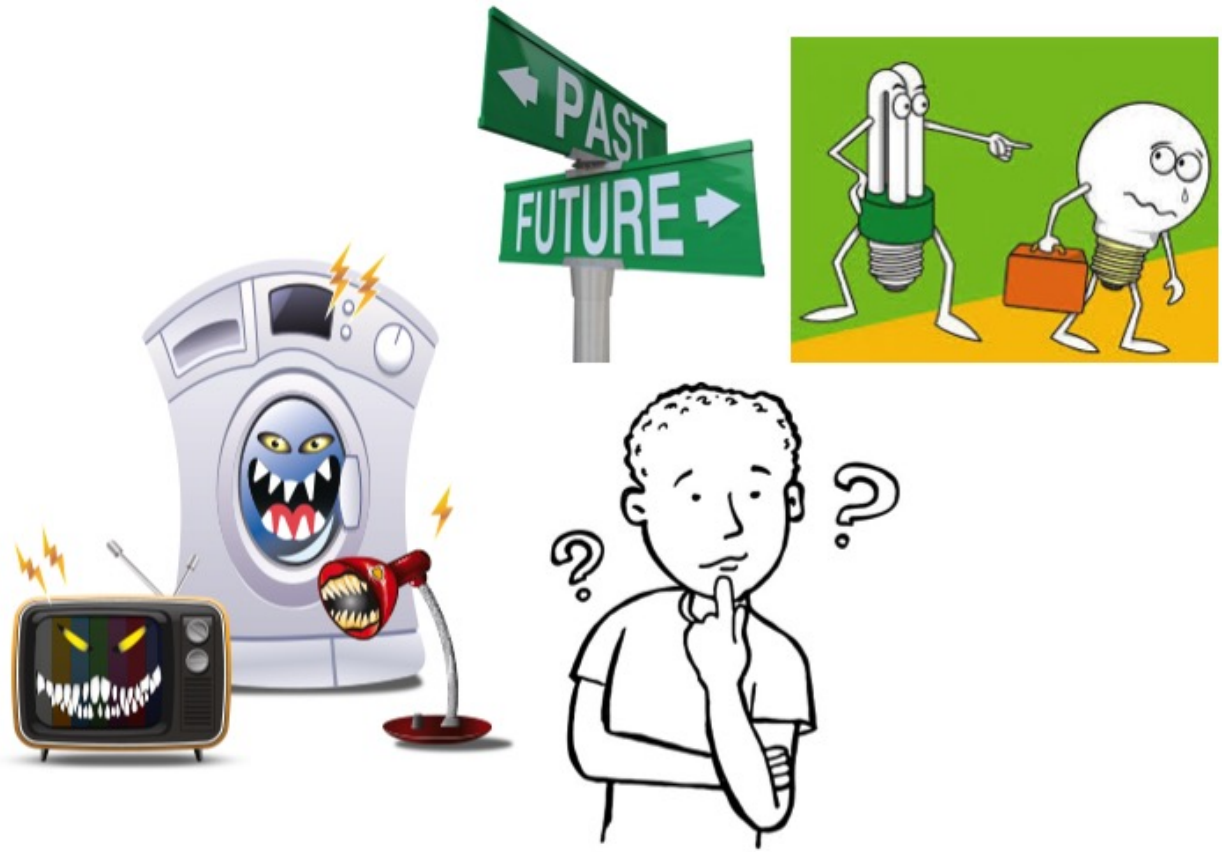
Rational habits in residential electricity demand?

Massimo Filippini, Bettina Hirl, Giuliano Masiero
Università della Svizzera Italiana (USI)

The Economics of Energy and Climate Change

Toulouse, September 8-9, 2015

The electricity consumption decision



Are households forward looking?

- Do households consider the future when deciding how much electricity to consume?
- If YES, what are the policy implications?

Example CO_2 tax:

- What is the impact of a CO_2 tax on energy consumption?
- Direct impact of the tax on today's consumption
- Impact on today's consumption through reaction to future tax
- If a household expects a tax in the future, takes this into account when making today's consumption decision

Are households forward looking?

- Do households consider the future when deciding how much electricity to consume?
- If YES, what are the policy implications?

Example CO_2 tax:

- What is the impact of a CO_2 tax on energy consumption?
- Direct impact of the tax on today's consumption
- Impact on today's consumption through reaction to future tax
- If a household expects a tax in the future, takes this into account when making today's consumption decision

Overview

What is this paper about?

- Estimating aggregated residential electricity demand in the US
- Panel data set of 48 states and 17 years

What is new?

- Combine rational habits and the partial dynamic adjustment model
- Allow for forward looking agents

How is that relevant?

