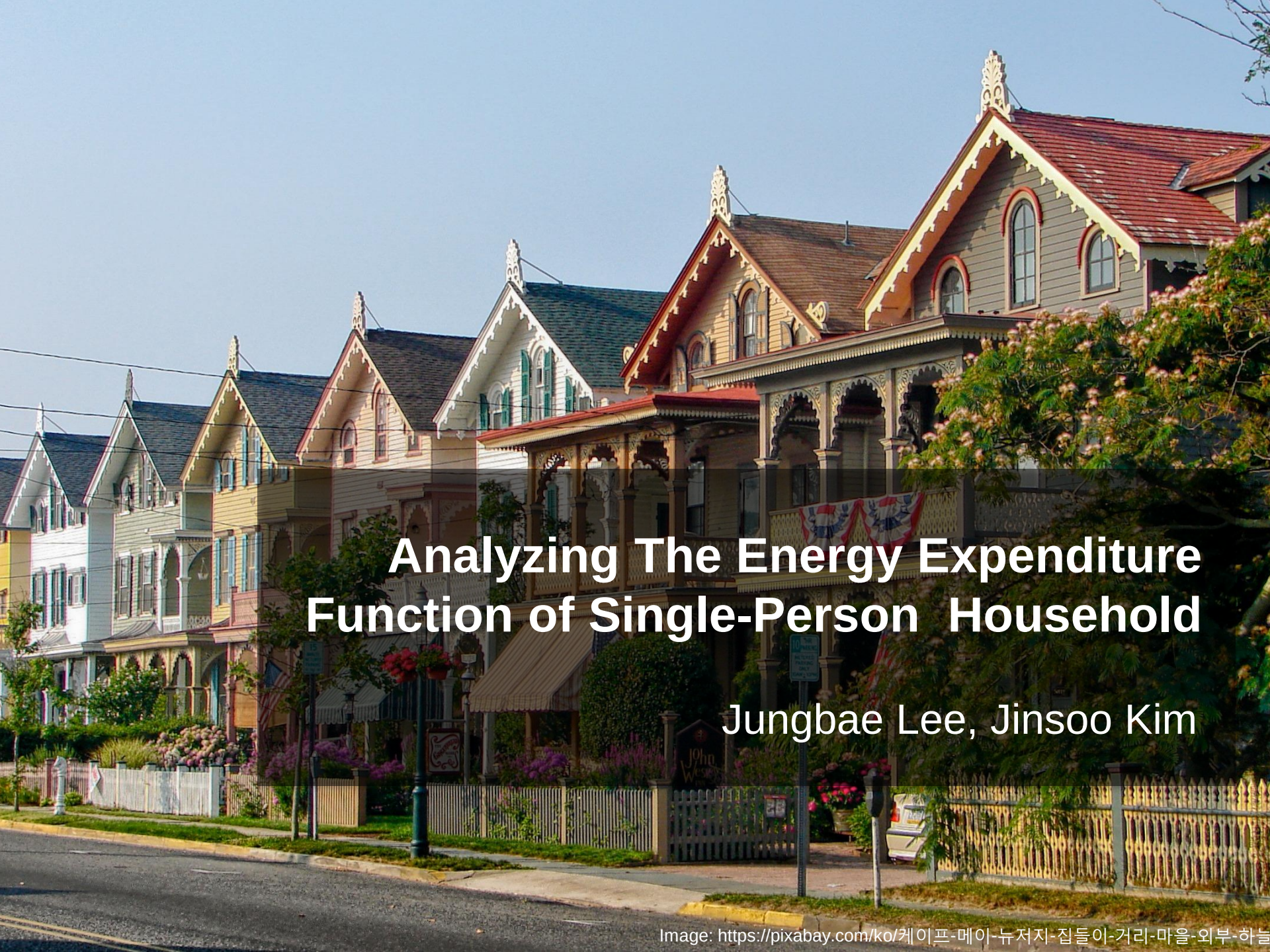


Analyzing The Energy Expenditure Function of Single-Person Household

Jungbae Lee, Jinsoo Kim

Image: https://pixabay.com/ko/케이프-메이-뉴저지-집들이-거리-마을-외부-하늘

1. Introduction: Energy consumption in 4 parts

- **Energy consumption can be divided into 4 sectors**
  - ✓ Commercial, Industrial, Residential, Transportation sector
  - ✓ Even though lots of technical improvement, their trends are…

