Assessing energy efficiency: econometric evidence and implications for Italian energy policy

Authors: Pierpaolo Perna (Oxera), Armando Castro (University College London)

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Energy security, efficiency and sustainability

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Introduction and objectives of the study

Energy efficiency as a key element of the European Green Deal

In the context of EU wide target setting, energy efficiency is approximated by imperfect proxies. Academic efficiency literature has developed robust efficiency definitions that can be used for target setting

In their National Action Plans (NAPs), Member States set out long term efficiency targets and the measures required to achieve these

This study represents an attempt to directly compare the efficiency assumptions in a National Action Plan using econometric benchmarking approaches.

European objectives and energy efficiency targets

Background: 2012 European Efficiency Directive (2012/27/EU) – setting efficiency targets

Table. Energy efficiency objectives at the EU level

	2020 objective	2030 objective
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-20%	-32,5% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

If energy consumption were to continue growing at its current rate, the EU would not meet its 20 % energy efficiency target for 2020

The case of Italy (I)

PNIEC outlines the measures that will be taken going forward, and aims to use a mix of regulatory and financial measures articulated across different sectors

Table. Energy efficiency objectives for Italy

	2020 objective	2030 objective
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-24%	-43% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

The latest Italian plan puts forward ambitious targets, considering several efficiency-enhancing opportunities (e.g. smart mobility in the transport sector, improving the efficiency of buildings and heat pumps)

Compared to period 2016-2018, PNIEC estimates a cumulated saving in total final energy consumption amounting to 51,4 Mtoe, or 9,3 Mtoe per year.

The case of Italy (II)

PNIEC's targets are based on a bottom-up assessment of cost-effectiveness and aimed at identifying sectors with the greatest potential.

Table. 2030 objectives for Italy

	Savings (Mtoe)	Share of saving, %
Residential	3,3	35%
Tertiary	2,4	26%
Industry	1,0	11%
Transport	2,6	28%
Total	**9,3**	**100%**

Table. Difference between expected savings in 2020 and improvement achieved since 2011

	% target
Residential	99,2%
Tertiary	17,5%
Industry	49%
Transport	30,7%
Overall	**51.9%**

The concept of energy efficiency

- Energy efficiency is generally approximated by energy intensity input based ratios. Some limitations – do not differentiate between true energy efficiency and other factors
- Stochastic Frontier Analysis (SFA) approach – e.g. Filippini and Hunt (2011, 2012), Saussay et al. (2012), Filippini et al (2014)

Approach	Modelling assumptions
BC95	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency. Truncation at zero of the normal distribution
PL81	v_{it}: normally distributed error term u_i: one-sided nonnegative term representing inefficiency. Half-normal distribution (time invariant)
TFE	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency a_i: time-invariant unmeasured heterogeneity captured through fixed effects
SK12	Error term split into a normally distributed component (noise) and a one-sided component (transient inefficiency). Random effects split into one sided non-negative term representing persistent inefficiency and in a term measuring time invariant heterogeneity

Empirical methodology

For total consumption, the main model can be expressed as follows:

$$Consumption_{it} = f(EnergyPrice_{i,t}, GDP_{i,t}, Population_{i,t}, EF_{i,t}, T_t)$$

In other words, final consumption ($Consumption_{it}$) is estimated as a function of real energy prices ($EnergyPrice_{i,t}$) real gross domestic Product ($GDP_{i,t}$), population ($Population_{i,t}$), a time trend (T_t), and efficiency ($EF_{i,t}$). The analysis considers different SFA approaches.