- Better understand underlying factors of residential electricity demand
- Formulate better policies aiming at, e.g. saving energy
- Calculate more precise price elasticities

Overview

What is this paper about?

- Estimating aggregated residential electricity demand in the US
- Panel data set of 48 states and 17 years

What is new?

- Combine rational habits and the partial dynamic adjustment model
- Allow for forward looking agents

How is that relevant?

- Better understand underlying factors of residential electricity demand
- Formulate better policies aiming at, e.g. saving energy
- Calculate more precise price elasticities

Overview

What is this paper about?

- Estimating aggregated residential electricity demand in the US
- Panel data set of 48 states and 17 years

What is new?

- Combine rational habits and the partial dynamic adjustment model
- Allow for forward looking agents

How is that relevant?

- Better understand underlying factors of residential electricity demand
- Formulate better policies aiming at, e.g. saving energy
- Calculate more precise price elasticities

What influences electricity demand?

Electricity prices, weather, household income etc.

- These are all in the present. Past? Future?

Past consumption matters

- Appliance stock cannot be replaced immediately
- It takes time to change behavioral patterns

Expectations matter

- Rational agents have expectations of the future
- Incorporate these in their behaviour

What influences electricity demand?

Electricity prices, weather, household income etc.

- These are all in the present. Past? Future?

Past consumption matters

- Appliance stock cannot be replaced immediately
- It takes time to change behavioral patterns

Expectations matter

- Rational agents have expectations of the future
- Incorporate these in their behaviour

What influences electricity demand?

Electricity prices, weather, household income etc.

- These are all in the present. Past? Future?

Past consumption matters

- Appliance stock cannot be replaced immediately
- It takes time to change behavioral patterns

Expectations matter

- Rational agents have expectations of the future
- Incorporate these in their behaviour

A quick overview of the literature (aggregate data, no info on capital stock)

Static model of electricity demand

Azevedo et al.(2011); Cebula et al.(2012); Eskeland and Mideska (2010)

Dynamic partial adjustment model:

Alberini and Filippini (2011); Paul et al.(2009); Bernstein and Griffin (2005)

Rational habits:

Becker et al.(1994); Baltagi and Griffin (2002)

Rational habits and gasoline consumption:

Scott (2012)

A quick overview of the literature (aggregate data, no info on capital stock)

Static model of electricity demand

Azevedo et al.(2011); Cebula et al.(2012); Eskeland and Mideska (2010)

Dynamic partial adjustment model:

Alberini and Filippini (2011); Paul et al.(2009); Bernstein and Griffin (2005)

Rational habits:

Becker et al.(1994); Baltagi and Griffin (2002)

Rational habits and gasoline consumption:

Scott (2012)

A quick overview of the literature (aggregate data, no info on capital stock)

Static model of electricity demand

Azevedo et al.(2011); Cebula et al.(2012); Eskeland and Mideska (2010)

Dynamic partial adjustment model:

Alberini and Filippini (2011); Paul et al.(2009); Bernstein and Griffin (2005)

Rational habits:

Becker et al.(1994); Baltagi and Griffin (2002)

Rational habits and gasoline consumption:

Scott (2012)

A quick overview of the literature (aggregate data, no info on capital stock)

Static model of electricity demand

Azevedo et al.(2011); Cebula et al.(2012); Eskeland and Mideska (2010)

Dynamic partial adjustment model:

Alberini and Filippini (2011); Paul et al.(2009); Bernstein and Griffin (2005)

Rational habits:

Becker et al.(1994); Baltagi and Griffin (2002)

Rational habits and gasoline consumption:

Scott (2012)

The rational habits model for electricity demand

Households maximize utility from energy services:

- E.g. Light, hot water, cooling, entertainment
- Energy services are produced from electricity and el. appliances

Household utility at time t:

$$U_t = u(e_t, e_{t-1}, c_t; x_t)$$

where e_t is current electricity consumption, e_{t-1} is past electricity consumption, c_t all other consumption goods, and x_t environmental factors.

Lifetime utility function of the household:

$$\sum_{t=1}^{\infty} \delta^{t-2} U_t = \sum_{t=1}^{\infty} \delta^{t-1} u(e_t, e_{t-1}, c_t; x_t)$$

where $\delta = (1+r)^{-}1$ is the constant rate of time preference and r is the interest rate.

The rational habits model for electricity demand

Households maximize utility from energy services:

- E.g. Light, hot water, cooling, entertainment
- Energy services are produced from electricity and el. appliances

Household utility at time t:

$$U_t = u(e_t, e_{t-1}, c_t; x_t)$$

where e_t is current electricity consumption, e_{t-1} is past electricity consumption, c_t all other consumption goods, and x_t environmental factors.