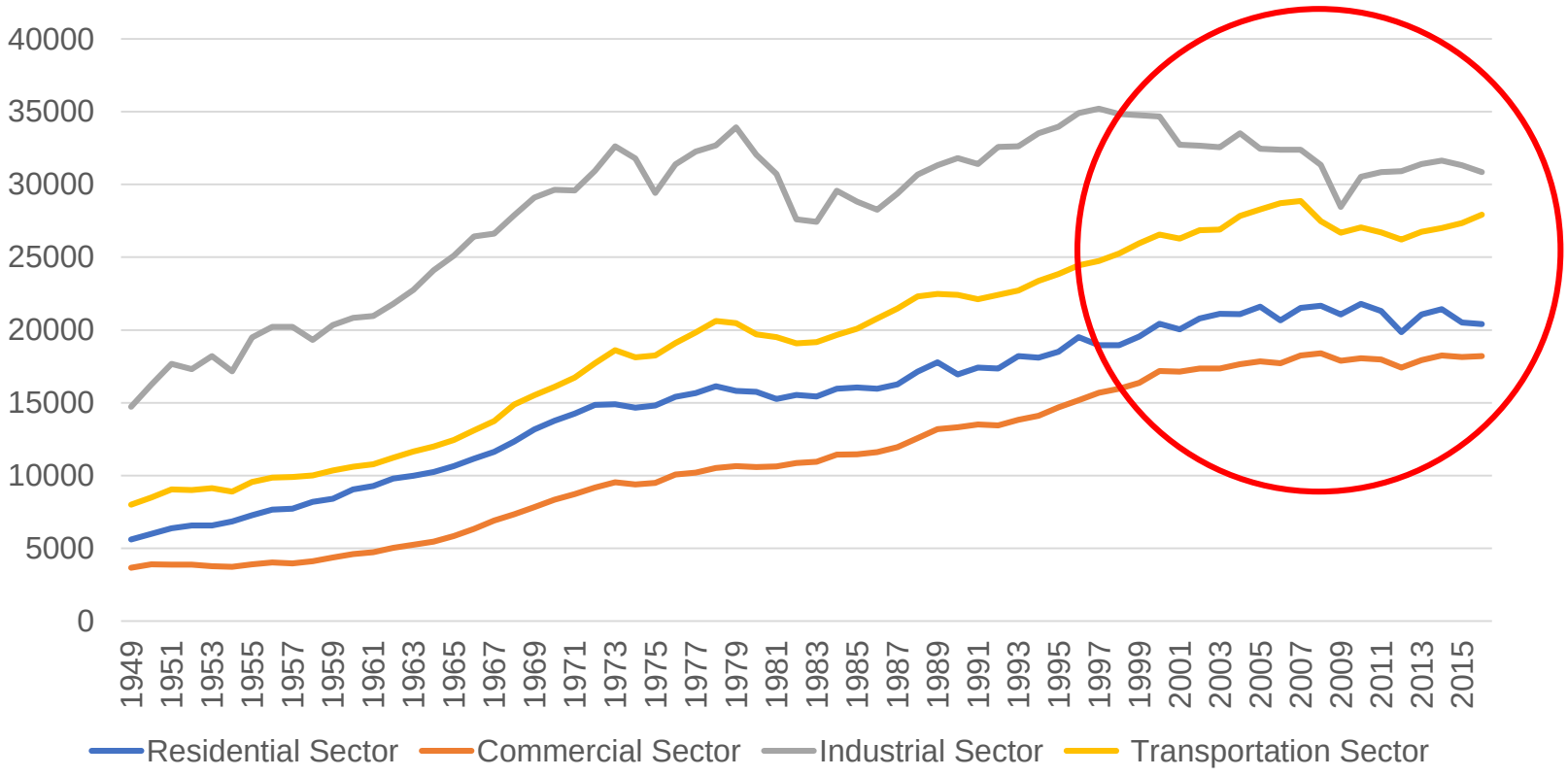


Fig 2. Energy consumption by sector (Trillion Btu)
Source: EIA's monthly energy review, 2017

1. Introduction: Household energy policy

- **Examples of household – related energy policy**

Country	Policy	Target
Australia	Building Code of Australia 2011	New residential, Existing residential
Canada	National Energy Code of Canada for Buildings 2011	New residential, New non-residential
Ireland	Conservation of Fuel and Energy : Dwellings (2011)	New residential
Italy	Decree for energy efficiency requirements in buildings (2015)	All
Japan	Building Energy Efficiency Act (2015)	
Korea	Building Design Code for Energy Saving (2010)	New residential, Existing residential
United Kingdom	Building Regulations (Seperated by England and Wales, Northern Ireland, Scotland) 2010	New residential
United States	International Energy Conservation Code (IECC 2012) - Residential	New residential

Table 1. Examples of household energy efficiency policy
Source: IEA's policies and measures databases, 2017

1. Introduction: Social change

- **Socio-demographical change: Single-person household**
  - ✓ Number of single-person household is steadily grown up