Sensitivities:

- Disaggregate analysis (residential, industrial, transport, other consumption)
- Inclusion of additional explanatory factors (area of dwellings, heating degree days)
- Inclusion of policy measures to explain efficiency levels

Main variables considered

Variable	Unit	N	Mean	Std. Dev.	Minimum	Maximum
Total Consumption	Thousands toe	357	51.6	59.3	1.5	231.4
Consumption, residential	Thousands toe	357	13.1	16.4	0.2	69.0
Consumption, transport	Thousands toe	357	15.9	18.6	0.7	66.4
Consumption, industrial	Thousands toe	357	14.4	15.8	0.2	64.6
Consumption, other	Thousands toe	357	8.2	9.4	0.2	39.8
Y	€b, '10 ex. rate	357	569.4	720.6	9.8	2870.6
POP	Thousands	357	21552.2	24671.6	656.3	82536.7
PE	2005=100	357	78.1	22.4	20.5	121.7
DWELL	Floor area of dwellings	325	94.85	20.2	52.5	146.0
DEGREE	Heating degree days	325	2793.6	1034.5	453	4947

Note: variables DWELL and DEGREE have been considered as a sensitivity but have not been included in the key specification due to missing data.

Main econometric results
Regression output

Estimation approach	BC95	PL81	TFE[1]	SK12
Parameters of the total demand function				
Ln(Energy prices)	-0.06	-0.09***	-0.09***	-0.09***
Ln(GDP)	0.45***	0.50***	0.46***	0.51***
Ln(Population)	0.51***	0.43***	0.21***	0.38***
Time trend	-0.01*	-0.01***	-0.01***	-0.01***
Constant	-3.89***	-3.31***		-2.62***
Parameters in the one sided error (u)				
Constant	-2.70***	0.09***	-14.68	
Variance parameters for the compound error (v)				
Constant	-5.74***	0.00***	-5.93***	
Lambda	4.58***	5.68***	0.009	
Observations	357	357	357	357

Note: [1] country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

Main econometric results
Efficiency scores

Table. SFA models, efficiency scores (%), total consumption, 1996-2016

Estimation approach	Sample	Italy	Average	Standard deviation	Minimum	Maximum
BC95	357	89.28	78.62	12.5	46.0	97.9
PL81	357	86.96	79.42	13.7	50.6	98.7
TFE	357	99.95	99.95	0.0	99.9	99.9
SK12	357	97.25	97.19	0.2	96.7	97.6

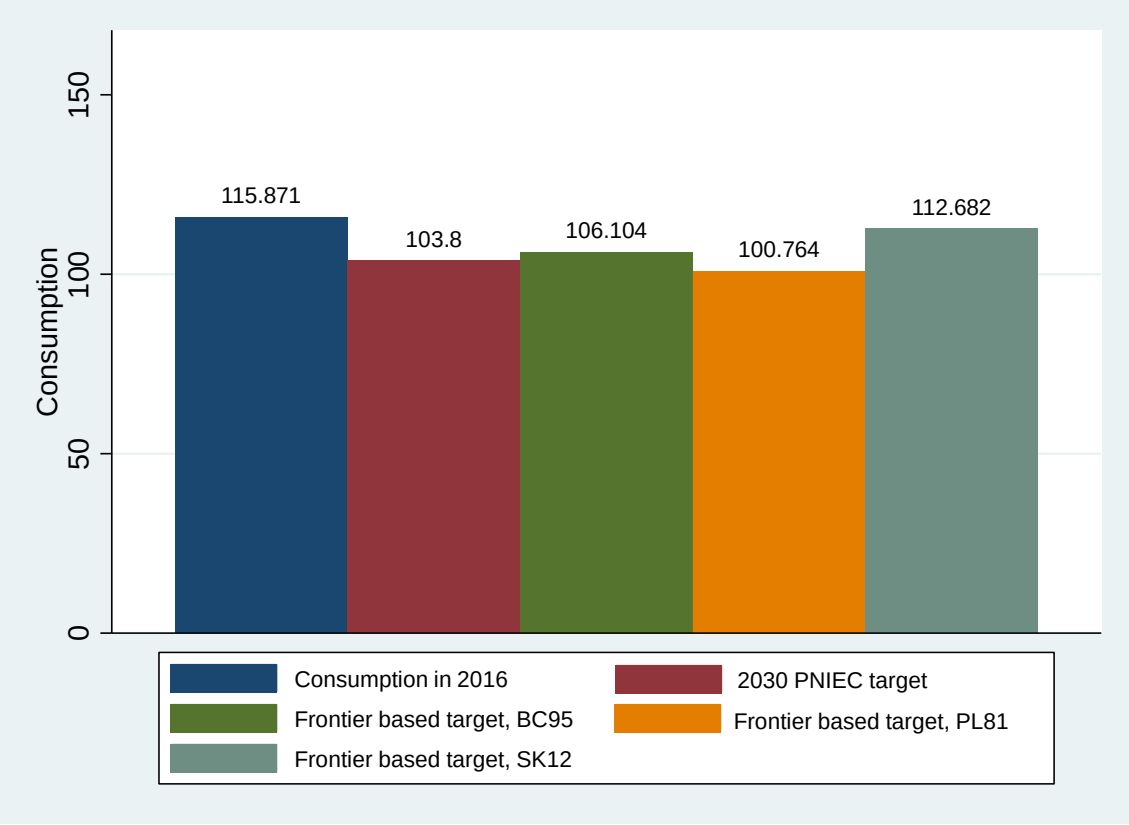
Note: for SFA analysis with an enhanced specification (N=324) including area of dwellings and degree days, efficiency scores for Italy are 94.2 (BC95), 67.0 (PL81), 99.9 (TFE), 99.9 (SK12).

