Assessing the Impact of Energy Efficiency Standards on Residential Electricity Consumption in Mexico

Hildegart Ahumada
Di Tella University, Buenos Aires

Fernando Navajas
University of Buenos Aires & FIEL

39th IAEE International Conference
Norwegian School of Economics, Bergen, June 21 2016

Motivation

- This paper is part of a joint research agenda we have on the disentangling of non-price vs. price instruments effects on the consumption of some good or service with an associated externality.
- Several potential applications: smoking (bans vs. taxes), alcohol (regulations vs. taxes), energy (efficiency standards vs. prices/taxes), emissions (regulations vs. taxes), etc.
- Main contribution of the research is to develop a methodology to test these effects and also relationships/interactions that may have policy-design and evaluation relevance.

Assessing energy efficiency standards

- ES are regulations that affect the consumption of energy, but interact with other instruments/effects or even with social norms or patterns (Sorrell, 2015).
- Several studies have enquired into the differential effects of ES versus prices in fuel transport consumption (Greene, 1990; Portney et.al., 2003; Clerides and Zacharias, 2008; Burke and Nishitateno, 2013).
- Effects of ES on electricity consumption has also been tested (Horowitz, 2007; Berry 2008; Filippini and Hunt, 2013)
- Few or no studies in Latam.
- Mexico looks an interesting case: relatively extended experience on introducing standards (e.g. residential) within a broader policy (McNeil and Carreño, 2015; Carpio and Covielo, 2013).

Queries

- What is the effect of ES on observed consumption of household electricity?
  - On aggregate? On an individual basis? Are ES programs different in their impact?
- How does it compare with the effect of electricity prices on consumption?
- How does the introduction of ES changes the effect of prices on consumption (i.e. the price-elasticity of demand)?
  - Relevant for price/tax design (Christiansen and Smith, 2012) or for the rebound effect magnitude (Goldstein et.al, 2011)

Modeling strategy

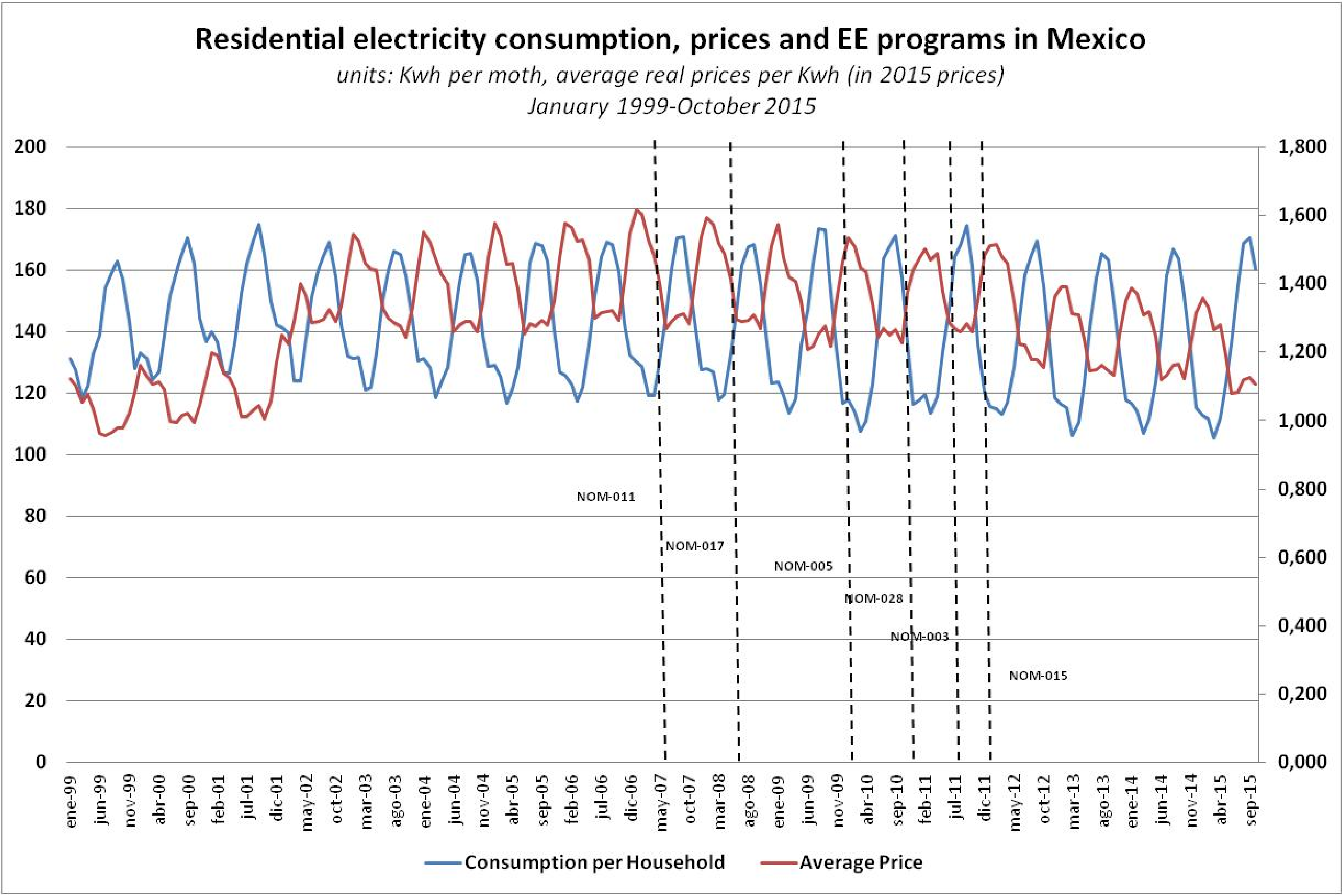
- We estimate a dynamic econometric model of aggregate monthly household electricity consumption in Mexico parameterized on real price, income, temperature and a set of federal (nation wide) efficiency standards (ES)
  - The basic idea of our testing is that omitting ES, a model of energy consumption will be subject to breaks.
- We use an automatic selection algorithm (Autometrics) to select variables, lags and impulse or step dummies
  - Because, although we observe when each ES is put in practice, the actual effect may be delayed several periods. That is why it may be difficult to detect intercept changes in this kind of model.

