$$

$$\ddot{EPThermal\_A60}_{it} = \beta_1 \ddot{IndVar}_{it} + \beta_2 \ddot{electprices}_{it} + \beta_3 \ddot{oilprices}_{it} + \beta_4 \ddot{ruralrate}_{it} + \beta_5 \ddot{unemploy}_{it} + \ddot{u}_{it} \quad (6)$$

Also:

The Variance Inflation Factor (VIF) test was performed to confirm that the model does not have multicollinearity (VIF < 10).
Heteroskedasticity is corrected with robust standard errors.
The model includes country clusters to account for serial correlation.

Results and Discussion

Results and Discussion

Affordability Issues: Arrears on Utility Bills (EPArrears) – **individual digitalization variables**

	OLS Fixed Effects								
	EPArrears (1)	EPArrears_A60 (2)	EPArrears_B60 (3)	EPArrears (4)	EPArrears_A60 (5)	EPArrears_B60 (6)	EPArrears (7)	EPArrears_A60 (8)	EPArrears_B60 (9)
ebuy	**-0.341*** **	**-0.351*****	**-0.332****						
	(0.001)	(0.001)	(0.016)						
infogs				**-0.145*****	**-0.126*****	**-0.231*****			
				(0.000)	(0.000)	(0.000)			
nextgen							**-0.076****	**-0.131****	**-0.060***
							(0.027)	(0.020)	(0.068)
unemp	0.680***	0.575*****	1.045*****	0.570*****	0.502*****	0.782*****	0.654*****	0.892****	0.590*****
	(0.001)	(0.001)	(0.001)	(0.005)	(0.009)	(0.008)	(0.005)	(0.012)	(0.006)
electprices	15.209	13.850*	19.053	14.042*	12.390	19.070	16.023*	22.247	13.855*
	(0.112)	(0.095)	(0.293)	(0.087)	(0.101)	(0.215)	(0.052)	(0.161)	(0.068)
oilprices	0.009*	0.010*	0.017**	0.010*	0.011*	0.018**	0.008	0.014	0.009
	(0.086)	(0.085)	(0.039)	(0.096)	(0.094)	(0.043)	(0.183)	(0.113)	(0.150)
ruralrate	0.779	0.573	1.599*	0.253	0.073	0.935	0.067	0.601	-0.053
	(0.156)	(0.235)	(0.082)	(0.644)	(0.885)	(0.267)	(0.920)	(0.541)	(0.933)
_cons	-16.164	-11.582	-32.137	4.859	7.125	-0.463	5.204	2.001	5.852
	(0.270)	(0.361)	(0.201)	(0.748)	(0.608)	(0.985)	(0.791)	(0.947)	(0.750)
R^2	0.55	0.52	0.48	0.54	0.49	0.51	0.52	0.49	0.47
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Affordability Issues: Arrears on Utility Bills (EPArrears) – **Individuals who ordered goods or services over the internet**

There is a **negative relationship between the share of internet buyers in the population and the number of households suffering from arrears on utility bills**.

The results are similar for families above and below the poverty line (C1,2,3).

The e-commerce facet of digitalization can potentially help cope with energy poverty related to utility bills.