Table. SFA models, correlation coefficients

	BC95	PL81	TFE	SK12
BC95	1.00			
PL81	0.93	1.00		
TFE	0.26	0.00	1.00	
SK12	0.87	0.97	0.00	1.00

Main econometric results
Consumption targets

Graph. SFA models, Comparison between 2016 consumption levels, 2030 targets and frontier based targets



Significant scope for efficiency savings (potentially above and beyond the 2030 PNIEC target)

Further econometric results
Disaggregated econometric analysis

Table. SFA models, efficiency scores (%), disaggregated consumption, 1996-2016 (PL81)

Demand	Sample	Italy	Average	Standard deviation	Minimum	Maximum
Total	357	86.9	79.5	13.7	50.6	98.7
Residential	357	60.2	51.8	18.8	31.7	97.9
Industrial	357	17.8	29.2	21.9	11.0	97.0
Transport	357	63.8	66.6	14.4	49.2	98.6
Other	357	80.8	68.5	17.4	43.1	98.0

- above-average efficiency with respect to the residential and ‘other’ sectors
- below-average efficiency for the industrial and transport sectors

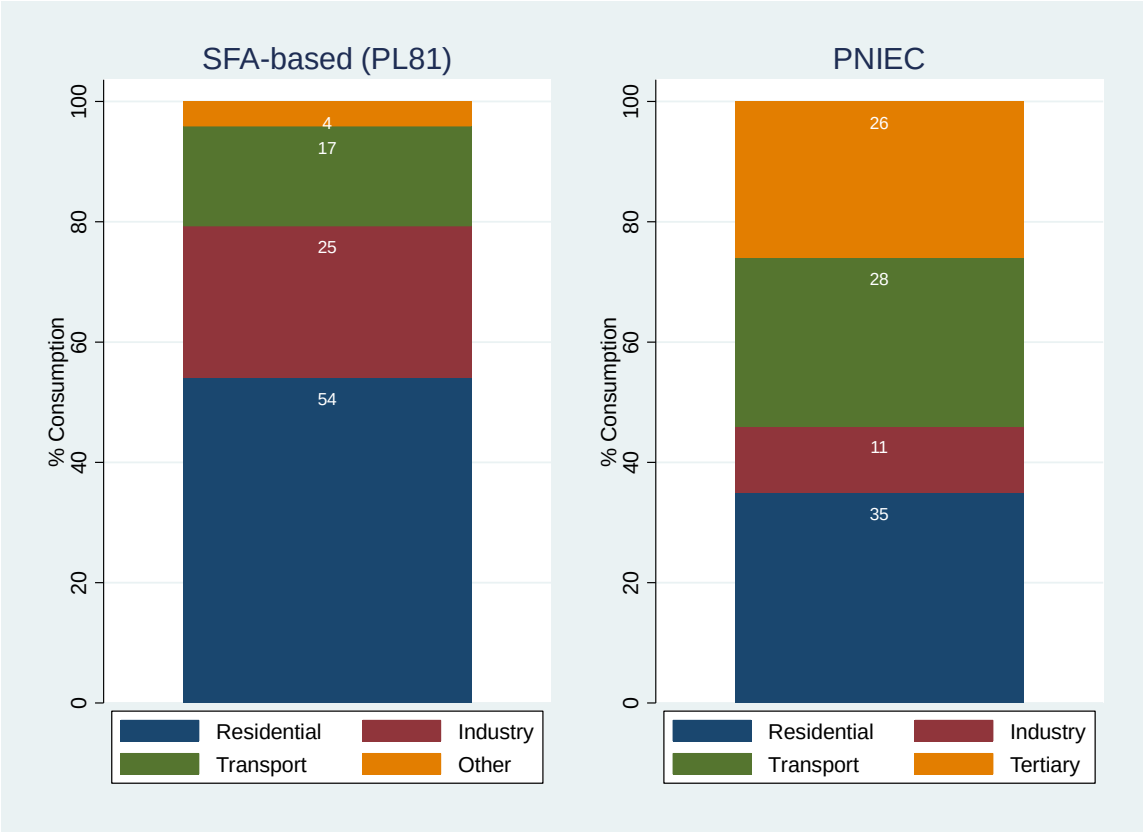
Further econometric results
Disaggregated econometric analysis

Table. SFA models, model coefficients, disaggregated consumption, 1996-2016, PL81

Estimation approach	PL81	PL81	PL81	PL81	PL81
Demand	Total	Residential	Industrial	Transport	Other
Parameters of the total demand function					
Ln(Energy prices)	-0.09***	0.03	-0.19***	0.01**	-0.19**
Ln(GDP)	0.50***	0.15***	0.69***	0.88***	0.31***
Ln(Population)	0.43***	0.90***		0.01	0.65***
Time trend	-0.01*	-0.01**	-0.01***	-0.01***	0.00
Constant	-3.31***	-8.12***	-2.29***	-3.17***	-5.92***
Parameters in the one sided error (u)					
Constant	-0.09***	0.61***	2.40**	0.23	0.23***
Variance parameters for the compound error (v)					
Constant	-0.00***	0.01***	-0.01***	-0.00***	0.01***
Lambda	5.68***	9.77***	15.96***	7.14***	4.49***
Observations	357	357	357	357	357

Main econometric results