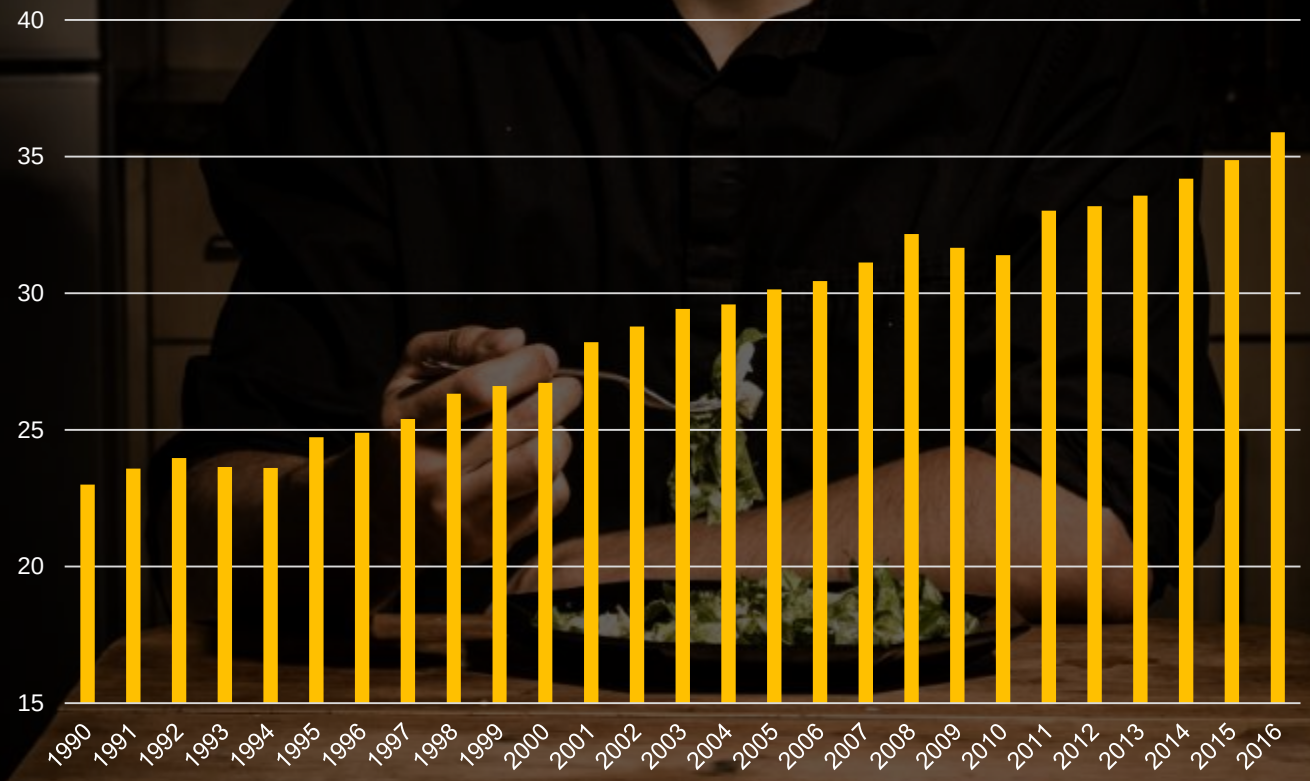


Fig 3. Number of single-person households in the U.S. from 1990 to 2016 (in millions)
Source: US Census Bureau

Image: https://notalentforcertainty.com/tag/inappropriate-poetic-subjects/

2. Literature Review

- **Literature researches are focusing on 5 factors**

  ✓ Household characteristics

  - Age, income, education level, family size
  - Studies referring to single-person households generally focus on research on energy expenditure, energy consumption per person
  - Pachauri (2004), Boonekamp (2007), Jackson (2007), Pachauri and Jiang (2008), Salari and Javid (2017)

  ✓ Housing characteristics

  - Age of structure, number of rooms, units in structure, house value rental status
  - Characteristics such as area and size of building have a significant impact on the energy efficiency and household energy consumption
  - Vaage (2000), McManus et al (2010), Irish Georgian Society (2013), City of Minneapolis (2015)

2. Literature Review

- **Literature researches are focusing on 5 factors**
  - ✓ Energy price
    - ➢ Average retail gas and electricity price
    - ➢ Energy price affect user's consumption behavior
    - ➢ Baker et al (1989), Nesbakken (1999), Shin (2015)
  - ✓ Climate condition
    - ➢ Heating degree days, Cooling degree days
    - ➢ People who live in region where has a extreme climate condition needs more energy
    - ➢ Henley and Peirson (1997, 1998), Christenson et al (2006) Vuuren (2009)

3. Data & Variables

- **Integrated Public Use Microdata Series (IPUMS)**
  - ✓ Developed by the Minnesota Population Center at the University of Minnesota
  - ✓ 2000, 2005, 2010, 2015's data (3,283,458 samples)
  - ✓ Consideration
    - ➢ Quantitative data
    - ➢ Include all of the household, housing variables mentioned above
- **Heating degree days, cooling degree days**
  - ✓ Extracted from the National Oceanic and Atmospheric Administration
    - ➢ Eliminated region's data where have extreme climate condition
- **Electricity price, gas price**
  - ✓ Using the Energy Information Agency (EIA)'s price information

