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FACULTY OF ECONOMICS AND SOCIOLOGY
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Modeling of Sectoral Investment for Poland

Jurand Skrzypek, MSc, Department of Social-Economic Analyses, Institute of Economics, Finance and Management, Faculty of Management and Social Communication, Jagiellonian University in Cracow

email: jurand.skrzypek@uj.edu.pl

Outline

1. Introduction
2. Investment demand function – variable selection
3. Problems related to the database building
4. Statistical analysis of the sectoral investment
5. Estimation results – sectoral investment models
6. Investments in the energy sector – facts, ideas, threats
7. Summary and directions of further research

1. Introduction

Investments play a major role in many areas of the economic life… for example:

ECONOMIC GROWTH

- Solow-Swan model (1956-1957) and its modifications
- The problem of the accumulation of the capital (Phelps 1961, Domar 1962)

EMPLOYMENT

- The relationship between investment expenditures and the levels of the income and employment (Keynes 1936 and others)

INNOVATIONS

- Diffusion of innovations and investments (Schumpeter 1960)

Dual nature of the investment:

- (demand side) generating National Income through the multiplier effects,
- (supply side) increasing production capacities of the economy.

1. Introduction

SCHEME OF INPUT - OUTPUT TABLE AT BASIC PRICES

ANNEX 1

No.	Uses / Products (CPA 2008)		Intermediate consumption (CPA 2008)					Final demand											Total (82+85+88)	OUTPUT
								final consumption expenditure				gross capital formation			exports fob					
			products of agriculture and hunting	products of forestry	etc. divisions following annex 3	private households with employed persons	total (01—77)	by households	by non-profit institutions serving households (NPISH)	by goverment	total (79+80+81)	gross fixed capital formation	changes in inventores and changes in valuables	total (83+84)	intra European Union	extra European Union	total (86+87)			
			(01)	(02)	....	(97-98)														
0			1	2	....	77	78	79	80	81	82	83	84	85	86	87	88	89		
01	products of agriculture and hunting	(01)																		
02	products of forestry	(02)																		
03	fish and other fishing products	(03)																		
04	Coal and lignite	(05)																		
.	etc. division following Annex 3	.																		
.	.	.																		
.	.	.																		
.																				
76	Other personal services	(96)																		
77	Private households with employed persons	(97-98)																		
78	Total products																			
79	Taxes less subsidies on products																			
80	Total intermediate consumption/final demand at purchasers' prices																			
81	Compensation of employees																			
82	Other net taxes on production																			
83	Consumption of fixed capital																			
84	Operating surplus, net																			
85	Operating surplus, gross																			
86	Value added at basic prices																			
87	Output at basic prices																			
88	Imports cif																			
89	Supply at basic prices																			

```
invR        = invSCALE[t] * INVbr * invc
```

$$\begin{bmatrix} invR_1 \\ \vdots \\ invR_{77} \end{bmatrix}_{77x1} = [s^0] * \left[INVbr_{kj}^0\right]_{77*4} * \begin{bmatrix} invc_1 \\ \vdots \\ invc_4 \end{bmatrix}_{4x1}$$

Pic. 1. Role of the investment in MMM

Source: Own modifications on the basis of CSO of Poland, *Input - output table at basic prices in 2010*, p. 24

$$for\ k = 1, \dots, 4, m = 1, \dots, 45, j = 1, \dots, 77$$

$$\begin{bmatrix} invc_1 \\ \vdots \\ invc_4 \end{bmatrix}_{4x1} = [BMTRbr_{km}]_{4x45} * \begin{bmatrix} invs_1 \\ \vdots \\ invs_m \end{bmatrix}_{45x1}$$

Modelled elements (total gross investment of the sector)

```
invc        = BMTRbr * invs;
```

1. Introduction

SCHEME OF INPUT - OUTPUT TABLE AT BASIC PRICES

ANNEX 1

No.	Uses / Products (CPA 2008)		Intermediate consumption (CPA 2008): products of agriculture and hunting (01)	products of forestry (02)	etc. divisions following annex 3	private households with employed persons (97-98)	total (01—77)	Final demand: final consumption expenditure: by households	by non-profit institutions serving households (NPISH)	by goverment	total (79+80+81)	gross capital formation: gross fixed capital formation	changes in inventores and changes in valuables	total (83+84)	exports fob: intra European Union	extra European Union	total (86+87)	total (82+85+88)	OUTPUT
0			1	2	....	77	78	79	80	81	82	83	84	85	86	87	88	89	
01	products of agriculture and hunting	(01)			↑							I_1					Y_1		
02	products of forestry	(02)			↑														
03	fish and other fishing products	(03)																	
04	Coal and lignite	(05)																	
.	etc. division following Annex 3	.										↑ I_i					↑ Y_i		
.		.																	
.		.																	
.																			
76	Other personal services	(96)																	
77	Private households with employed persons	(97-98)			↑							I_{77}					Y_{77}		
78	Total products																		
79																			
80																			
81					↑ v_1														
82																			
83					⋮														
84																			
85					↑ v_{z1}														
86																			
87	Output at basic prices																		
88	Imports cif																		
89	Supply at basic prices		↑ X_1		↑ X_i		↑ X_{77}												

Measuring the individual effects:

$$\forall i,j = 1,\dots,77 \quad \frac{\partial X_i}{\partial Y_j} = \alpha_{ij}$$

etc...

$$\begin{bmatrix} invR_1 \\ \vdots \\ \uparrow invR_i \\ \vdots \\ invR_{77} \end{bmatrix}_{77x1} = [s^0] * \left[INVbr^0_{kj}\right]_{77*4} * \begin{bmatrix} \uparrow invc_1 \\ \vdots \\ invc_4 \end{bmatrix}_{4x1}$$

Pic. 1. Investments – economic growth path example

Source: Own modifications on the basis of CSO of Poland, *Input - output table at basic prices in 2010*, p. 24

$$for\ k = 1,\dots,4, \qquad m,l = 1,\dots,45, \qquad i,j = 1,\dots,77$$

$$\begin{bmatrix} \uparrow invc_1 \\ \vdots \\ invc_4 \end{bmatrix}_{4x1} = [BMTRbr_{km}]_{4x45} * \begin{bmatrix} invs_1 \\ \vdots \\ \uparrow invs_l \\ \vdots \\ invs_m \end{bmatrix}_{45x1}$$

Sector l reports a higher demand for the buildings and the structures

2. Investment demand function – variable selection

In the literature there exist diverse approaches to the problem of determining factors that have significant impact on the investments. For example:

- Hicks (1937)

$$I_t = f(\Pi_t, r_t)$$

where: Π_t - profits after taxes, r_t - real interest rate.