Consumption targets

Graph. Comparison frontier-based composition of efficiency savings versus PNIEC



- Disaggregated analysis leads to more stringent targets
- Relative to the PNIEC targets, more emphasis on the industry and residential sectors

Further evidence
Policy measures

Estimation approach	PL81	PL81
Demand	Total	Total
Parameters of the total demand function		
Ln(Energy prices)	-0.15**	-0.24***
Ln(GDP)	0.43***	0.44***
Ln(Population)	0.55***	0.51***
Time trend	-0.01*	-0.01***
Constant	-3.83***	-2.96***
Parameters in the one sided error (u)	(dummy)[1]	Ln(number)
Measures (residential)	0.6	2.04***
Measures (industrial)	-0.97*	-1.10***
Measures (transport)	25.26	1.15***
Measures (other)	2.58***	3.68***
Constant	0.28***	0.08***
Variance parameters for the compound error (v)		
Constant	-5.76***	-5.42***
Observations	357	357

- Mixed evidence (partly due to imperfect proxies)
- Only policy variable found to be effective (and of expected sign) is in relation to the industrial sector

[1] Equal to one if the number of measures implemented in a country i in year t is above the sample mean

Conclusions

- Relative to the sample, which covers 17 EU countries over the period 1996-2016, the analysis provides evidence of Italy's above-average efficiency performance.
- However, it also shows that long term targets may be achieved by simply converging to existing best practice (without considering further technological change), which indicates significant scope for further efficiency improvements in the long term
- Disaggregate econometric analysis shows that further scope for efficiency may lie in the residential and the industrial sectors.
- Alternative approaches and further analysis may be required to explore the drivers of efficiency and inform long-term policy decisions.