Lifetime utility function of the household:

$$\sum_{t=1}^{\infty} \delta^{t-2} U_t = \sum_{t=1}^{\infty} \delta^{t-1} u(e_t, e_{t-1}, c_t; x_t)$$

where $\delta = (1+r)^{-}1$ is the constant rate of time preference and r is the interest rate.

The rational habits model for electricity demand

Households maximize utility from energy services:

- E.g. Light, hot water, cooling, entertainment
- Energy services are produced from electricity and el. appliances

Household utility at time t:

$$U_t = u(e_t, e_{t-1}, c_t; x_t)$$

where e_t is current electricity consumption, e_{t-1} is past electricity consumption, c_t all other consumption goods, and x_t environmental factors.

Lifetime utility function of the household:

$$\sum_{t=1}^{\infty} \delta^{t-2} U_t = \sum_{t=1}^{\infty} \delta^{t-1} u(e_t, e_{t-1}, c_t; x_t)$$

where $\delta = (1+r)^{-}1$ is the constant rate of time preference and r is the interest rate.

Today's consumption as function of past and future consumption

We get the following maximization problem assuming the appliance/habits stock fully depreciates after one period:

$$\sum_{t=1}^{\infty} \delta^{t-1} u(e_t, e_{t-1}, c_t; x_t)$$

s.t.

- $e_0 = E_0$
- $\sum_{t=1}^{\infty} \delta^{t-1}(c_t + P_t e_t) = W^0$

Solution of the FOC leads to the first-difference equation:

$$e_t = \theta e_{t-1} + \delta\theta e_{t+1} + \theta_1 P_t + \theta_2 x_t + \delta\theta_3 x_{t+1}$$

Today's consumption as function of past and future consumption

We get the following maximization problem assuming the appliance/habits stock fully depreciates after one period:

$$\sum_{t=1}^{\infty} \delta^{t-1} u(e_t, e_{t-1}, c_t; x_t)$$

s.t.

- $e_0 = E_0$
- $\sum_{t=1}^{\infty} \delta^{t-1}(c_t + P_t e_t) = W^0$

Solution of the FOC leads to the first-difference equation:

$$e_t = \theta e_{t-1} + \delta\theta e_{t+1} + \theta_1 P_t + \theta_2 x_t + \delta\theta_3 x_{t+1}$$

Empirical model

We modify the first-difference equation to obtain:

$$e_{it} = \beta_0 + \beta_1 e_{it-1} + \beta_2 e_{t+1} + \beta_3 P_{it} + \beta_4 PG_{it} + \beta_5 Y_{it}$$

$$+\beta_6 HDD_{it} + \beta_7 CDD_{it} + \beta_8 HS_{it} + v_{it}$$

e_{it}: consumption today
P_{it}: price of electricity
PG_{it}: price of gas
Y_{it}: income
HDD_{it}, CDD_{it}: heating and cooling degree days
HS_{it}: numbers of detached houses

Econometric issues

Three potential econometric issues to deal with:

- Heterogeneity bias due to low number of regressors
- Endogeneity of past and future consumption
- Measurement error in the price of electricity

Properties of the dataset:

- Relatively long time dimension (T=17)
- Small number of units (N=48)
- Properties of panel data estimators like GMM hold especially for N large

Econometric issues

Three potential econometric issues to deal with:

- Heterogeneity bias due to low number of regressors
- Endogeneity of past and future consumption
- Measurement error in the price of electricity

Properties of the dataset:

- Relatively long time dimension (T=17)
- Small number of units (N=48)
- Properties of panel data estimators like GMM hold especially for N large

Empirical strategy

How to solve the econometric issues:

- FE and RE account for unobserved heterogeneity
- 2SLSFE to fix the endogeneity problem
- Instrument for the price of electricity

We estimate the rational habits model using:

- Fixed effects estimators
- 2 stages least squares fixed effects estimator

Empirical strategy

How to solve the econometric issues:

- FE and RE account for unobserved heterogeneity
- 2SLSFE to fix the endogeneity problem
- Instrument for the price of electricity

We estimate the rational habits model using:

- Fixed effects estimators
- 2 stages least squares fixed effects estimator

Empirical model

We modify the first-difference equation to obtain:

$$e_{it} = \beta_0 + \beta_1 e_{it-1} + \beta_2 e_{t-1} + \beta_3 P_{it} + \beta_4 PG_{it} + \beta_5 Y_{it}$$

$$+\beta_6 HDD_{it} + \beta_7 CDD_{it} + \beta_8 HS_{it} + v_{it}$$

e_{it}: consumption today
P_{it}: price of electricity
PG_{it}: price of gas
Y_{it}: income
HDD_{it}, CDD_{it}: heating and cooling degree days
HS_{it}: numbers of detached houses