- Clark (1979)

$$I_t = f(\Delta Y_t, \dots, \Delta Y_{t-s}, K_{t-1})$$

where : ΔY_{t-s} - lagged s periods first difference in the production, K_{t-1} - level of fixed capital from the previous period.

- Hall, Taylor (1995)

$$I_t = f\left(\frac{W_t}{R_t^K}, Y_t, K_{t-1}\right)$$

where : W_t- wage rate, R_t^K - rental price of the capital.

- Welfe W. (2012)

$$I_t = f(I_{t-1}, Y_t, KU_{t-1})$$

where : KU_{t-1} - lagged user cost of the capital (dependent on, inter alia, depreciation rate, interest rate, tax rate or price of investment goods)

- Almon (2017)

$$I_t = f\left(rep_t\ , \Delta Y_{t-1}, \dots, \Delta Y_{t-s}, SP_{t-s}^{500}, \Delta SP_{t-1}^{500}, \dots, \Delta SP_{t-s}^{500}\right)$$

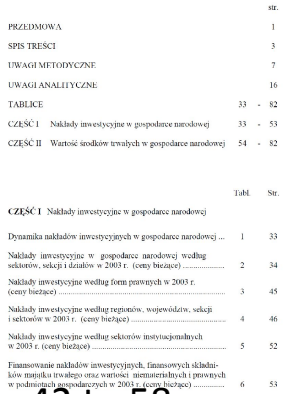
where : rep_t - capital replacement, SP_{t-s}^{500} - real value of SP500 index.

Lots of the other examples can be found in: D. Meade (1990), *Investment in a Macroeconometric Interindustry Model.*

3. Problems related to the database building

1993-2008

PCA 2004

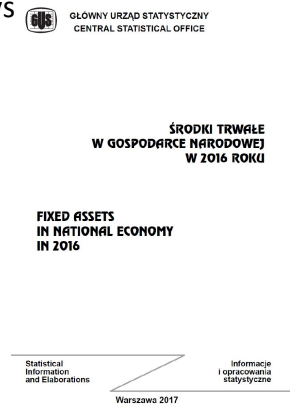


From 42 to 58 aggreg.

Transition keys

2008-2016

PCA 2007



From 63 to 68 aggreg.

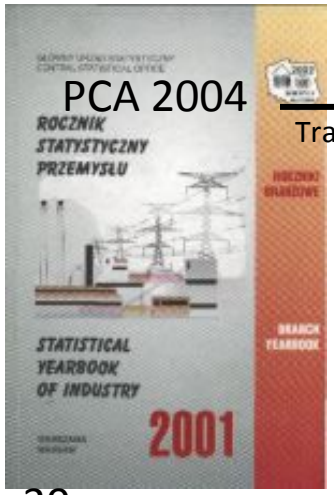
Sectoral investment data

Pic. 2. Data sources

Investment data from National Accounts (yearly macroeconomic indices)

1993-2008

PCA 2004



39 aggreg.

Transition keys

2005-2015

PCA 2007

48 aggreg.

Sectoral output data

Unified database for 44 sectors (+balancing position) in 1993-2016 period

+ as a supplementary document – Statistical Yearbook of

Source: Own elaboration. Graphs taken from CSO of Poland site.

4. Statistical analysis of the sectoral investment

According to the publication *„Fixed assets in national economy”* total gross investment (s) contains following categories:

- buildings and structures (b);
- machinery, technical equipment and tools (m);
- transport equipment (t);
- rest of investment (r).

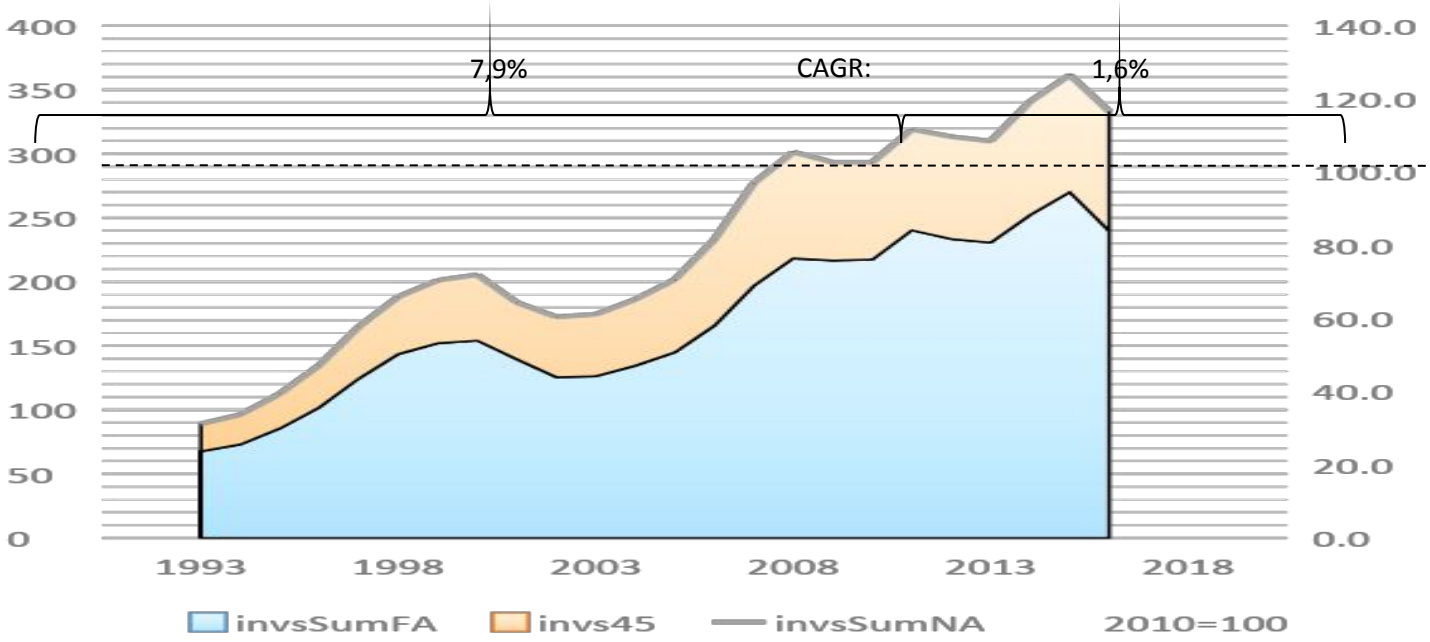
National accounts include additionally:

- expenditures on military equipment;
- expenditures on small tools;
- spendings on intellectual property products (like software or R&D spendings).

Differences between data sources give rise to the necessity of creating a balancing position.