Data Description

- Sample is monthly 1999m1-2015m10
- Total Consumption per Household (KWh montlhy, source CRE-CFE)
- Real Price of electricity (2 sources: *CPI dataset (index Electricity to General Level, INEGI) and Sectorial dataset (Average price= Sales/Volumes))*
- Several income variables: GDP, Private Consumption per capita, Real Wages (sources: INEGI, CEFP-STPS)
- Temperature, Heating and Cooling Degree Days in Mexico DF and weighted national average (source: www.wunderground.com)
- Efficiency norms (source: SENER)

Main household efficiency starndards on electricity consumption in Mexico

Name	Date of Introduction	Type	Link and Description
NOM-011-ENER-2006	May 15, 2007	Air conditioning	http://www.dof.gob.mx/normasOficiales/2464/SENER_2_22062007/SENER_2_22062007.htm
NOM-017-ENER/SCFI-2008	August 26, 2008	Fluorescent Lamps	http://www.dof.gob.mx/nota_detalle.php?codigo=5057809&fecha=26/08/2008
NOM-005-ENER-2010	February 3, 2010	Washing Machines	http://dof.gob.mx/nota_detalle.php?codigo=5130186&fecha=03/02/2010
NOM-028-ENER-2010	December 6, 2010	Lamps in general	http://dof.gob.mx/nota_detalle.php?codigo=5169747&fecha=06/12/2010
NOM-003-ENER-2011	August 5, 2011	Water Boilers	http://www.dof.gob.mx/normasOficiales/4458/sener/sener.htm
NOM-015-ENER-2012	February 16, 2012	Refrigerators and fridges	http://dof.gob.mx/nota_detalle.php?codigo=5234117&fecha=16/02/2012


Residential electricity consumption, prices and EE programs in Mexico
units: Kwh per moth, average real prices per Kwh (in 2015 prices)
January 1999-October 2015
200
180
160
140
120
100
80
60
40
20
0
1,800
1,600
1,400
1,200
1,000
0,800
0,600
0,400
0,200
0,000
NOM-011
NOM-017
NOM-005
NOM-028
NOM-003
NOM-015
ene-99
jun-99
nov-99
abr-00
sep-00
feb-01
jul-01
dic-01
may-02
oct-02
mar-03
ago-03
ene-04
jun-04
nov-04
abr-05
sep-05
feb-06
jul-06
dic-06
may-07
oct-07
mar-08
ago-08
ene-09
jun-09
nov-09
abr-10
sep-10
feb-11
jul-11
dic-11
may-12
oct-12
mar-13
ago-13
ene-14
jun-14
nov-14
abr-15
sep-15
Consumption per Household
Average Price

Modelling Strategy

- Autometrics (Doornik 2009 and Doornik and Hendry, 2013)
  - Can handle many steps dummies to date the breaks and help us to choose the other explanatory variables at the same time, following a general to particular approach.
- A tree-search algorithm which selects significant variables based on the ordered square “t “ statistics to obtain a congruent representation according to a set a diagnostic tests (not only a best fit) for a given significance level.
  - Can select impulse (and step) indicator variables including each for every observation (for ending in every observation), named as Impulse IS (and Step Saturation, SS) together with many regressors, including the case of more variables than observations.