Image: http://blog.popdata.org/category/data-projects/ipumsusa/

3. Data & Variables

Category		Variable	Symbol
Explanatory variables	Socio-demographic factor	Age	AGE
		Education level	EDUCD
		Household income	HHINCOME
		Family size	FAMSIZE
	Housing characteristics	Age of structure	BUILT
		Number of rooms	ROOMS
		Units in structure	UNIT
		Monthly condominium fee	CONDO
		House value	VALUE
	Climate factor	Heating degree days	HDD
		Cooling degree days	CDD
	Energy Price	Annual average electricity retail price	EP
		Annual average gas retail price	GP
Dependent variable		Annual gas cost	COSTGAS
		Annual electricity cost	COSTELEC
		Annual home heating fuel cost	COSTFUEL
		Energy expenditure = COSTGAS + COSTELEC + COSTFUEL	EXP

Table 2. List of variables

4. Log-linear Model

- **Concept of Log-linear modelling for cross-sectional analysis**
  - ✓ Log-linear model has some advantages
  - ✓ Multicollinearity, heteroskedasticity and auto-correlation problem

$$EXP_i = f(HC_1, HC_2, EP, CF)$$

$$EXP_i = COSTELEC_i + COSTGAS_i + COSTFUEL_i$$

$HC_1 = Household\ characteristic$ $HC_2 = Housing\ characteristic$

$EP = Energy\ price$ $CF = Climate\ factor$

Formula 1. The concept of non-linear modelling

$$\ln(EXP_i) = \ln AGE_i + \ln EDUCD_i + \ln HHINCOME_i + \ln FAMSIZE_i + \ln BUILT_i + \ln ROOMS_i + \ln UNIT_i + \ln CONDO_i + \ln VALUE_i + \ln HDD_i + \ln CDD_i + \ln EP_i + \ln GP_i$$

Formula 2. Non-linear modelling

	2000's single		2005's single		2010's single		2015's single	
	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)
(Intercept)	1.09631 (***)	< 2.20E-16	0.37202 (***)	=1.89E-08	-0.00296	=0.96310	-0.26593 (***)	=0.000648
age	-0.01790 (***)	= 2.14E-08	-0.02342 (***)	< 2.20E-16	-0.02418 (***)	< 2.20E-16	-0.01096 (***)	< 2.20E-16
educd	-0.02814 (***)	< 2.20E-16	-0.06367 (***)	< 2.20E-16	-0.06591 (***)	< 2.20E-16	-0.07151 (***)	< 2.20E-16
hhincome	0.04861 (***)	< 2.20E-16	0.03859 (***)	< 2.20E-16	0.04409 (***)	< 2.20E-16	0.03597 (***)	< 2.20E-16
built	-0.05401 (***)	< 2.20E-16	-0.06010 (***)	< 2.20E-16	-0.04003 (***)	< 2.20E-16	-0.04494 (***)	< 2.20E-16
rooms	0.38604 (***)	< 2.20E-16	0.49187 (***)	< 2.20E-16	0.40058 (***)	< 2.20E-16	0.34798 (***)	< 2.20E-16
unit	-0.10774 (***)	< 2.20E-16	-0.13139 (***)	< 2.20E-16	-0.14898 (***)	< 2.20E-16	-0.14064 (***)	< 2.20E-16
condo	-0.01167 (***)	< 2.20E-16	-0.01000 (***)	< 2.20E-16	-0.01067 (***)	< 2.20E-16	-0.01008 (***)	< 2.20E-16
value	0.08566 (***)	< 2.20E-16	0.05629 (***)	< 2.20E-16	0.06394 (***)	< 2.20E-16	0.05185 (***)	< 2.20E-16
hdd	0.25495 (***)	< 2.20E-16	0.32236 (***)	< 2.20E-16	0.37550 (***)	< 2.20E-16	0.42729 (***)	< 2.20E-16
cdd	0.11412 (***)	< 2.20E-16	0.23915 (***)	< 2.20E-16	0.20766 (***)	< 2.20E-16	0.28153 (***)	< 2.20E-16
gp	0.31579 (***)	< 2.20E-16	0.26166 (***)	< 2.20E-16	0.43789 (***)	< 2.20E-16	0.39467 (***)	< 2.20E-16
ep	0.24586 (***)	< 2.20E-16	0.22152 (***)	< 2.20E-16	0.13813 (***)	< 2.20E-16	0.05653 (***)	< 2.20E-16
famsize	-	-	-	-	-	-	-	-
Adjusted R	0.1348		0.1856		0.1812		0.1537	
Sample Size	163892		203299		211136		217310	
	2000's multi		**2005's multi**		**2010's multi**		**2015's multi**	
	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)
(Intercept)	0.86049 (***)	< 2.20E-16	0.12197 (***)	= 3.01E-04	-0.03354	= 0.31440	-0.58883 (***)	< 2.20E-16
age	0.07705 (***)	< 2.20E-16	0.08401 (***)	< 2.20E-16	0.09350 (***)	< 2.20E-16	0.11857 (***)	< 2.20E-16
educd	0.02610 (***)	< 2.20E-16	-0.00172	= 3.17E-01	-0.01067 (***)	= 1.58E-10	-0.00550 (**)	= 0.001291
hhincome	0.06740 (***)	< 2.20E-16	0.05588 (***)	< 2.20E-16	0.04910 (***)	< 2.20E-16	0.04354 (***)	< 2.20E-16
built	-0.05958 (***)	< 2.20E-16	-0.06009 (***)	< 2.20E-16	-0.03969 (***)	< 2.20E-16	-0.03971 (***)	< 2.20E-16
rooms	0.31564 (***)	< 2.20E-16	0.39820 (***)	< 2.20E-16	0.30320 (***)	< 2.20E-16	0.29060 (***)	< 2.20E-16
unit	-0.08798 (***)	< 2.20E-16	-0.10074 (***)	< 2.20E-16	-0.13385 (***)	< 2.20E-16	-0.11731 (***)	< 2.20E-16
condo	-0.00914 (***)	< 2.20E-16	-0.00930 (***)	< 2.20E-16	-0.00905 (***)	< 2.20E-16	-0.00897 (***)	< 2.20E-16
value	0.07972 (***)	< 2.20E-16	0.05586 (***)	< 2.20E-16	0.06626 (***)	< 2.20E-16	0.04201 (***)	< 2.20E-16
hdd	0.21096 (***)	< 2.20E-16	0.26516 (***)	< 2.20E-16	0.30367 (***)	< 2.20E-16	0.38403 (***)	< 2.20E-16
cdd	0.11379 (***)	< 2.20E-16	0.22833 (***)	< 2.20E-16	0.19679 (***)	< 2.20E-16	0.27367 (***)	< 2.20E-16
gp	0.26913 (***)	< 2.20E-16	0.22252 (***)	< 2.20E-16	0.41614 (***)	< 2.20E-16	0.37250 (***)	< 2.20E-16
ep	0.29150 (***)	< 2.20E-16	0.28037 (***)	< 2.20E-16	0.18765 (***)	< 2.20E-16	0.08894 (***)	< 2.20E-16
famsize	0.15610 (***)	< 2.20E-16	0.22687 (***)	< 2.20E-16	0.23761 (***)	< 2.20E-16	0.22127 (***)	< 2.20E-16
Adjusted R	0.1305		0.1845		0.1837		0.1379	
Sample Size	559304		650145		642828		635544	

