UNIVERSITY OF GOTHENBURG
DEPARTMENT OF ECONOMICS

ivl Swedish Environmental Research Institute

CIRED
CENTRE INTERNATIONAL DE RECHERCHE SUR L'ENVIRONNEMENT ET LE DÉVELOPPEMENT

EnvEcon Decision Support

SMASH
Société de Mathématiques Appliquées et de Sciences Humaines

An ex post evaluation of the Energy Performance of Buildings Directive across the EU

E. Ó BROIN, J. EWALD, F. NADAUD, É. MATA,
M. HENNLOCK, T. STERNER and L-G. GIRAUDET

Érika Mata, IVL Swedish Environmental Research Institute

2018 INTERNATIONAL ENERGY WORKSHOP, Gothenburg, Sweden

formas
The Swedish Research Council Formas
Committed to excellence in research for sustainable development

Background

- FORMAS funded project
  - Climate policies for urban households – Attitudes and effects
- Empirical analysis of determining factors of buildings' energy use
- 6 EU countries: France, Germany, Italy, Sweden, and the UK
- Panel data econometric modelling

ivl CIRED UNIVERSITY OF GOTHENBURG

Results

- ‘lowering’ of U-Values reduces demand. Is this related to EPBD? Too early to say.
- Regulations (national & EU including EPBD) not found to be significant. Need to examine delayed/lagged effects of regulatory policy.
- Financial policies found to be significant

ivl CIRED UNIVERSITY OF GOTHENBURG

EU Energy and Carbon Goals

- 20-20-20 by 2020
- 40% reduction in CO_2 by 2030
- 27-40% reduction in Energy Use by 2030
- EPBD(Recast; **2018/844**)/ Energy Efficiency Directive
- National energy efficiency policy

Into force as of 9 July 2018

1. Ren Strategy by 2050, cost-eff decarb
2. Set NR buildings up for electric car charging
3. Inspect heating systems
4. Inspect AC systems (over 70 kW)
5. Information to households on EPC and ESMs

ivl

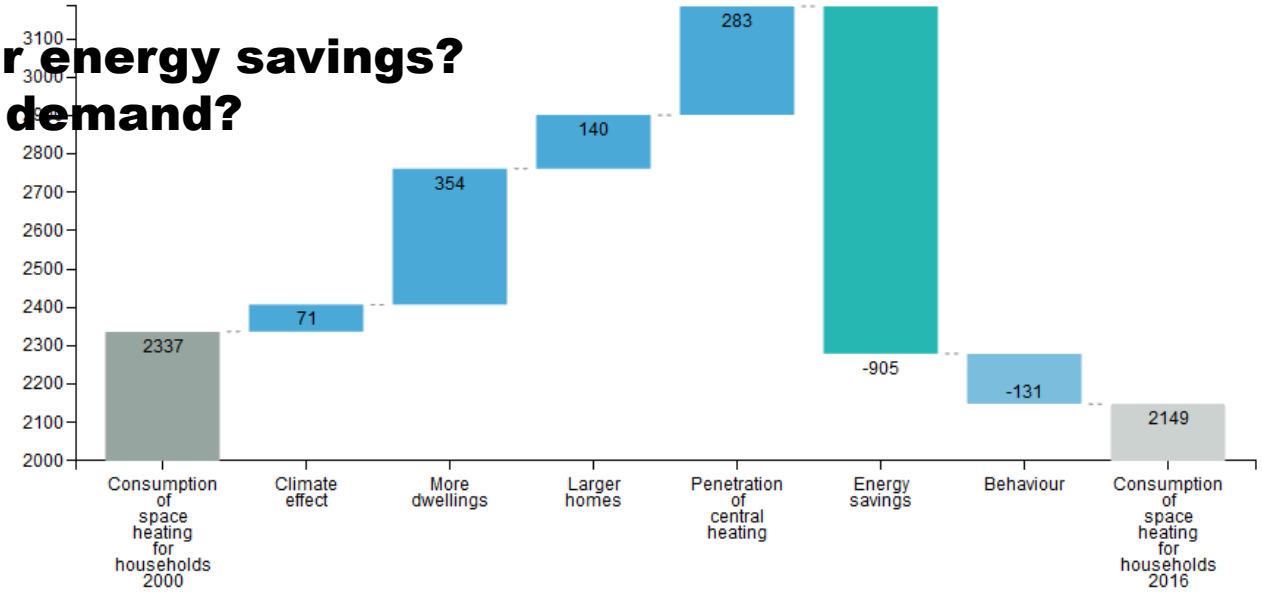
CIRED

UNIVERSITY OF GOTHENBURG

Efficiency Progress

Variation households consumption for space heating - European Union - TWh (2000-2016)

Really?
Drivers for energy savings?
And total demand?