4. Statistical analysis of the sectoral investment

Pic. 2. The level (left scale, constant prices from 2010, in bln zł) and the dynamics (right scale, 2010=100) of the total gross investment by two data sources in Poland in 1993-2016



Tab. 1. The structure of investment spendings in Poland in chosen periods

	% of total gross investment			
Category	1993	2004	2009	2016
buildings & structures	59	56	60	55
machinery & tech.equip.	28	32	30	34
transport equip.	7	10	9	10
other investments	6	3	1	1

Source: Own elaboration.

4. Statistical analysis of the sectoral investment

Tab. 2. Five sectors with the highest share in total gross investent in Polish economy in chosen periods

1993		2004		2009		2016		Change in 2016 in relation to 1993	
Sector	**% share**	**Sector**	**% share**	**Sector**	**% share**	**Sector**	**% share**	**% change**	**change in p.p.**
Real estate services	14.3	Real estate services	14.5	Transportation and storage	17.3	Transportation and storage	17.1	19.4	2.8
Transportation and storage	14.3	Transportation and storage	12.3	Real estate services	13.1	Real estate services	13.2	-8.0	-1.1
Electricity, gas, steam and a/c	11.1	Sale and repair of motor vehicles	9.4	Sale and repair of motor vehicles	9.0	Electricity, gas, steam and a/c	9.5	-14.6	-1.6
Sale and repair of motor vehicles	7.5	Electricity, gas, steam and a/c	6.1	Electricity, gas, steam and a/c	6.2	Sale and repair of motor vehicles	7.4	-1.2	-0.1
Natural water	5.5	Natural water	4.7	Natural water	5.8	Motor vehicles	3.6	569.0	3.0
Other sectors	47.3	Other sectors	53.0	Other sectors	48.6	Other sectors	49.3	x	x

Source: Own elaboration.

Tab. 3. Sectors with the highest share of particular category of the investment in total investments of the sector in 2016.

Category	% of total investment (s) in sector in 2016			
	highest	**sector**	**lowest**	**sector**
buildings & structures	97.1	Real estate services	6.4	Office administrative services
machinery & tech.equip.	89.1	Tobacco products	2.0	Real estate services
transport equip.	70.3	Office administrative services	0.4	Tobacco products
other investments	11.6	Agriculture and hunting	0.0	Repair and inst. of mach. and equip.

Source: Own elaboration.

5. Estimation results – sectoral investment models

The process of building the sectoral investment models for Poland was as follows:

1. Estimation of the parameters of the investment model for each of 45 sectors (basic model form). Method - OLS:

$\forall i = 1,2,\dots,45$ i $t = 1(1996),\dots,21(2016)$

$$\boldsymbol{inv_{it} = a_1 caprep_{it} + a_2 dout_{it} + \cdots + a_4 dout_{it-2} + a_5 rlomr_t + a_6 rlomr_{t-1} + e_{it}} \quad (1)$$

```
r invsR%1 = !caprep, doutR%1, doutR%1[1], doutR%1[2], rlomr, rlomr[1]
```

Soft constraints: `con [] 1=a1`

where:

$\boldsymbol{caprep_{it}}$ – the capital replacement (see: Almon 2017. *The craft*…), computed on the basis of the fixed capital stock estimation. Capital stock here is the sum of the investment spendings from a previous periods (minus an appropriate amount of deprecation),

```
fdates 1990 2050
f ub20 = @cum(ub20,1.,.20)
f caprep = @cum(invcum, invs%1[1], .20)/ub20
```

$\boldsymbol{dout_{it}}$ – first difference in the real output in *ith* sector in the moment *t,*

$\boldsymbol{rlomr_t}$ – real weighted lombard rate.

5. Estimation results – sectoral investment models

The process of building the sectoral investment models for Poland was as follows:

2. Estimation of the parameters of the investment model with external production effects of the entire economy:

$$\boldsymbol{inv_{it} = a_1 caprep_{it} + a_2 dout_t + \cdots + a_4 dout_{t-2} + a_5 rlomr_t + a_5 rlomr_{t-1} + e_{it}} \quad (1)$$

Soft constraints: `con [] 1=a1`

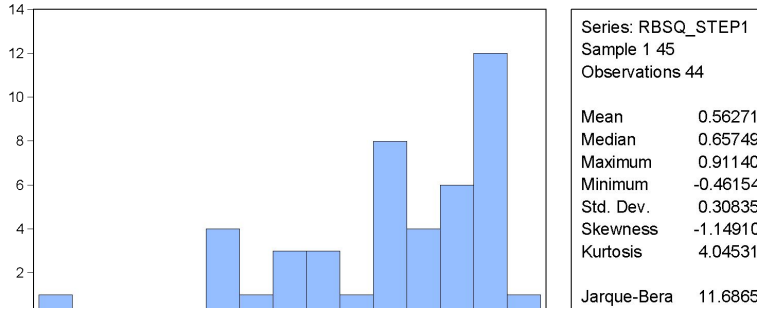
$\boldsymbol{dout_t}$ – first difference in the real output of the economy in the moment *t.*

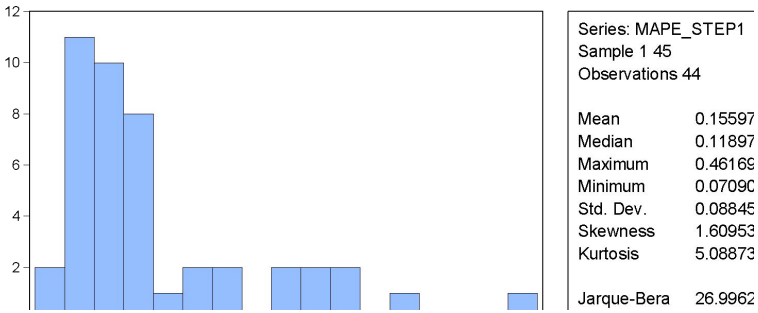
3. In the last step individual approach to each of the sector was used. The modifications consisted in:
   - the elimination of the variables, which were characterized by statistically insignificant structural parameter,
   - the elimination of the variables with the parameter's sign that was inconsistent with theory,
   - including PMI index instead of real weighted lombard rate in some equations.