Table 3. Cross-sectional analysis for household energy expenditure

4. Log-linear model: Result

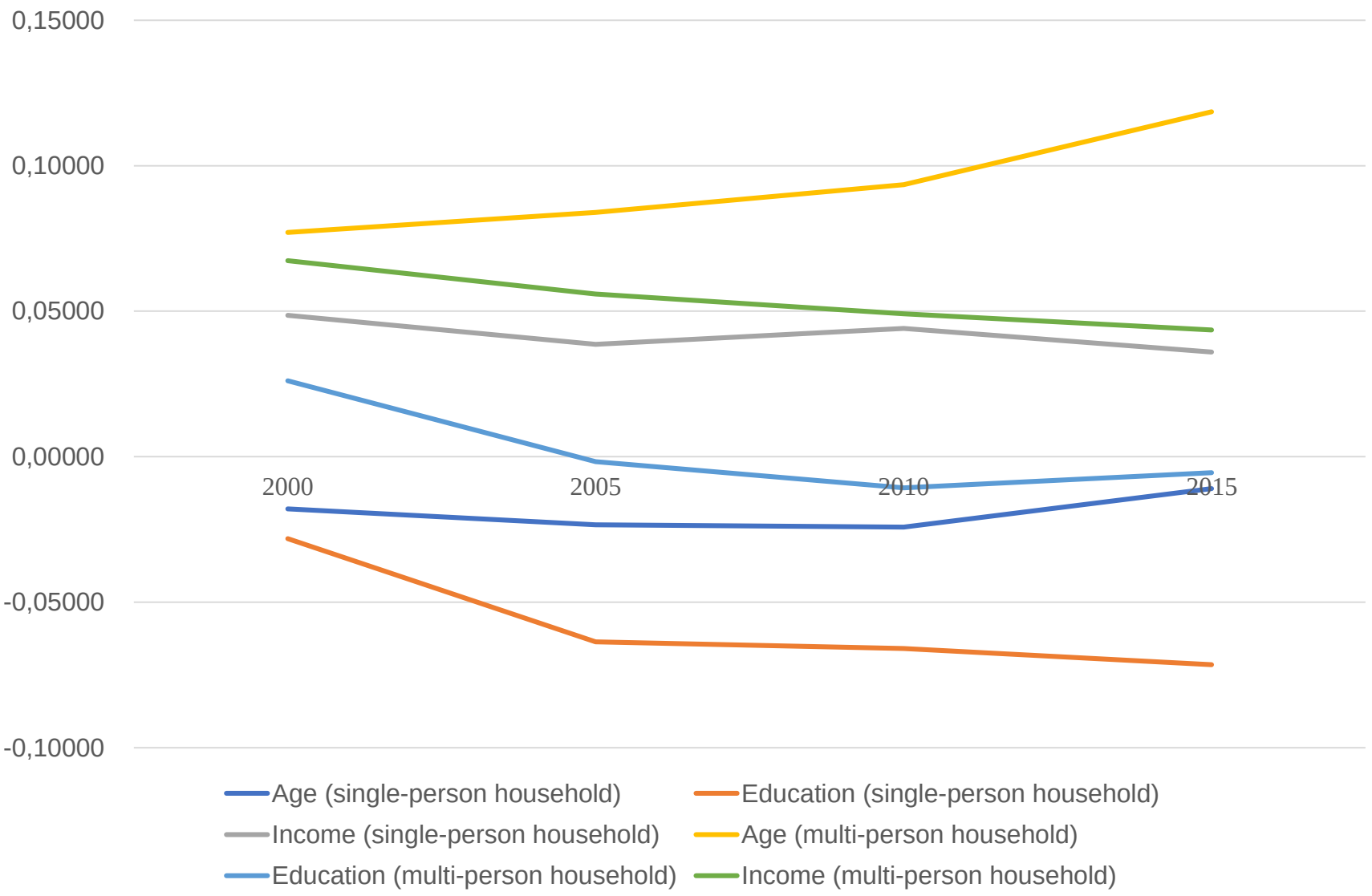


Fig 5. Trend of socio-demographic (household characteristic) factor elasticity

4. Log-linear model: Result

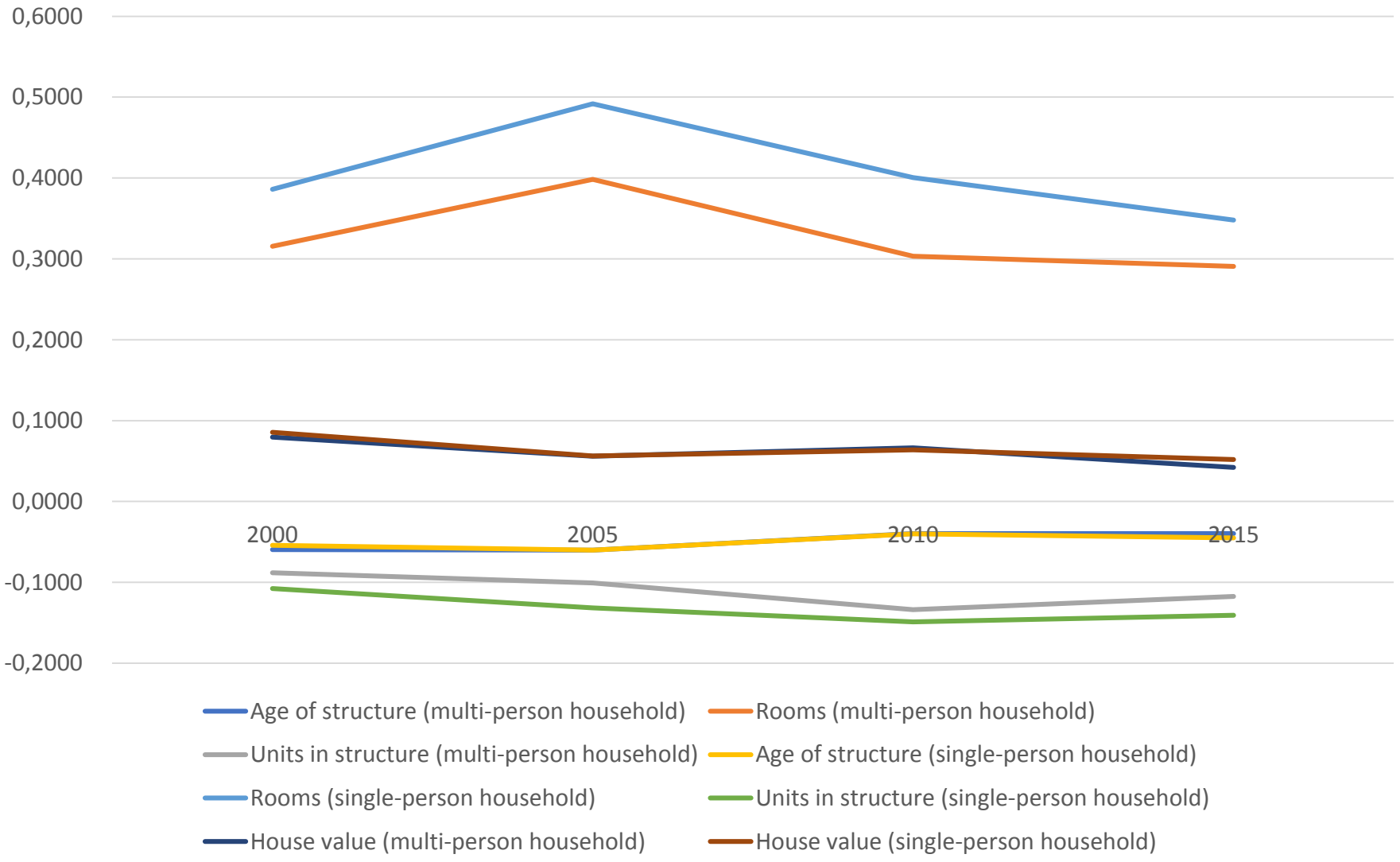


Fig 6. Trend of housing characteristic factor elasticity

5. Policy Implication: Education

- **Policy implication about household characteristics**

  ✓ Education related issue

  - Korea: Korea Energy Economics Institute (KEEI) provides basic education program for energy saving
  - United States: Department of Energy (DOE) conducting theoretical knowledge, ministry and policy promotion of energy through webinars and workshops