	OLS Fixed Effects								
	EPArrears (1)	EPArrears_A60 (2)	EPArrears_B60 (3)	EPArrears (4)	EPArrears_A60 (5)	EPArrears_B60 (6)	EPArrears (7)	EPArrears_A60 (8)	EPArrears_B60 (9)
ebuy	**-0.341*** ** (0.001)	**-0.351*** (0.001)	**-0.332** (0.016)						
infogs				**-0.145*** (0.000)	**-0.126*** (0.000)	**-0.231*** (0.000)			
nextgen							**-0.076** (0.027)	**-0.131** (0.020)	**-0.060* (0.068)
unemp	0.680*** (0.001)	0.575*** (0.001)	1.045*** (0.001)	0.570*** (0.005)	0.502*** (0.009)	0.782*** (0.008)	0.654*** (0.005)	0.892** (0.012)	0.590*** (0.006)
electprices	15.209 (0.112)	13.850* (0.095)	19.053 (0.293)	14.042* (0.087)	12.390 (0.101)	19.070 (0.215)	16.023* (0.052)	22.247 (0.161)	13.855* (0.068)
oilprices	0.009* (0.086)	0.010* (0.085)	0.017** (0.039)	0.010* (0.096)	0.011* (0.094)	0.018** (0.043)	0.008 (0.183)	0.014 (0.113)	0.009 (0.150)
ruralrate	0.779 (0.156)	0.573 (0.235)	1.599* (0.082)	0.253 (0.644)	0.073 (0.885)	0.935 (0.267)	0.067 (0.920)	0.601 (0.541)	-0.053 (0.933)
_cons	-16.164 (0.270)	-11.582 (0.361)	-32.137 (0.201)	4.859 (0.748)	7.125 (0.608)	-0.463 (0.985)	5.204 (0.791)	2.001 (0.947)	5.852 (0.750)
R^2	0.55	0.52	0.48	0.54	0.49	0.51	0.52	0.49	0.47
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Results and Discussion

Affordability Issues: Arrears on Utility Bills (EPArrears) – **Individuals using the Internet for information about goods and services**

Increasing 1pp of the population's share using the internet to learn about goods and services **decreases the share of families with arrears on utility bills by 0.145pp** for total households, 0.126pp for households above the poverty line, and 0.231pp for households below the line (C4, 5 & 6).

Having digital access to information appears to contribute to a decrease in energy debts, especially in families with less income.

	OLS Fixed Effects								
	EPArrears (1)	EPArrears_A60 (2)	EPArrears_B60 (3)	EPArrears (4)	EPArrears_A60 (5)	EPArrears_B60 (6)	EPArrears (7)	EPArrears_A60 (8)	EPArrears_B60 (9)
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electprices	15.209	13.850*	19.053	14.042*	12.390	19.070	16.023*	22.247	13.855*
	(0.112)	(0.095)	(0.293)	(0.087)	(0.101)	(0.215)	(0.052)	(0.161)	(0.068)
oilprices	0.009*	0.010*	0.017**	0.010*	0.011*	0.018**	0.008	0.014	0.009
	(0.086)	(0.085)	(0.039)	(0.096)	(0.094)	(0.043)	(0.183)	(0.113)	(0.150)
ruralrate	0.779	0.573	1.599*	0.253	0.073	0.935	0.067	0.601	-0.053
	(0.156)	(0.235)	(0.082)	(0.644)	(0.885)	(0.267)	(0.920)	(0.541)	(0.933)
_cons	-16.164	-11.582	-32.137	4.859	7.125	-0.463	5.204	2.001	5.852
	(0.270)	(0.361)	(0.201)	(0.748)	(0.608)	(0.985)	(0.791)	(0.947)	(0.750)
R^2	0.55	0.52	0.48	0.54	0.49	0.51	0.52	0.49	0.47
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Affordability Issues: Arrears on Utility Bills (EPArrears) – **next-generation broadband connectivity**

There is a negative relationship between next-generation broadband connectivity and the number of households suffering from energy debts.

Having next-generation connectivity might contribute to coping with energy poverty.

Note that households with higher purchasing power will more likely feel the effects of modern technologies over families with outdated equipment.