Variation influenced by: http://www.indicators.odyssee-mure.eu/decomposition.html

- Climatic difference between these two dates ("climatic effect");
- Change in number of occupied dwelling ("more dwellings");
- Change in floor area of dwelling for space heating ("larger homes");
- Diffusion of central heating, mainly in southern countries;
- Energy savings, as measured from ODEX;
- Other effects (mainly change in heating behaviors).

ivl

CIRED

UNIVERSITY OF GOTHENBURG

EPBD Evaluation

- EC, 2016. Evaluation of Directive 2010/31/EU on the energy performance of buildings.
  - Directive 2002/91/EC and the EPBD resulted in major modernisation of national building codes through the introduction of minimum requirements for existing buildings, *BUT*…
  - It is impossible to precisely segregate and quantify a specific contribution of the EPBD as other policies national measures may have influenced the observed trends

ivl CIRED UNIVERSITY OF GOTHENBURG

Efficiency Policies

Code	Title	Type	Start	End	SQI
HOU-SWE6	Assignment 2000	Co-operative	1986	1992	High
HOU-SWE23	Technology procurement groups	Co-operative	1989		High
HOU-SWE4	Energy and carbon dioxide tax	Cross-cutting	1991		Medium
HOU-SWE3	Testing and trial of energy intensive products	Information/Education	1995		Low
HOU-SWE9	Labelling of domestic appliances and windows	Legislative/Informative	1995	2011	Low
HOU-SWE10	Grants for biofuel heating systems and energy efficient windows	Fiscal/Tariffs	2006	2009	Low
HOU-SWE14	Support for conversion from direct electric systems	Financial	2006	2010	Low
HOU-SWE25	EPBD (Directive 2002/91/EC) - Energy efficiency certificates	Legislative/Informative, Legislative/Normative	2006		Low
HOU-SWE22	Programme for buildings with very low energy use (LÅGAN)	Financial	2010		Unknown
HOU-SWE21	Investment support for photovoltaic cells	Financial	2013	2016	Unknown
HOU-SWE12	Building regulations (Planning and building law)	Legislative/Normative	2016		Unknown

Example of Sweden

- Eleven Policies
- Different durations
- One EU policy

111 such policies for the six countries

MURE Policy Database
http://www.measures-odyssee-mure.eu/

ivl

CIRED

UNIVERSITY OF GOTHENBURG

Drivers of energy demand

1. Energy Price (Weighted for energy carriers)
2. Income per capita
3. Climate (Heating Degree Days?)
4. Population
5. Lock-in (lag)
6. Number of dwellings
7. Household Size
8. Floor area per dwelling
9. Autonomous technical progress (Time trend - UEDT)
10. U-Values
11. Indoor Temperature
12. Efficiency Policies

- Technical Change
  - Efficiency
  - Inertia
  - Inventions
  - Learning
- Economics
- Climate
- Policy
- Fashion

ivl

CIRED

UNIVERSITY OF GOTHENBURG

	O Broin et al.	Filippini et al.	Saussay et al.	Bigano et al.
Temporal scope	1990–2010	1996–2009	1990–2008	1980–2006
Spatial scope	EU-15 except Luxembourg	EU-27 except Malta	Seven EU countries: Austria, Denmark, Finland, France, Germany, Poland and the United Kingdom	EU-15 plus Norway
Panel structure	Balanced	Unbalanced	Unbalanced	Unbalanced
Panel approach	Fixed Effects	Fixed and random effects separately	Random effects	Fixed effects
Dependent variable	Unit Consumption (kWh/m^2/year) of residential sector space heating energy demand from five energy carriers: electricity, natural gas, oil, coal and district heating	Total energy demand in residential sector	Sum of residential sector space heating energy demand from three energy carriers: electricity, natural gas and oil	Unit consumption for total energy demand in residential sector
Price variable	WAP for heat from five energy carriers: coal, district heating, electricity, natural gas and oil.	Index of household energy prices	WAP of market prices for three energy carriers: electricity, natural gas and oil.	Electricity prices
Policy data source	MURE Policy Database	MURE Policy Database	IEA BEEP Database	MURE Policy Database
Policy parameterization	Index that increases by 20, 10 or 1 every time a High-, Medium-, or Low-impact policy is introduced respectively.	Separate dummy variables for cases of 1–2 or $\geqslant$ 3 policies in a particular category that are in force.	Index that increases by 1 for every year a policy is in force.	Dummy variable for each year at least one policy in a particular category is in force.
Inclusion of policy variables in model	Variable in panel OLS	Stochastic frontier approach	Stochastic frontier approach	Variable in panel OLS
Lagged effects of policy variables	Up to 7 years	None	Implicit *via* annually increasing policy index	Up to 2 years
Lagged effects of dependent variable	No	Yes	No	No
Policy categories modelled	Four: (i) all; (ii) financial; (iii) informative; and (iv) regulatory	Six: (i,ii) building standards; (iii,iv) financial; (v) appliances; and (vi) information	One: building standards	Twelve: (i) mandatory standards for buildings; (ii) Regulation for heating systems and hot water systems; (iii) other regulation in the field of buildings; (iv) mandatory standards for electrical appliances; (v) legislative/ informative; (vi) grants/subsidies; (vii) loans/ others, (viii), Tax exemption/reduction; (ix) tariffs; (x) information/education; (xi) co-operative measures; (xii) cross-cutting with sector-specific characteristics