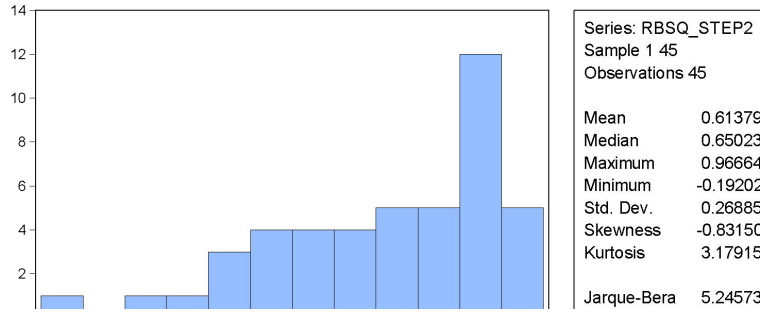
5. Estimation results – sectoral investment models

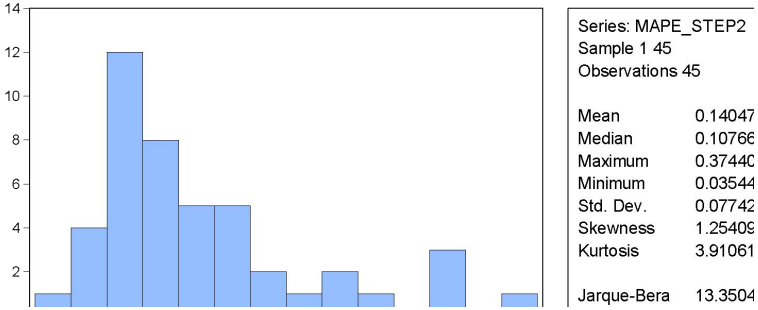
General conclusions from the estimation:

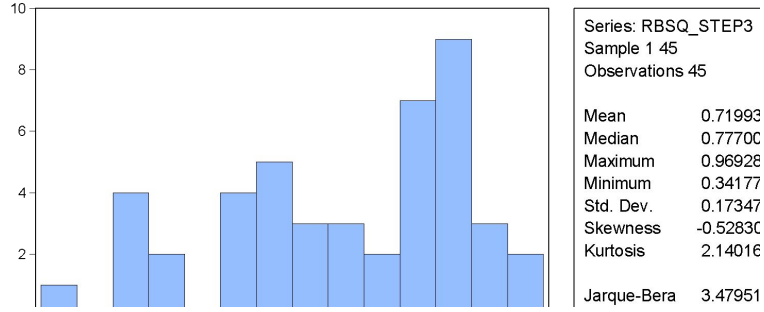
1. In 30 sectors the inclusion of the external production effects of the entire economy gives better stochastic structure parameters of the model.

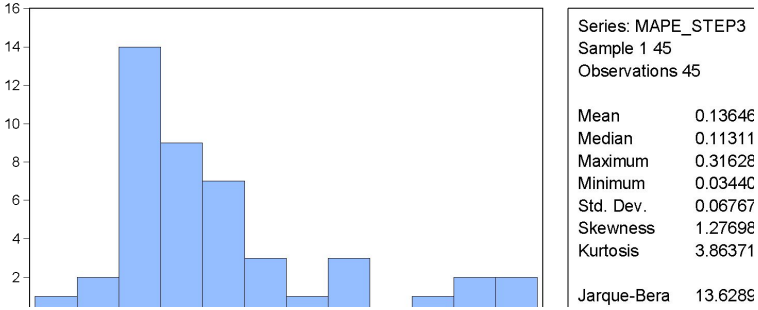








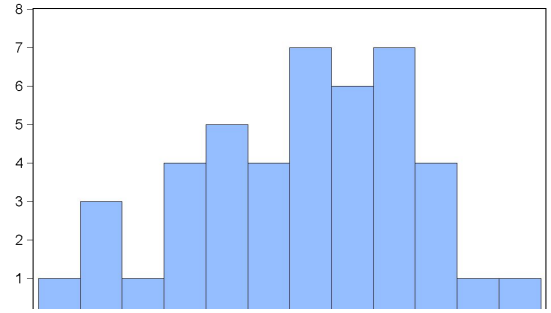




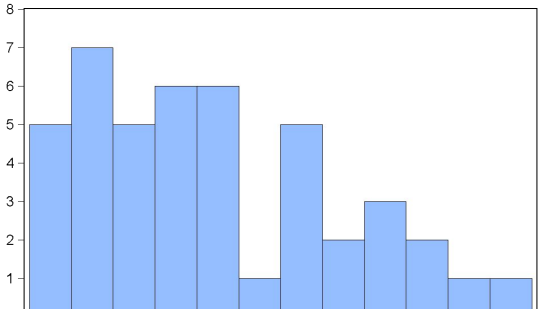
Source: Own elaboration based on Eviews software.

5. Estimation results – sectoral investment models

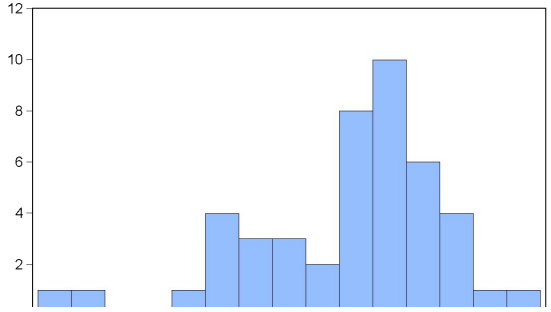
2. Structural parameter of the lombard rate and its lags often took a positive value.
3. Structural parameter next to replacement was always statistically significant, but not always was around 1.0.



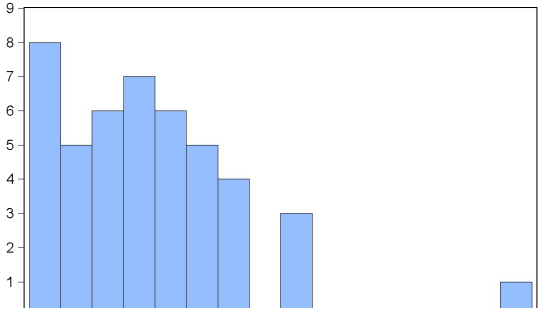
Series: A1_STEP1	
Sample 1 45	
Observations 44	
Mean	1.03219
Median	1.02869
Maximum	1.50924
Minimum	0.44555
Std. Dev.	0.25957
Skewness	-0.25147
Kurtosis	2.41825
Jarque-Bera	1.08421



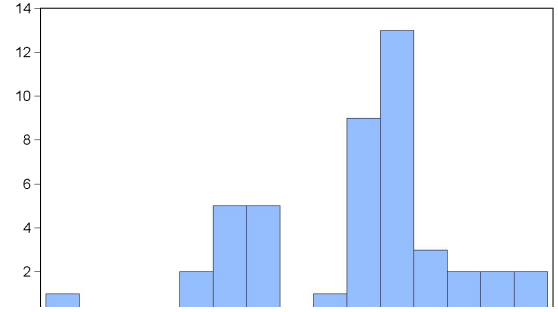
Series: M1_STEP1	
Sample 1 45	
Observations 44	
Mean	220.496
Median	189.379
Maximum	580.850
Minimum	14.3208
Std. Dev.	150.476
Skewness	0.61391
Kurtosis	2.36958
Jarque-Bera	3.49249