OLS Fixed Effects

	EPArrears (1)	EPArrears_A60 (2)	EPArrears_B60 (3)	EPArrears (4)	EPArrears_A60 (5)	EPArrears_B60 (6)	EPArrears (7)	EPArrears_A60 (8)	EPArrears_B60 (9)
ebuy	**-0.341*** **	**-0.351***	**-0.332**						
	(0.001)	(0.001)	(0.016)						
infogs				**-0.145***	**-0.126***	**-0.231***			
				(0.000)	(0.000)	(0.000)			
nextgen							**-0.076****	**-0.131****	**-0.060***
							(0.027)	(0.020)	(0.068)
unemp	0.680***	0.575***	1.045***	0.570***	0.502***	0.782***	0.654***	0.892**	0.590***
	(0.001)	(0.001)	(0.001)	(0.005)	(0.009)	(0.008)	(0.005)	(0.012)	(0.006)
electprices	15.209	13.850*	19.053	14.042*	12.390	19.070	16.023*	22.247	13.855*
	(0.112)	(0.095)	(0.293)	(0.087)	(0.101)	(0.215)	(0.052)	(0.161)	(0.068)
oilprices	0.009*	0.010*	0.017**	0.010*	0.011*	0.018**	0.008	0.014	0.009
	(0.086)	(0.085)	(0.039)	(0.096)	(0.094)	(0.043)	(0.183)	(0.113)	(0.150)
ruralrate	0.779	0.573	1.599*	0.253	0.073	0.935	0.067	0.601	-0.053
	(0.156)	(0.235)	(0.082)	(0.644)	(0.885)	(0.267)	(0.920)	(0.541)	(0.933)
_cons	-16.164	-11.582	-32.137	4.859	7.125	-0.463	5.204	2.001	5.852
	(0.270)	(0.361)	(0.201)	(0.748)	(0.608)	(0.985)	(0.791)	(0.947)	(0.750)
R^2	0.55	0.52	0.48	0.54	0.49	0.51	0.52	0.49	0.47
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Affordability Issues: Arrears on Utility Bills (EPArrears) – **digitalization index**

Digitalization Index via PCA: levelnet, netbank and netdaily

On average, a 1% increase in the Digitalization Index reduces the share of households with arrears on utility bills by 0.007pp (1). Similarly, the results are 0.006pp and 0.099pp for households above and below the poverty line, respectively (2, 3).

OLS Fixed Effects	EPArrears (1)	EPArrears_A60 (2)	EPArrears_B60 (3)
EDig	-0.750***	-0.649***	-0.999***
	(0.001)	(0.003)	(0.002)
unemp	-0.024	-0.056	-0.308
	(0.812)	(0.546)	(0.401)
electprices	1.366	2.502	-2.362
	(0.614)	(0.345)	(0.704)
oilprices	0.003	0.004	0.003
	(0.316)	(0.237)	(0.793)
ruralrate	0.297	0.195	0.655
	(0.110)	(0.191)	(0.171)
_cons	-1.495	-0.601	-3.363
	(0.642)	(0.821)	(0.683)
R^2	0.33	0.28	0.24
N	146	146	146

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Thermal Comfort Issues: Inability to Keep Home Warm (EPThermal) – **individual digitalization variables**

	OLS Fixed Effects								
	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ebuy	**-0.325*** **	**-0.324** **	**-0.303**						
	(0.023)	(0.016)	(0.156)						
infogs				**-0.124** **	**-0.114** **	**-0.170** **			
				(0.022)	(0.030)	(0.029)			
nextgen							**-0.048**	**-0.037**	**-0.084**
							(0.286)	(0.378)	(0.263)
unemp	0.523***	0.482***	0.535*	0.438***	0.414**	0.366	0.551**	0.531**	0.481
	(0.006)	(0.005)	(0.081)	(0.038)	(0.035)	(0.236)	(0.022)	(0.019)	(0.181)
electprices	18.800	19.033	15.418	17.269	17.354*	14.865	18.298	17.969*	17.317
	(0.153)	(0.102)	(0.463)	(0.137)	(0.089)	(0.436)	(0.112)	(0.079)	(0.348)
oilprices	0.010	0.010	0.016	0.011	0.012	0.017	0.009	0.010	0.013
	(0.243)	(0.199)	(0.176)	(0.165)	(0.128)	(0.141)	(0.280)	(0.215)	(0.259)
ruralrate	0.741	0.585	1.504	0.252	0.113	0.965	0.188	0.092	0.765
	(0.163)	(0.203)	(0.143)	(0.660)	(0.824)	(0.338)	(0.776)	(0.877)	(0.477)
_cons	-15.018	-12.768	-25.390	3.622	4.616	-1.570	-0.251	-0.510	-2.206
	(0.268)	(0.266)	(0.335)	(0.827)	(0.754)	(0.956)	(0.990)	(0.978)	(0.946)
R^2	0.45	0.45	0.30	0.42	0.41	0.31	0.40	0.38	0.29
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Thermal Comfort Issues: Inability to Keep Home Warm (EPThermal) – **Individuals who ordered goods or services over the internet**