Literature to date

ivl

CIRED

UNIVERSITY OF GOTHENBURG

Findings to date

- Bigano et al. (2011) and Saussay et al. (2012) found that energy efficiency in the residential sector had been improved by the application of, in particular, mandatory standards for buildings while and Ó Broin et al (2015) found regulatory policy to be paramount.
- Filippini et al. (2014) found that financial measures had the greatest impact, mandatory standards for appliances or buildings less of an impact; they found no improvement in efficiency from informative policies.

ivl CIRED UNIVERSITY OF GOTHENBURG

Modelling specification

- Basic *model*
  - $E_{it} = f(E_{it-1}, wap_{it}, inc_{it}, Year, hdd_{it}, dwe_{it})$
- Introduce t_int_{it}, u_val_{it}
- Introduce Ep_{it} using policy sub-categories
  - Regulations (BH)
  - Financial (FIN)
  - Informative (INFO)
  - Appliances & lighting (APP)
- Separate dummy variables for each sub-category if either 1 or >1 policy in place

ivl CIRED UNIVERSITY OF GOTHENBURG

Econometric panel data approach

- Dynamic fixed effects (FE)
  - biased and inconsistent for a finite T (time) with a lagged endogenous variable
- General Method Moments (GMM)
  - Biased when N is small. N=7 in this work.
- Least Squares Dummy Variable Corrected (LSDVC)

ivl CIRED UNIVERSITY OF GOTHENBURG

Results – Basic SH Model

	(1) FE	(2) GMM	(3) LSDVC
L.l_sh_tot	0.46***	0.46***	0.49***
	(0.056)	(0.049)	(0.083)
l_wap_sh	-0.20***	-0.20***	-0.20***
	(0.046)	(0.039)	(0.058)
l_inc	0.17***	0.20***	0.17***
	(0.055)	(0.050)	(0.037)
l_hdd	0.94***	0.94***	0.94***
	(0.080)	(0.069)	(0.086)
l_dwe	0.63***	0.64***	0.58***
	(0.15)	(0.14)	(0.17)
year	-0.0046**	-0.0051**	-0.0041*
	(0.0023)	(0.0021)	(0.0023)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

variables for floor area, persons per household and population were not found to be significant.

- Polarities as expected
- Price/Income inelastic
- FE bias negligible
- Time trend (UEDT) 0.5% pa

there is 0.5% reduction in demand every year regardless of all the other factors in the model like price/income/climate

ivl

CIRED

UNIVERSITY OF GOTHENBURG

Results – Basic TotE Model

	(1) FE	(2) GMM	(3) LSDVC
L.l_tot	0.41***	0.36***	0.44***
	(0.061)	(0.055)	(0.087)
l_wap_tot	-0.23***	-0.23***	-0.22***
	(0.030)	(0.027)	(0.041)
l_inc	0.098***	0.13***	0.096***
	(0.033)	(0.031)	(0.025)
l_hdd	0.46***	0.47***	0.46***
	(0.048)	(0.042)	(0.056)
l_dwe	0.80***	0.83***	0.76***
	(0.12)	(0.12)	(0.16)
year	-0.0041***	-0.0046***	-0.0038**
	(0.0015)	(0.0013)	(0.0016)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

- Price and time trend elasticities similar to SH
- Income and HDD elasticities less than SH

ivl

CIRED

UNIVERSITY OF GOTHENBURG

Results with t_int & u_val

	(1) FE	(2) GMM	(3) LSDVC
L.l_sh_tot	0.45***	0.44***	0.48***
	(0.056)	(0.050)	(0.088)
l_wap_sh	-0.22***	-0.22***	-0.22***
	(0.047)	(0.041)	(0.059)
l_inc	0.15***	0.16***	0.14***
	(0.056)	(0.053)	(0.042)
l_hdd	0.95***	0.95***	0.95***
	(0.078)	(0.070)	(0.087)
l_dwe	0.70***	0.71***	0.66***
	(0.15)	(0.14)	(0.16)
year	-0.0024	-0.0027	-0.0018
	(0.0025)	(0.0023)	(0.0027)
l_t_int	1.16	1.12	1.10
	(1.21)	(1.08)	(1.51)
l_u_val	0.077**	0.076***	0.077***
	(0.030)	(0.026)	(0.020)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