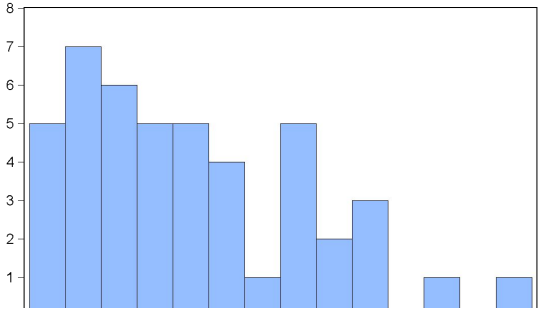
Series: A1_STEP2	
Sample 1 45	
Observations 45	
Mean	0.92383
Median	0.99789
Maximum	1.47693
Minimum	0.09378
Std. Dev.	0.29589
Skewness	-0.82923
Kurtosis	3.55189
Jarque-Bera	5.72839



Series: M1_STEP2	
Sample 1 45	
Observations 45	
Mean	189.726
Median	162.980
Maximum	751.495
Minimum	0.89165
Std. Dev.	145.799
Skewness	1.38008
Kurtosis	6.15235
Jarque-Bera	32.9174



Series: A1_STEP3	
Sample 1 45	
Observations 45	
Mean	0.92283
Median	0.99259
Maximum	1.43298
Minimum	0.08932
Std. Dev.	0.29154
Skewness	-0.55606
Kurtosis	3.06972
Jarque-Bera	2.32816



Series: M1_STEP3	
Sample 1 45	
Observations 45	
Mean	227.507
Median	199.235
Maximum	673.237
Minimum	10.6882
Std. Dev.	162.023
Skewness	0.79411
Kurtosis	2.91538
Jarque-Bera	4.74300

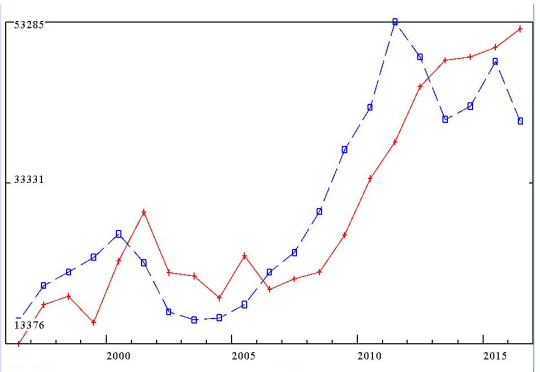
Source: Own elaboration based on Eviews software.

5. Estimation results – sectoral investment models

33. Transportation and storage

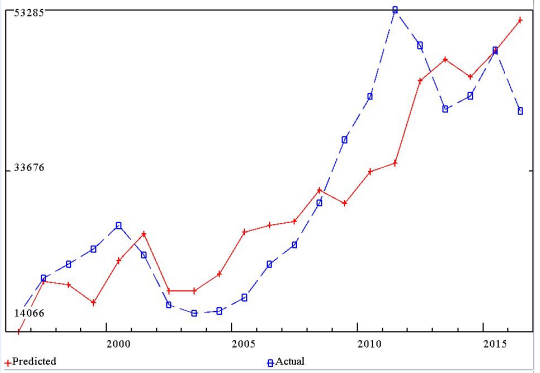
Stage 1

```
SEE   =    6761.62 RSQ   = 0.6844 RHO =   0.65 Obser  =   21 from 1996.000
SEE+1 =    5276.30 RBSQ  = 0.5792 DW  =   0.69 DoFree =   15 to   2016.000
MAPE  =      20.07
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR33              - - - - - - - - - - - - - - - - -  30206.08 - - -
1 caprep                  1.34705   184.2   1.00    1.23  22463.34
2 doutR33                -0.15276     0.5  -0.04    1.22   7003.69 -0.061
3 doutR33[1]              0.01244     0.0   0.00    1.22   6809.82  0.005
4 doutR33[2]             -0.24713     1.4  -0.05    1.21   6315.39 -0.109
5 rlomr                1470.19439     9.5   0.27    1.12      5.57  0.439
6 rlomr[1]             -1193.57651    5.9  -0.22    1.00      5.52 -0.360
```



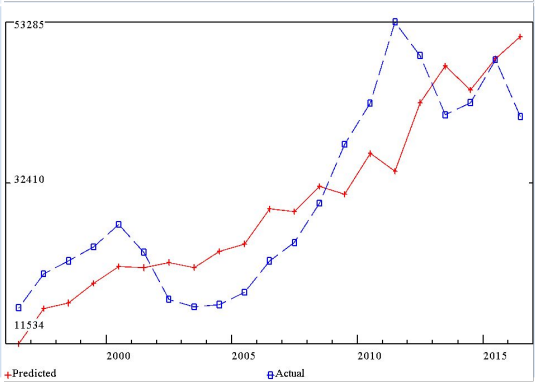
Stage 2

```
SEE   =    6477.92 RSQ   = 0.7103 RHO =   0.58 Obser  =   21 from 1996.000
SEE+1 =    5421.43 RBSQ  = 0.6137 DW  =   0.84 DoFree =   15 to   2016.000
MAPE  =      16.64
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR33              - - - - - - - - - - - - - - - - -  30206.08 - - -
1 caprep                  1.16058   156.1   0.86    1.34  22463.34
2 doutRsum                0.01454     1.1   0.05    1.27  96691.89  0.076
3 doutRsum[1]             0.01349     0.8   0.04    1.18  96449.89  0.070
4 doutRsum[2]             0.02210     2.2   0.07    1.13  90705.85  0.112
5 rlomr                 984.85874     4.2   0.18    1.13      5.57  0.294
6 rlomr[1]             -1162.94692    6.2  -0.21    1.00      5.52 -0.351
```



Stage 3

```
SEE   =    6833.71 RSQ   = 0.6776 RHO =   0.60 Obser  =   21 from 1996.000
SEE+1 =    5610.77 RBSQ  = 0.6207 DW  =   0.79 DoFree =   17 to   2016.000
MAPE  =      20.94
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR33              - - - - - - - - - - - - - - - - -  30206.08 - - -
1 caprep                  1.14612   147.4   0.85    1.20  22463.34
2 doutRsum                0.02435     3.3   0.08    1.14  96691.89  0.127
3 doutRsum[2]             0.03619     6.6   0.11    1.04  90705.85  0.183
4 rlomr[1]             -306.45637     1.9  -0.06    1.00      5.52 -0.092
```