Dealing with impulse and step dummies

- For the case of energy efficiency measures as we know the date of implementation, we built *step dummies* (000,1111) for each month in which the efficiency measures .
  - These step dummies and theirs lags were unrestrictedly included in an starting model to consider delayed effects up to 12 months after the date in which the ES was implemented or up to the month when the next measure was put in practice.
- We generate the step dummies although IIS and/or SS may be applied too.
  - As we know the date of implementation, the search is more efficient since it is limited to the periods only after such date.

Econometric modelling

- We rewrite the selected equation as an Error Correction Model (ECM) with the levels unrestricted (in Bardsen´s form; see Banerjee, 1993) to have a clearer view of the different effects.
- This form is also useful when the model includes integrated variables to analyse cointegration. We reject the null of No Cointegration according to the statistics known as PcGive unit-root based on critical values of Ericsson and Mackinnon(2002).
- Similarly, using their Monte Carlo approximation of the *t- statistics* of the lagged dependent, critical value is given by *–3 - 0.2k- 0.3(d-1)*, where *k* is number of variables and *d* of deterministic components; the estimated *t-statistic* is 16.02.
- When steps are detected for two consecutive periods with similar coefficient estimates, it indicates an impulse rather than a step, which may be due to an outlier rather than a shift. This is the case of dumm2009m2 and dumm2010m12.

Econometric Results

DLCONSperUSER = - 1.68 - 0.194 *DLCONSperUSER_2_12* + 0.853 *DLWAGES* + 0.000627 *F_CDD*
(SE) (0.35) (0.024) (0.099) (0.0002)

- 0.413 *LCONSperUSER_1* + 0.166 *LWAGES_1* - 0.152 *LPRICEcpi_1*
(0.025) (0.043) (0.018)

- 0.038 *FLUOLAMPS2008-9_12* + 0.034 *WASHMACH2010-2_5*
(0.0049) (0.0059)

- 0.019 *WATBOIL2011-8_3* - 0.024 *FRIDGE2012-2_10*
(0.0055) (0.0052)

- 0.048 *dumm2009m2* - 0.054 *dumm2010m12*+ *Seasonals*
(0.015) (0.015)

SER = 0.0142 Adj.R^2 =0.967 T=190

AR 1-7 test: $F(7,163)$ = 1.5657 [0.1491] ; ARCH 1-7 test: $F(7,176)$ = 1.4078 [0.2048]

Hetero test: $F(23,164)$ = 1.4848 [0.0819] ; Hetero-X test: $F(38,149)$ = 1.4003 [0.0809]

Normality test: $Chi^2(2)$ = 0.17579 [0.9159]; RESET23 test: $F(2,168)$ = 1.6780 [0.1899]

Econometric Results

- Price elasticity of 0.37 in the LR (adjustment coefficient 40% in the first month)
- Several ES programs with effects, lags between 3 and 9 months
  - Fluo Lamps (NOMs 017), refrigerators and freezers (NOM 015) and water boilers (NOM 013) with a reduction in household electricity consumption between 1.9% and 3.8% (4.7% and 9.1% in the LR). They all add up 20% net impact in the long run.
- Some without effects or wrong sign
  - Air conditioning (NOM 011) non-significant effect, washing machines (NOM 005) with a positive effect on consumption of +3.4% (8,2% in the LR). If theses are included, ES programs add up to 11.4% net impact of electricity in the long run.
- Those ES with impact (e.g. fluo Lamps) increase the price-elasticity.