Pierpaolo Perna
(Oxera)

Armando Castro
(University College London)

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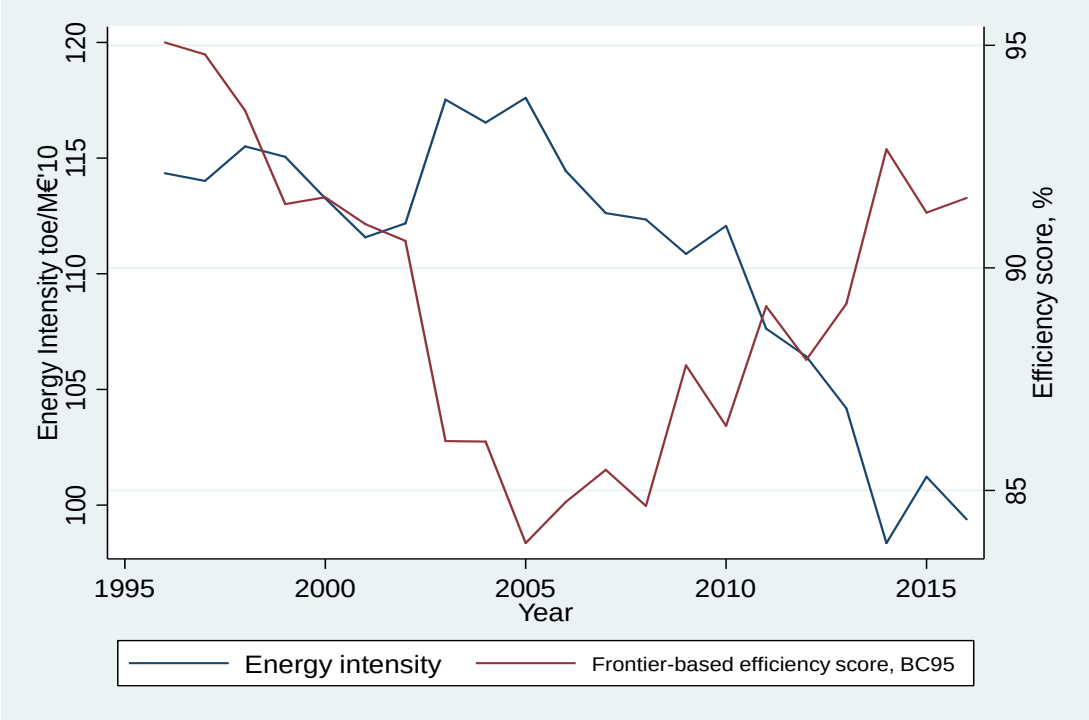
Main econometric results
Efficiency scores

Graph. Energy intensity and efficiency score (BC95), Italy, 1996-2016



Further econometric results

Disaggregated econometric analysis

Table. SFA models, efficiency scores (%), total consumption, 1996-2016 (PL81)

Demand	Sample	Italy	Average	Standard deviation	Minimum	Maximum
Total	357	86.9	79.5	13.7	50.6	98.7
Residential	357	60.2	51.8	18.8	31.7	97.9
Industrial	357	17.8	29.2	21.9	11.0	97.0
Transport	357	63.8	66.6	14.4	49.2	98.6
Other	357	80.8	68.5	17.4	43.1	98.0

Further econometric results
Disaggregated econometric analysis

Table. SFA models, model coefficients, disaggregated consumption, 1996-2016, BC95