  ✓ Suggestions

  - Curtin and Nelson (1999) found that education funding policy has a positive effect on the economy and health
  - Energy-related programs addition to the regular curriculum can contribute to the reduction of household's energy expenditure

5. Policy Implication: Age

- **Policy implication about household characteristics**
  - ✓ Age is much more complicated..
    - ➢ Many studies said older person needs more energy
    - ➢ However, it is insufficient to explain the negative age elasticity of energy expenditure in single-person households
    - ➢ Referring Bennett and Dixon's study (2006): Elective and forced single → They noted that there is an age-related decline in income
  - ✓ Suggestion
    - ➢ It is not only energy-related problem, but also related with welfare policy
    - ➢ Current policy, Low Income Home Energy Assistance Program (LIHEAP), needs to improve

5. Policy Implication: Units in Structure

- **Policy implication about housing characteristics**
  - ✓ Housing related energy policy
    - ➢ Korea: Land & Housing Institute (2016)
    - ➢ United States: Department of Housing and Urban Development (HUD) provided subsides for new residential building construction
    - ➢ United States: Environmental Protection Agency (EPA) provided technical and financial support for energy efficiency
  - ✓ Suggestions
    - ➢ Expanding targets of single-room occupancy (SRO) program for increasing single-person household
    - ➢ Supplying high-density buildings in future housing planning can contribute to the reduction of energy consumption