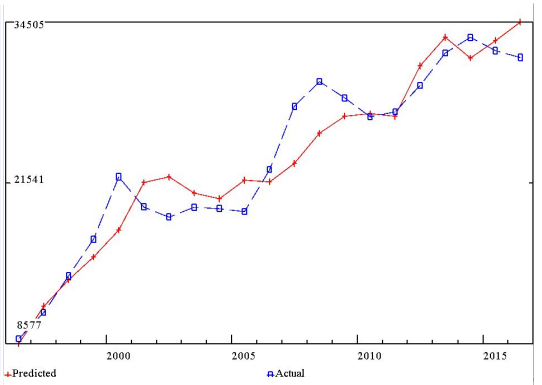
Source: Own elaboration

5. Estimation results – sectoral investment models

37. Real estate services

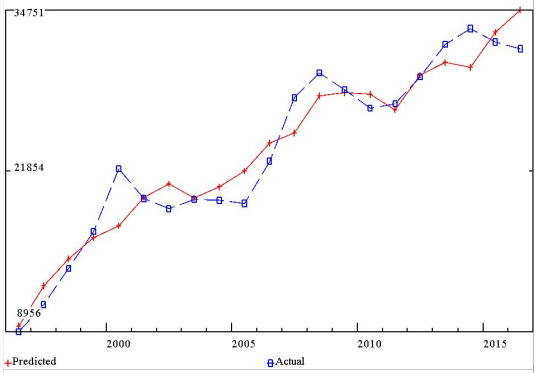
Stage 1

```
SEE   =    2186.62 RSQ   = 0.9028 RHO =   0.42 Obser  =   21 from 1996.000
SEE+1 =    2012.95 RBSQ  = 0.8704 DW  =   1.17 DoFree =   15 to   2016.000
MAPE  =       7.48
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR37              - - - - - - - - - - - - - - - - -  23354.68 - - -
1 caprep                  1.14928   580.9   0.88    2.46  17903.79
2 doutR37                -0.11144     1.8  -0.02    2.44   3639.45 -0.069
3 doutR37[1]             -0.03807     0.3  -0.01    2.30   3386.81 -0.023
4 doutR37[2]              0.11275     1.8   0.02    1.78   3243.57  0.068
5 rlomr                 487.00401     9.4   0.12    1.00      5.57  0.250
6 rlomr[1]               20.45390     0.0   0.00    1.00      5.52  0.011
```



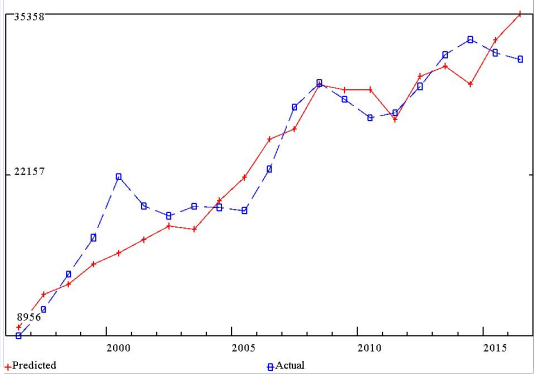
Stage 2

```
SEE   =    1873.73 RSQ   = 0.9286 RHO =   0.28 Obser  =   21 from 1996.000
SEE+1 =    1825.89 RBSQ  = 0.9049 DW  =   1.44 DoFree =   15 to   2016.000
MAPE  =       6.48
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR37              - - - - - - - - - - - - - - - - -  23354.68 - - -
1 caprep                  1.03717   428.0   0.80    3.35  17903.79
2 doutRsum                0.00794     3.5   0.03    2.89  96691.89  0.071
3 doutRsum[1]             0.00677     2.4   0.03    2.35  96449.89  0.061
4 doutRsum[2]             0.01783    14.4   0.07    1.51  90705.85  0.155
5 rlomr                 145.60093     1.1   0.03    1.03      5.57  0.075
6 rlomr[1]              172.90312     1.6   0.04    1.00      5.52  0.089
```



Stage 3

```
SEE   =    2302.41 RSQ   = 0.8923 RHO =   0.44 Obser  =   21 from 1996.000
SEE+1 =    2108.16 RBSQ  = 0.8732 DW  =   1.12 DoFree =   17 to   2016.000
MAPE  =       8.26
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR37              - - - - - - - - - - - - - - - - -  23354.68 - - -
1 caprep                  1.03697   352.3   0.79    2.22  17903.79
2 doutRsum                0.01382     7.5   0.06    1.92  96691.89  0.124
3 doutRsum[1]             0.00823     2.4   0.03    1.56  96449.89  0.074
4 doutRsum[2]             0.02649    24.8   0.10    1.00  90705.85  0.230
```



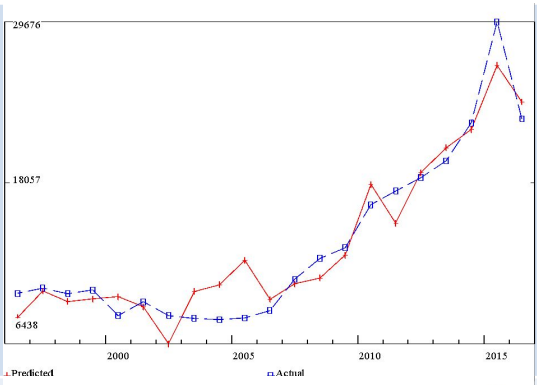
Source: Own elaboration

5. Estimation results – sectoral investment models

29. Electricity, gas, steam and a/c

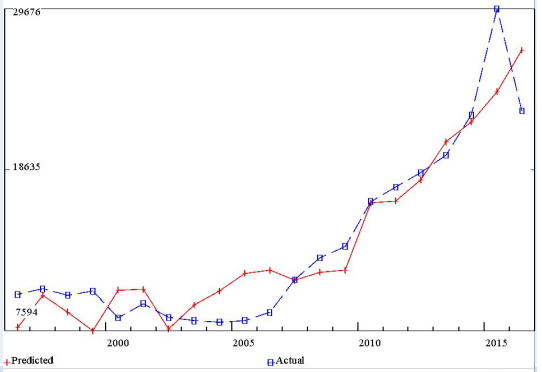
Stage 1

```
SEE   =    1697.01 RSQ   = 0.9172 RHO =   0.18 Obser  =   21 from 1996.000
SEE+1 =    1680.64 RBSQ  = 0.8896 DW  =   1.64 DoFree =   15 to   2016.000
MAPE  =      12.08
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR29              - - - - - - - - - - - - - - - - -  13568.87 - - -
1 caprep                  1.46396   513.9   1.10    2.53  10158.74
2 doutR29                -0.09572     1.4  -0.01    2.53   1463.20 -0.058
3 doutR29[1]             -0.47732    24.3  -0.05    1.25   1472.03 -0.288
4 doutR29[2]             -0.00237     0.0  -0.00    1.19   1213.43 -0.001
5 rlomr                 357.24151     7.8   0.15    1.19      5.57  0.218
6 rlomr[1]             -435.48929     8.9  -0.18    1.00      5.52 -0.268
```