There is a **negative relationship between the share of internet buyers in the population and the ability to keep home warm in total households and households above the poverty threshold.**

Poorer households did not show significant results. This might be because conditions in poorer households have to be drastically improved for e-commerce to implement changes efficiently

The e-commerce facet of digitalization can potentially help cope with energy poverty related to thermal comfort.

OLS Fixed Effects

	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ebuy	**-0.325*** **	**-0.324** **	**-0.303**						
	(0.023)	(0.016)	(0.156)						
infogs				**-0.124** **	**-0.114** **	**-0.170** **			
				(0.022)	(0.030)	(0.029)			
nextgen							**-0.048**	**-0.037**	**-0.084**
							(0.286)	(0.378)	(0.263)
unemp	0.523***	0.482***	0.535*	0.438***	0.414**	0.366	0.551**	0.531**	0.481
	(0.006)	(0.005)	(0.081)	(0.038)	(0.035)	(0.236)	(0.022)	(0.019)	(0.181)
electprices	18.800	19.033	15.418	17.269	17.354*	14.865	18.298	17.969*	17.317
	(0.153)	(0.102)	(0.463)	(0.137)	(0.089)	(0.436)	(0.112)	(0.079)	(0.348)
oilprices	0.010	0.010	0.016	0.011	0.012	0.017	0.009	0.010	0.013
	(0.243)	(0.199)	(0.176)	(0.165)	(0.128)	(0.141)	(0.280)	(0.215)	(0.259)
ruralrate	0.741	0.585	1.504	0.252	0.113	0.965	0.188	0.092	0.765
	(0.163)	(0.203)	(0.143)	(0.660)	(0.824)	(0.338)	(0.776)	(0.877)	(0.477)
_cons	-15.018	-12.768	-25.390	3.622	4.616	-1.570	-0.251	-0.510	-2.206
	(0.268)	(0.266)	(0.335)	(0.827)	(0.754)	(0.956)	(0.990)	(0.978)	(0.946)
R^2	0.45	0.45	0.30	0.42	0.41	0.31	0.40	0.38	0.29
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Thermal Comfort Issues: Inability to Keep Home Warm (EPThermal) – **Individuals using the Internet for information about goods and services**

Digital information about goods and services can decrease the incapacity of keep home warm by 0.124pp on total households, 0.114pp on households above the income, and 0.170pp in households below the income level, with a 1 pp increase in the indicator.

Next-generation broadband did not show statistically significant results on EPThermal, and subsequent poverty thresholds.

OLS Fixed Effects

	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60	EPThermal	EPThermal_ A60	EPThermal_ B60
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ebuy	**-0.325*** **	**-0.324** **	**-0.303**						
	(0.023)	(0.016)	(0.156)						
infogs				**-0.124** **	**-0.114** **	**-0.170** **			
				(0.022)	(0.030)	(0.029)			
nextgen							**-0.048**	**-0.037**	**-0.084**
							(0.286)	(0.378)	(0.263)
unemp	0.523***	0.482***	0.535*	0.438***	0.414**	0.366	0.551**	0.531**	0.481
	(0.006)	(0.005)	(0.081)	(0.038)	(0.035)	(0.236)	(0.022)	(0.019)	(0.181)
electprices	18.800	19.033	15.418	17.269	17.354*	14.865	18.298	17.969*	17.317
	(0.153)	(0.102)	(0.463)	(0.137)	(0.089)	(0.436)	(0.112)	(0.079)	(0.348)
oilprices	0.010	0.010	0.016	0.011	0.012	0.017	0.009	0.010	0.013
	(0.243)	(0.199)	(0.176)	(0.165)	(0.128)	(0.141)	(0.280)	(0.215)	(0.259)
ruralrate	0.741	0.585	1.504	0.252	0.113	0.965	0.188	0.092	0.765
	(0.163)	(0.203)	(0.143)	(0.660)	(0.824)	(0.338)	(0.776)	(0.877)	(0.477)
_cons	-15.018	-12.768	-25.390	3.622	4.616	-1.570	-0.251	-0.510	-2.206
	(0.268)	(0.266)	(0.335)	(0.827)	(0.754)	(0.956)	(0.990)	(0.978)	(0.946)
R^2	0.45	0.45	0.30	0.42	0.41	0.31	0.40	0.38	0.29
N	278	278	278	279	279	279	280	280	280