Estimation results FE specification

	FE	
e_{t-1}	0.476***	(14.97)
e_{t+1}	0.309***	(10.84)
P_t	-5602.4***	(-3.80)
PG_t	-10921.8	(-1.08)
Y_t	0.0114	(1.36)
HS_t	-306.9*	(-2.28)
HDD_t	0.181***	(9.72)
CDD_t	0.724***	(14.18)
Constant	182.5	(0.51)
N	719	

Instruments 2SLSFE specification

Following Becker et al. (1994) and Baltagi et al. (2002), we use the following instruments:

- Input prices of coal and gas for the electricity sector
- Two-period lags and leads of the price of electricity
- one-period lag and lead of heating degree days

Estimation results 2SLSFE specification

Instrumented:	e_{t-1}, e_{t+1}		e_{t-1}, e_{t+1}, P_t	
	(1)		(2)	
e_{t-1}	0.432***	(4.90)	0.422***	(4.70)
e_{t+1}	0.221**	(2.85)	0.206**	(2.80)
P_t	-6787.8***	(-4.19)	-8196.7**	(-2.60)
PG_t	-1243.3	(-0.12)	-121.5	(-0.01)
Y_t	0.0309**	(2.87)	0.0325**	(3.02)
HS_t	-562.0**	(-3.11)	-588.6**	(-3.29)
HDD_t	0.185***	(10.16)	0.182***	(9.21)
CDD_t	0.641***	(16.84)	0.635***	(16.76)
N	611		611	
Underidentification test	41.495	[0.0000]	42.007	[0.0000]
Weak identification test	7.096		6.164	
5% critical value	3.78		NA	
Hansen J statistic	9.848	[0.1312]	10.210	[0.1161]

Short and long run elasticities

All elasticities are negative and shown in absolute values.

	Model	Short run	Long run
FE	(1)	0.1073	0.2603
FE2SLS	(2)	0.0931	0.2847
	(3)	0.0942	0.2207

Short run: residential electricity demand inelastic

Immediate adjustment appliances stock and behavioural habits is costly

Long run: residential electricity demand more elastic

Agents have more time to adapt habits and replace equipment

Short and long run elasticities

All elasticities are negative and shown in absolute values.

	Model	Short run	Long run
FE	(1)	0.1073	0.2603
FE2SLS	(2)	0.0931	0.2847
	(3)	0.0942	0.2207

Short run: residential electricity demand inelastic

Immediate adjustment appliances stock and behavioural habits is costly

Long run: residential electricity demand more elastic

Agents have more time to adapt habits and replace equipment

Short and long run elasticities

All elasticities are negative and shown in absolute values.

	Model	Short run	Long run
FE	(1)	0.1073	0.2603
FE2SLS	(2)	0.0931	0.2847
	(3)	0.0942	0.2207

Short run: residential electricity demand inelastic

Immediate adjustment appliances stock and behavioural habits is costly

Long run: residential electricity demand more elastic

Agents have more time to adapt habits and replace equipment

A quick summary

Rational habits?

- Do households consider the future in their consumption decision?
- Extend and generalize existing DPA model
- Allowing for forward looking agents

Empirical evidence

- YES, households consider the future in their consumption decision
- Current electricity consumption depends on past and future (expectation of) consumption
- Does that mean agents are rational? Maybe it does.

A quick summary

Rational habits?

- Do households consider the future in their consumption decision?
- Extend and generalize existing DPA model
- Allowing for forward looking agents

Empirical evidence

- YES, households consider the future in their consumption decision
- Current electricity consumption depends on past and future (expectation of) consumption
- Does that mean agents are rational? Maybe it does.

Conclusions

Understanding demand:

- Knowing the factors influencing demand is crucial for policy makers
- Especially true for policies targeting energy savings
- DPA models may lead to biased estimates of policy impact

Future consumption impacts current consumption

- We can conclude that agents are forward looking
- We cannot conclude that agents are rational
- Elasticities only differ slightly from DPA model elasticities

Conclusions

Understanding demand:

- Knowing the factors influencing demand is crucial for policy makers
- Especially true for policies targeting energy savings
- DPA models may lead to biased estimates of policy impact

Future consumption impacts current consumption

- We can conclude that agents are forward looking
- We cannot conclude that agents are rational
- Elasticities only differ slightly from DPA model elasticities

Policy Implications

Long-term policies

- Effect of policies today may depend on anticipated effect on future consumption
- Effect reinforced by anticipating the effect on future consumption

Thank you