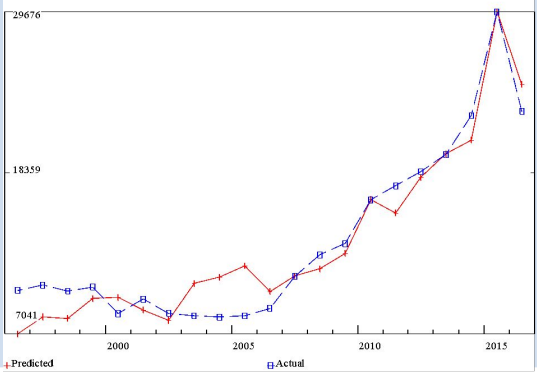
Stage 2

```
SEE   =    2171.14 RSQ   = 0.8645 RHO =   0.10 Obser  =   21 from 1996.000
SEE+1 =    2182.72 RBSQ  = 0.8193 DW  =   1.80 DoFree =   15 to   2016.000
MAPE  =      13.80
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR29              - - - - - - - - - - - - - - - - -  13568.87 - - -
1 caprep                  1.47694   256.3   1.11    1.55  10158.74
2 doutRsum                0.00666     1.9   0.05    1.54  96691.89  0.071
3 doutRsum[1]            -0.00697     1.8  -0.05    1.49  96449.89 -0.074
4 doutRsum[2]            -0.00103     0.0  -0.01    1.48  90705.85 -0.011
5 rlomr                 398.86693     6.2   0.16    1.35      5.57  0.243
6 rlomr[1]             -643.69920    16.2  -0.26    1.00      5.52 -0.396
```



Stage 3

```
SEE   =    1686.82 RSQ   = 0.9182 RHO =   0.64 Obser  =   21 from 1996.000
SEE+1 =    1409.86 RBSQ  = 0.9038 DW  =   0.71 DoFree =   17 to   2016.000
MAPE  =      12.68
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR29              - - - - - - - - - - - - - - - - -  13568.87 - - -
1 caprep                  1.43298   482.0   1.07    2.56  10158.74
2 doutR29[1]             -0.29520    10.5  -0.03    1.31   1472.03 -0.178
3 rlomr[1]             -156.71401     7.3  -0.06    1.18      5.52 -0.096
4 Uinv29               4386.03340     8.7   0.02    1.00      0.05  0.158
```



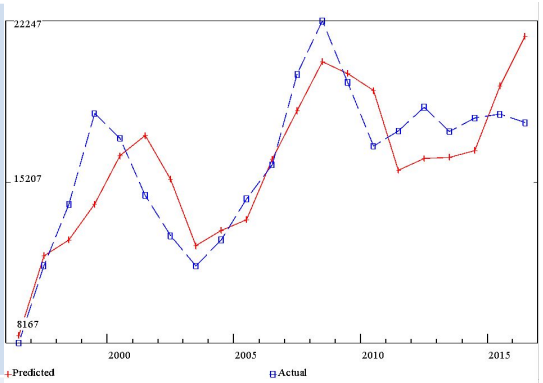
Source: Own elaboration

5. Estimation results – sectoral investment models

32. Sale and repair of motor vehicles

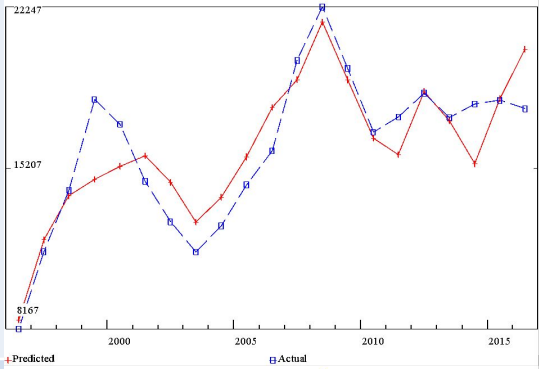
Stage 1

```
SEE   =    1859.01 RSQ   = 0.6777 RHO =   0.44 Obser  =   21 from 1996.000
SEE+1 =    1723.20 RBSQ  = 0.5703 DW  =   1.13 DoFree =   15 to   2016.000
MAPE  =       9.42
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR32              - - - - - - - - - - - - - - - - -  16046.98 - - -
1 caprep                  0.97427   396.4   0.79    4.11  12971.34
2 doutR32                 0.12087    22.8   0.08    2.06  10493.37  0.417
3 doutR32[1]              0.10404    14.3   0.07    1.31  10261.87  0.355
4 doutR32[2]              0.08394     8.6   0.05    1.05   9162.56  0.281
5 rlomr                 225.58292     2.5   0.08    1.04      5.57  0.248
6 rlomr[1]             -187.89111     1.8  -0.06    1.00      5.52 -0.208
```



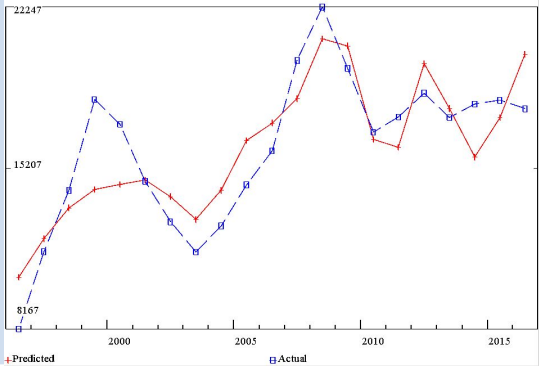
Stage 2

```
SEE   =    1486.22 RSQ   = 0.7940 RHO =   0.40 Obser  =   21 from 1996.000
SEE+1 =    1392.75 RBSQ  = 0.7253 DW  =   1.20 DoFree =   15 to   2016.000
MAPE  =       7.39
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR32              - - - - - - - - - - - - - - - - -  16046.98 - - -
1 caprep                  0.72022   209.2   0.58    6.42  12971.34
2 doutRsum                0.01365    15.5   0.08    5.11  96691.89  0.262
3 doutRsum[1]             0.01922    27.0   0.12    3.01  96449.89  0.368
4 doutRsum[2]             0.02301    33.5   0.13    1.53  90705.85  0.428
5 rlomr                 179.91271     2.6   0.06    1.01      5.57  0.198
6 rlomr[1]               79.97621     0.5   0.03    1.00      5.52  0.089
```



Stage 3

```
SEE   =    1693.88 RSQ   = 0.7324 RHO =   0.42 Obser  =   21 from 1996.000
SEE+1 =    1587.70 RBSQ  = 0.6852 DW  =   1.15 DoFree =   17 to   2016.000
MAPE  =       9.45
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR32              - - - - - - - - - - - - - - - - -  16046.98 - - -
1 caprep                  0.53889    60.7   0.44    4.94  12971.34
2 doutRsum[1]             0.01991    24.0   0.12    2.51  96449.89  0.382
3 doutRsum[2]             0.01976    23.2   0.11    1.62  90705.85  0.368
4 pmi                   106.73158    27.4   0.33    1.00     50.08  0.083
```