Estimation approach	BC95	BC95	BC95	BC95	BC95
Demand	Total	Residential	Industrial	Transport	Other
Parameters of the total demand function					
Ln(Energy prices)	-0.06	0.08	-0.40***	0.13**	-0.26**
Ln(GDP)	0.45***	0.29***	0.44***	0.57***	0.44***
Ln(Population)	0.51***	0.69***	0.68***	0.36***	0.53***
Time trend	-0.01*	-0.01**	-0.01***	-0.01**	0.01
Constant	-3.89***	-6.40***	-5.41***	-4.96***	-4.84***
Parameters in the one sided error (u)					
Constant	-2.70***	-5.37	0.28	-0.25	-5.36
Variance parameters for the compound error (v)					
Constant	-5.74***	-2.37***	-6.17***	-4.44***	-2.67***
Lambda	4.58***	0.48	25.10***	8.12***	0.260
Observations	357	357	357	357	357

Main econometric results

Top- and bottom-quartile Member States

Top quartile	Countries
Energy intensity	Denmark, Ireland, Italy, France, Netherlands
BC95	Portugal, Denmark, Spain, Ireland, Italy
PL81	Denmark, Cyprus, Ireland, Portugal, Spain
TFE	(all MS at around 100% efficiency)
SK12	Cyprus, Denmark, Ireland, Portugal, Latvia

Bottom quartile	Countries
Energy intensity	Latvia, Slovakia, Poland, Latvia, Finland
BC95	Finland, Sweden, Belgium, Slovakia, Latvia
PL81	Finland, Sweden, Belgium, Slovakia, Poland
TFE	(all MS at 100% efficiency)
SK12	Finland, Poland, Belgium, Sweden, Denmark

Main econometric results (sensitivities)

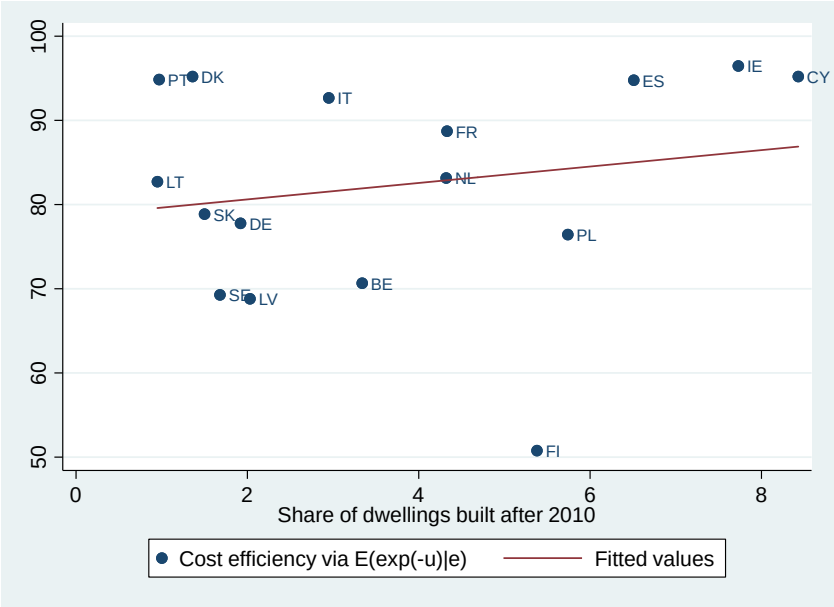
Top- and bottom-quartile Member States

Top quartile	Countries
Energy intensity	Denmark, Ireland, Italy, France, Netherlands
BC95	Denmark, Latvia, Ireland, Spain, Italy
PL81	Denmark, Ireland, Belgium, Cyprus, Latvia
TFE	(all MS at around 100% efficiency)
SK12	(all MS at around 100% efficiency)