References

- Berry D., 2008. "The impact of energy efficiency programs on the growth of electricity sales", Energy Policy, 36(9), 3620-25
- Burke P. and Nishitateno S., 2013, "Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries", Energy Economics, 36, 363-70
- Carpio, C. and Coviello M., 2013. *Eficiencia energética en América Latina y el Caribe: avances y desafíos del último quinquenio*. UN ECLAC, Natural Resource and Infrastructure Division, Santiago de Chile.
- Christiansen V and Smith S, 2012. "Externality correcting taxes and regulation", *Scandinavian Journal of Economice, 114(2), 358-83.*
- Clerides S. and Zachariadis T., 2008. "The effect of standards and fuel prices on automobile fuel economy: An international analysis", *Energy Economics*, 30, 2657-72.
- Doornik, J. A., 2009. "Autometrics", Chapter 4 in J. L. Castle and N. Shephard (eds.) *The Methodology and Practice of Econometrics: A Festschrift in Honour of David F. Hendry*, Oxford University Press, 88-121.
- Goldstein D., Martinez S. and Roy R. (2011) "Are There Rebound Effects from Energy Efficiency? – An Analysis of Empirical Data, Internal Consistency, and Solutions", *Electricity Policy.com*.
- Greene, D., 1990. "CAFE or price? An analysis of the effects of federal fuel economy regulations and gasoline price on new car MPG 1978–89". *Energy Journal*. 11, 37–57.
- Horowitz M. , 2007. "Changes in Electricity Demand in the United States from the 1970s to 2003", *The Energy Journal,* 28, 3, 93-119.
- McNeil M and Carreño A.M., 2015: "Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000. Final Report". Technical Report 10//2015, SEAD, www.superefficient.org
- Portney, P.R., Parry, I.W.H.,Gruenspecht,H.P., and Harrington,W.,2003. "The Economics of fuel economy standards", *Journal of Economics Perspectives*.17, 203–217.
- Sorrell S., 2015, "Reducing energy demand: A review of issues, challenges and approaches", *Renewable and Sustainable Energy Reviews*, 47, 74-82

Appendix: Results from Autometrics

Econometric Results

Eq. 1. Modelling LCONSperUSER by Autometrics (at 1%)

	Coefficient	Std.Error	HCSE	t-HCSE	t-prob
LCONSperUSER_1	0.586834	0.05702	0.06501	9.03	0.0000
LCONSperUSER_2	-0.194113	0.03867	0.04045	-4.80	0.0000
LCONSperUSER_12	0.194378	0.03946	0.04078	4.77	0.0000
LPRICEcpi_1	-0.152408	0.01948	0.02032	-7.50	0.0000
LWAGES	0.853834	0.1143	0.1015	8.41	0.0000
LWAGES_1	-0.683596	0.1181	0.1103	-6.20	0.0000
Seasonal_2	-0.0453539	0.004994	0.004612	-9.83	0.0000
Seasonal_4	0.0208503	0.006284	0.007152	2.92	0.0040
Seasonal_5	0.0443528	0.008184	0.007949	5.58	0.0000
Seasonal_6	0.0737738	0.009351	0.008671	8.51	0.0000
Seasonal_7	0.0820787	0.009489	0.007881	10.4	0.0000
Seasonal_8	0.0940528	0.008801	0.007893	11.9	0.0000
Seasonal_9	0.0412516	0.006837	0.006560	6.29	0.0000
FRIDGE2012-2_10	-0.0245636	0.005275	0.004968	- 4.94	0.0000
FLUOLAMPS2008-9_5	-0.0478197	0.01482	0.003488	- 13.7	0.0000
FLUOLAMPS2008-9_6	0.0439598	0.01603	0.008580	5.12	0.0000
FLUOLAMPS2008-9_12	-0.0340830	0.007571	0.009823	-3.47	0.0007
WASHMACH2010-2_5	0.0324116	0.008162	0.01055	3.07	0.0025
LAMPS2010-12	-0.0521371	0.01639	0.008599	-6.06	0.0000
LAMPS2010-12_1	0.0546728	0.01554	0.006150	8.89	0.0000
WATBOIL2011-8_3	-0.0202096	0.006367	0.006306	-3.20	0.0016
F_CDD	0.000652753	0.0002170	0.0002039	3.20	0.0016
Constant	-1.70914	0.3683	0.3333	-5.13	0.0000

Econometric Results

Modelling LCONSperUSER by Autometrics (at 1%). Diagnostic statistics

SER= 0.01428 Adj.R^2= 0.9896 T= 190 (2000m1 – 2015m10)

AR 1-7 test: F(7,160) = 1.8739 [0.0771]

ARCH 1-7 test: F(7,176) = 1.4413 [0.1915]

Normality test: $Chi^2(2)$ = 0.10430 [0.9492]

Hetero test: F(27,160) = 1.7245 [0.0209]* (HCSE similar to SE)

RESET23 test: F(2,165) = 3.5094 [0.0322]*