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared. N is the number of observations.

Results and Discussion

Thermal Comfort Issues: Inability to Keep Home Warm (EPThermal)

Digitalization Index via PCA: levelnet, netbank and netdaily

The Digitalization Index has a negative relationship with energy poverty regarding thermal comfort, especially for households below the poverty line. A 1% increase in a country's Digitalization Index is conducive to a 0.002 and 0.006pp decrease in the share of total households and households below the poverty line, respectively, unable to keep their homes warm (1, 3)

OLS Fixed Effects	EPThermal (1)	EPThermal_A60 (2)	EPThermal_B60 (3)
EDig	-0.257*	-0.156	-0.626***
	(0.083)	(0.287)	(0.057)
unemp	-0.007	0.050	-0.270
	(0.959)	(0.702)	(0.194)
electprices	9.132*	10.963**	-0.906*
	(0.063)	(0.028)	(0.875)
oilprices	0.004	0.003	0.007
	(0.411)	(0.524)	(0.478)
ruralrate	-0.653***	-0.585***	-0.836***
	(0.000)	(0.000)	(0.008)
_cons	16.662***	13.313***	30.730***
	(0.000)	(0.000)	(0.000)
R^2	0.15	0.14	0.07
N	146	146	146

Note: * p<0.1; ** p<0.05; *** p<0.01. Values in brackets represent the P>| t |. R^2 is the within R-squared.

The reasons behind digitalization's impact on this energy poverty indicator can be many. By enhancing digital factors, families can leverage their knowledge on optimizing their homes' heating and cooling with small behavioral changes.

Conclusions
Limitations & Future Research

Conclusions

1. **Digitalization has the potential to alleviate energy affordability problems.**

The share of internet buyers (a proxy for digital savviness) and the number of households suffering from arrears on utility bills has a negative relationship across all thresholds of income;
More digital access to information regarding products & services appears to contribute to a decrease in energy debts, especially in families below the poverty threshold;

2. **Digitalization has the potential to alleviate thermal comfort problems.**

The share of internet buyers and the ability to keep home warm has a negative relationship in total households and households above the poverty threshold;
Digital information about goods and services can decrease the incapacity to keep home warm across all income levels;

Digitalization seems to ease informed and responsible decision-making regarding energy products, decrease switching costs, and improve financial management.

Despite not drastically changing the financial situation of the users or impacting the price of energy, these digital mechanisms can increase the household's commitment to pay utility bills on time.

Through increased digitalization, families gain a better understanding of energy usage and can use this knowledge to optimize home climate control through behavioral adjustments and adoption of appropriate technologies.

Limitations and Future Work

Limitations

- Limited data available. The Digitalization Index incorporates few digital indicators;
- Just two indicators measuring energy poverty;
- Inability to keep home warm can be affected by denial bias;
- OLS-FE does not address endogeneity.

Future Work

- Analysis with more variables, building more complete digital indexes; E.g., information about smart meters, smart houses etc; more control variables (education, income, housing conditions, others?)
- Measure energy poverty with other indicators such as Energy Equity and Absolute Energy Expenditure (robustness check);
- Test dynamic model (GMM) to account for endogeneity;
- Test different groups of countries/regions.

Thank you for your attention!
Questions? / Ideas?