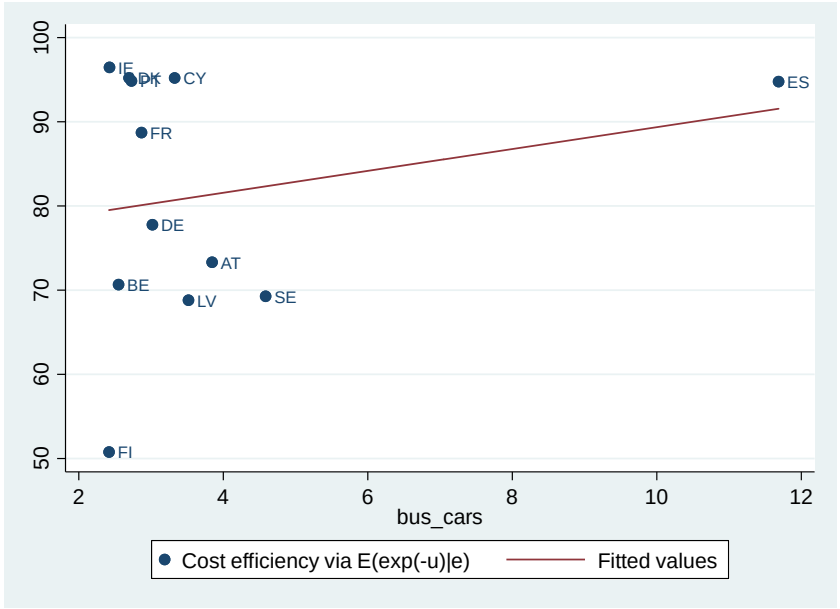
Bottom quartile	Countries
Energy intensity	Latvia, Slovakia, Poland, Latvia, Finland
BC95	Belgium, Finland, Sweden, Cyprus, Austria
PL81	Finland, Poland, Denmark, France, Sweden
TFE	(all MS at around 100% efficiency)
SK12	(all MS at around 100% efficiency)

Further evidence
Policy measures (2014)

Overall efficiency (BC95) vs share of dwellings built after 2010

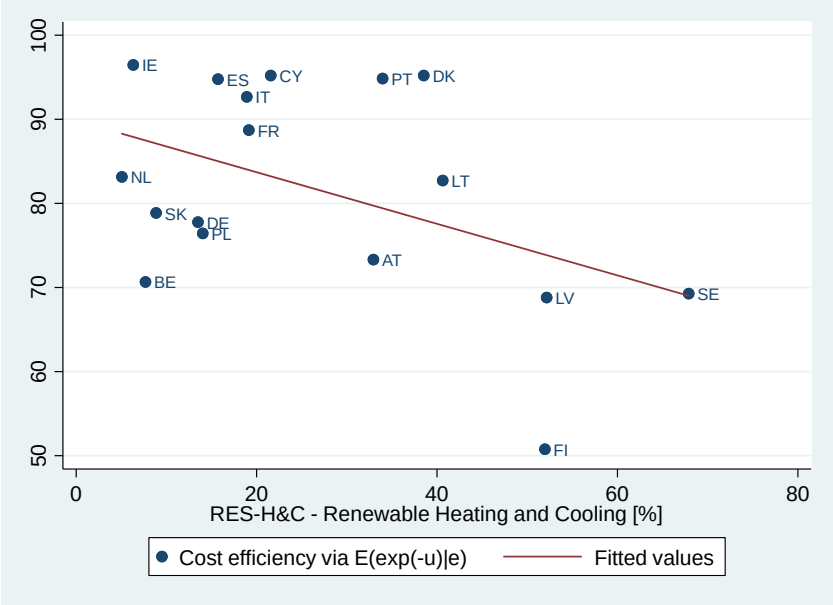


Overall efficiency (BC95) vs bus/car (annual distance travelled/km)



Further evidence
Policy measures (2014)

Overall efficiency (BC95) vs share of renewable H&C



Overall efficiency (BC95) vs share of renewable transport