6. On-progress Work

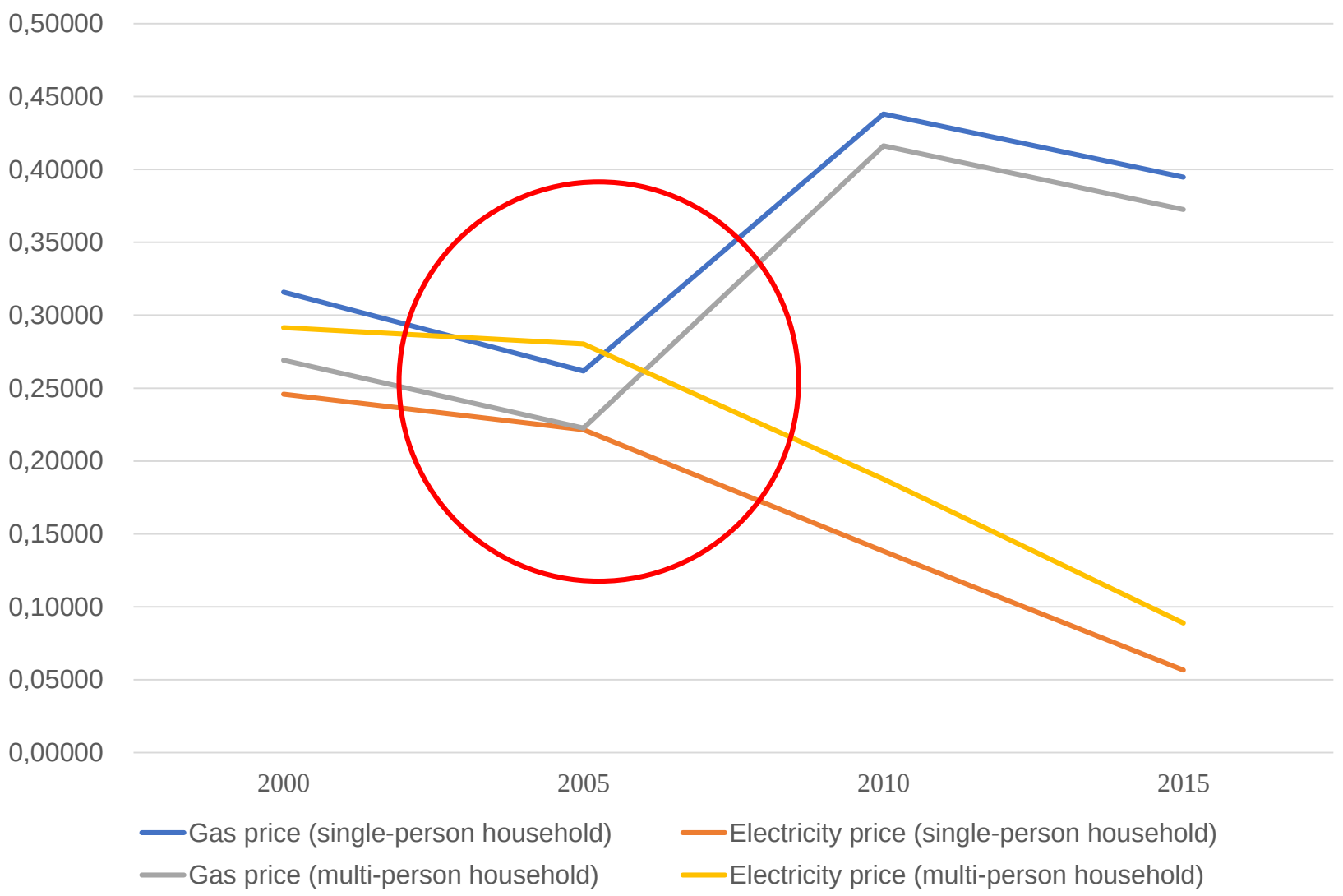
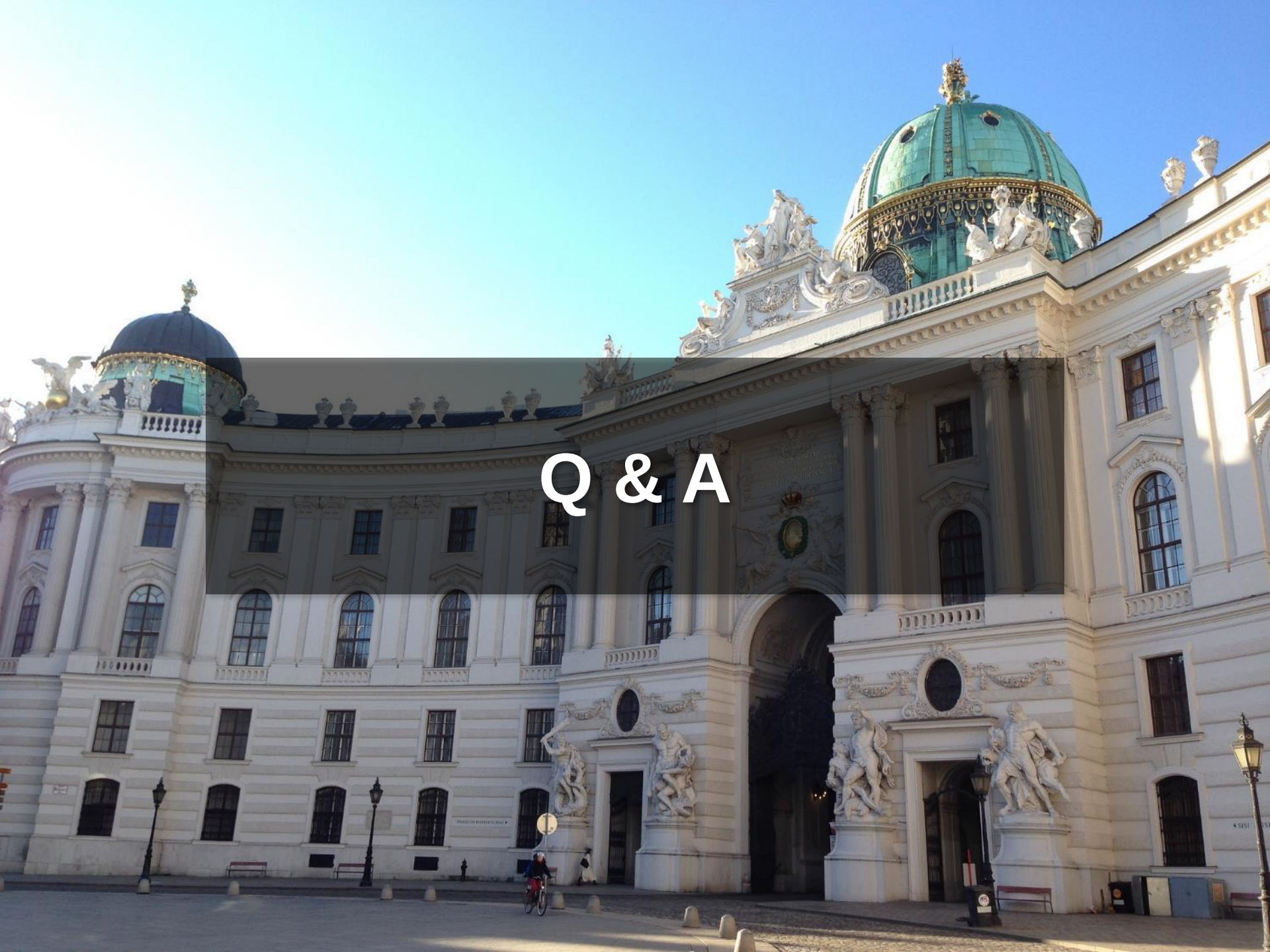


Fig 8. Trend of energy price factor elasticity


Q & A