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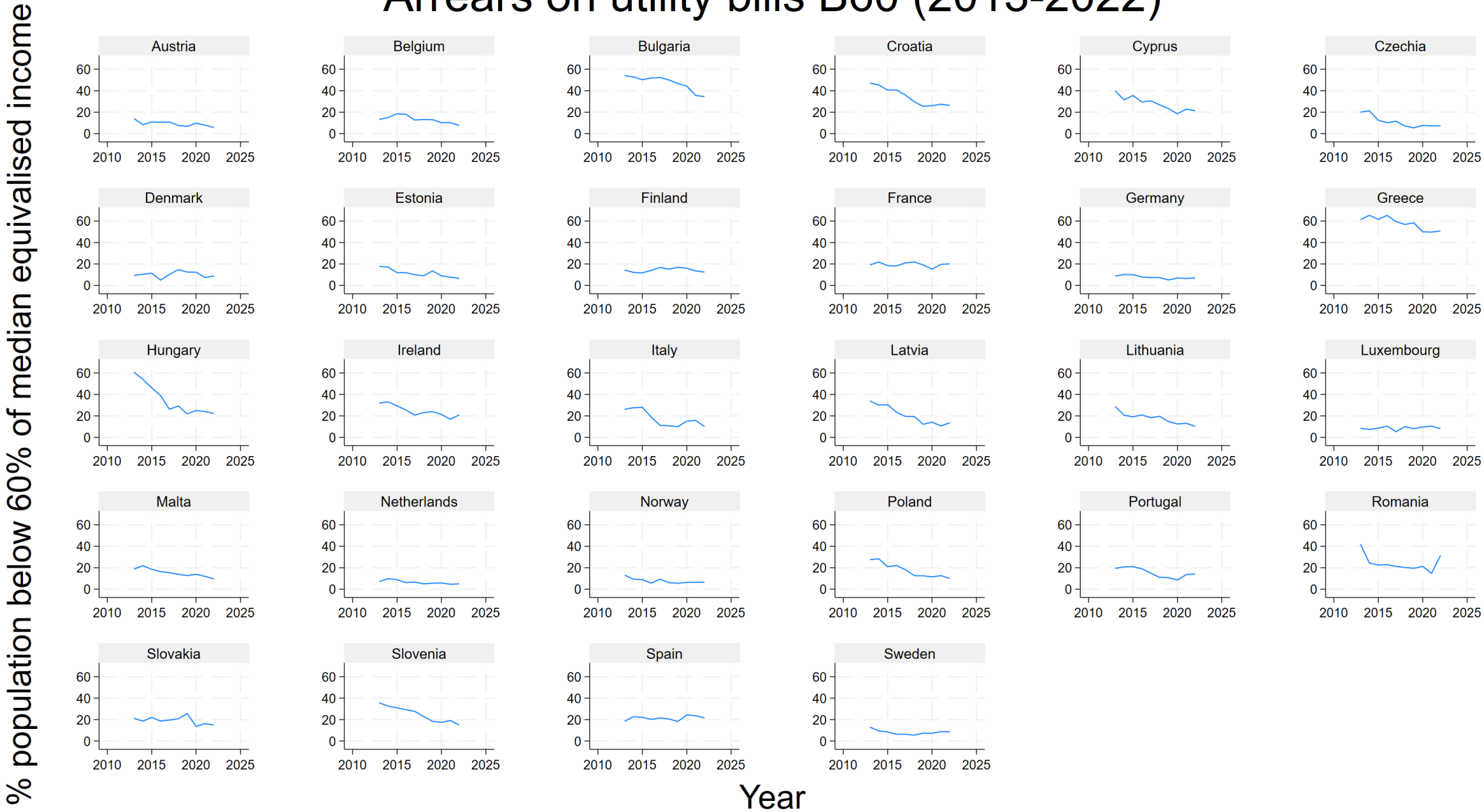
Arrears on utility bills B60 (2013-2022)



Inability to keep home adequately warm B60 (2013-2022)