- Time trend (UEDT) reduced & t_int not significant
- Increase in U-Values of 1 increases demand by 0.75%

ivl

CIRED

UNIVERSITY OF GOTHENBURG

Results with policy variables

	(1) FE	(2) GMM	(3) LSDVC
L.l_sh_tot	0.42***	0.42***	0.45***
	(0.059)	(0.051)	(0.080)
l_wap_sh	-0.17***	-0.17***	-0.16***
	(0.049)	(0.042)	(0.060)
l_inc	0.19***	0.19***	0.18***
	(0.061)	(0.055)	(0.043)
l_hdd	0.92***	0.92***	0.93***
	(0.081)	(0.070)	(0.092)
l_dwe	0.68***	0.72***	0.63***
	(0.17)	(0.15)	(0.18)
year	-0.0048*	-0.0046*	-0.0043
	(0.0028)	(0.0025)	(0.0029)
bh3_sh	-0.029	-0.027	-0.028
	(0.023)	(0.020)	(0.023)
bh4_sh	-0.037	-0.042	-0.036
	(0.029)	(0.026)	(0.029)
fin3_sh	-0.013	-0.018	-0.014
	(0.019)	(0.018)	(0.024)
fin4_sh	-0.044*	-0.045**	-0.043*
	(0.024)	(0.021)	(0.025)
info3_sh	0.039*	0.031	0.039*
	(0.022)	(0.020)	(0.021)
info4_sh	0.034	0.023	0.034
	(0.029)	(0.026)	(0.030)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

SH

- >1 Financial Policy significant
  Regulatory policy not significant
- Informative policy wrong polarity…
- Time trend back up to 0.5% but lower significance

ivl CIRED UNIVERSITY OF GOTHENBURG

Results with policy variables

	(1) FE	(2) GMM	(3) LSDVC
L.l_tot	0.28***	0.27***	0.30***
	(0.059)	(0.056)	(0.077)
l_wap_tot	-0.28***	-0.27***	-0.27***
	(0.031)	(0.029)	(0.039)
l_inc	0.058*	0.077**	0.057**
	(0.035)	(0.036)	(0.026)
l_hdd	0.42***	0.43***	0.42***
	(0.045)	(0.042)	(0.051)
l_dwe	0.92***	0.90***	0.88***
	(0.13)	(0.12)	(0.13)
year	-0.0023	-0.0028*	-0.0020
	(0.0016)	(0.0015)	(0.0016)
bh3_tot	-0.041***	-0.041***	-0.040***
	(0.013)	(0.012)	(0.013)
bh4_tot	-0.086***	-0.082***	-0.085***
	(0.017)	(0.017)	(0.017)
fin3_tot	0.021*	0.022**	0.020
	(0.011)	(0.011)	(0.013)
fin4_tot	-0.011	-0.0070	-0.011
	(0.013)	(0.012)	(0.014)
info3_tot	0.014	0.0046	0.014
	(0.016)	(0.015)	(0.017)
info4_tot	0.028	0.030*	0.027
	(0.017)	(0.016)	(0.017)
app3_tot	0.0080	0.0065	0.0079
	(0.013)	(0.012)	(0.014)
app4_tot	-0.0086	-0.0047	-0.0087
	(0.019)	(0.019)	(0.021)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Total E

- 1 Financial Policy significant
- 1 or more Regulatory policies significant

Need more due to SH/EL interactions; Linda? Persistence

- Informative & appliance policy not significant

Higher EL demand

- Time trend halved

ivl CIRED UNIVERSITY OF GOTHENBURG

Conclusions (For Space Heating)

- ‘lowering’ of U-Values reduces demand. Is this related to EPBD? Too early to say.
- Regulations (national & EU including EPBD) not found to be significant. Need to examine delayed/lagged effects of regulatory policy.
- Financial policies found to be significant

ivl CIRED UNIVERSITY OF GOTHENBURG

UNIVERSITY OF GOTHENBURG

DEPARTMENT OF ECONOMICS

ivl SVENSKA MILJÖINSTITUTET

CIRED
CENTRE INTERNATIONAL DE RECHERCHE SUR L'ENVIRONNEMENT ET LE DÉVELOPPEMENT

EnvEcon
Decision Support

SMASH
Société de Mathématiques Appliquées et de Sciences Humaines

Comments appreciated!

erika.mata@ivl.se
@ErikaMata_tw

formas
The Swedish Research Council Formas
Committed to excellence in research for sustainable development