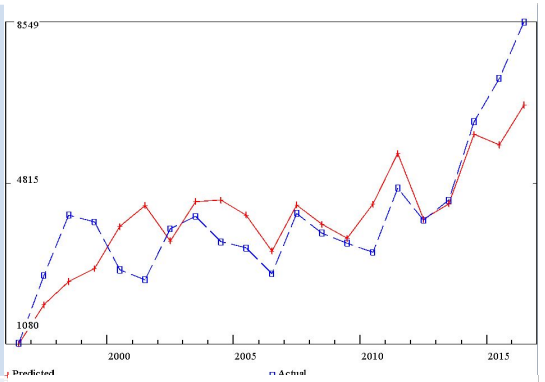
Source: Own elaboration

5. Estimation results – sectoral investment models

24. Motor vehicles

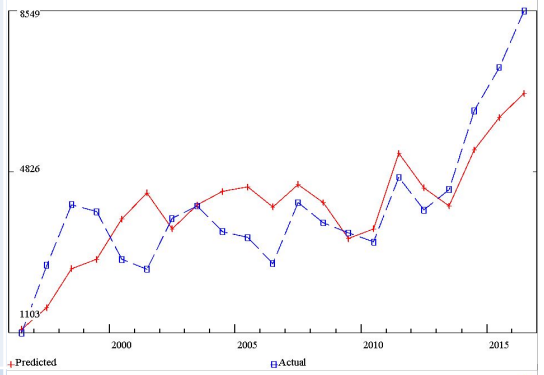
Stage 1

```
SEE   =     930.27 RSQ   = 0.6642 RHO =   0.60 Obser  =   21 from 1996.000
SEE+1 =     775.49 RBSQ  = 0.5523 DW  =   0.81 DoFree =   15 to   2016.000
MAPE  =      19.00
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR24              - - - - - - - - - - - - - - - - -   3992.02 - - -
1 caprep                  1.28662   119.0   0.90    1.66   2785.67
2 doutR24                 0.02020     1.0   0.03    1.58   5754.03  0.087
3 doutR24[1]              0.01150     0.3   0.02    1.55   5291.56  0.049
4 doutR24[2]             -0.07125    10.9  -0.09    1.40   4849.29 -0.303
5 rlomr                 176.12093     6.7   0.25    1.02      5.57  0.394
6 rlomr[1]              -70.82589     1.0  -0.10    1.00      5.52 -0.160
```



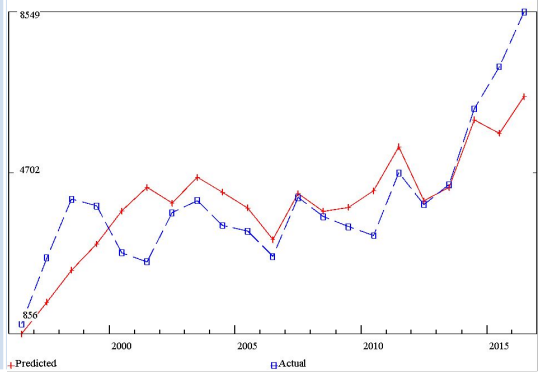
Stage 2

```
SEE   =     960.60 RSQ   = 0.6419 RHO =   0.63 Obser  =   21 from 1996.000
SEE+1 =     775.40 RBSQ  = 0.5226 DW  =   0.75 DoFree =   15 to   2016.000
MAPE  =      21.48
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR24              - - - - - - - - - - - - - - - - -   3992.02 - - -
1 caprep                  1.22819   103.3   0.86    1.55   2785.67
2 doutRsum                0.00158     0.5   0.04    1.37  96691.89  0.062
3 doutRsum[1]             0.00371     2.7   0.09    1.32  96449.89  0.145
4 doutRsum[2]            -0.00658     7.7  -0.15    1.28  90705.85 -0.250
5 rlomr                 132.56073     3.1   0.18    1.00      5.57  0.297
6 rlomr[1]              -13.09995     0.0  -0.02    1.00      5.52 -0.030
```



Stage 3

```
SEE   =     950.92 RSQ   = 0.6491 RHO =   0.69 Obser  =   21 from 1996.000
SEE+1 =     716.06 RBSQ  = 0.6101 DW  =   0.61 DoFree =   18 to   2016.000
MAPE  =      20.28
  Variable name          Reg-Coef  Mexval  Elas   NorRes     Mean   Beta
0 invsR24              - - - - - - - - - - - - - - - - -   3992.02 - - -
1 caprep                  1.32824   205.1   0.93    1.59   2785.67
2 doutR24[2]             -0.07360    12.8  -0.09    1.38   4849.29 -0.313
3 rlomr                 116.01999    17.3   0.16    1.00      5.57  0.260
```



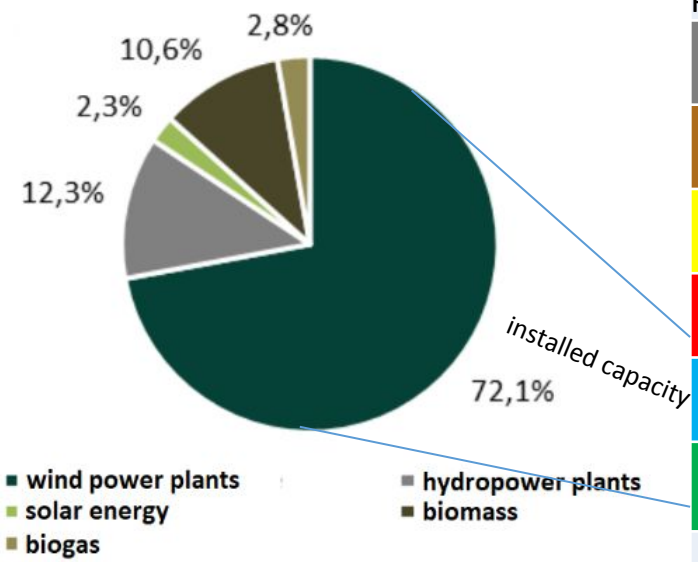
Source: Own elaboration

6. Investments in the energy sector – facts, ideas, threats

Why am I interested in the topic…?

Facts:

- Polish energy sector has been historically based on the fossil fuels;
- the majority of existing power plants and installations are old;
- the energy sector requires significant investments…



Tab. 4. The structure of installed capacity and electricity generation in Polish electric power system as at 31 December 2017

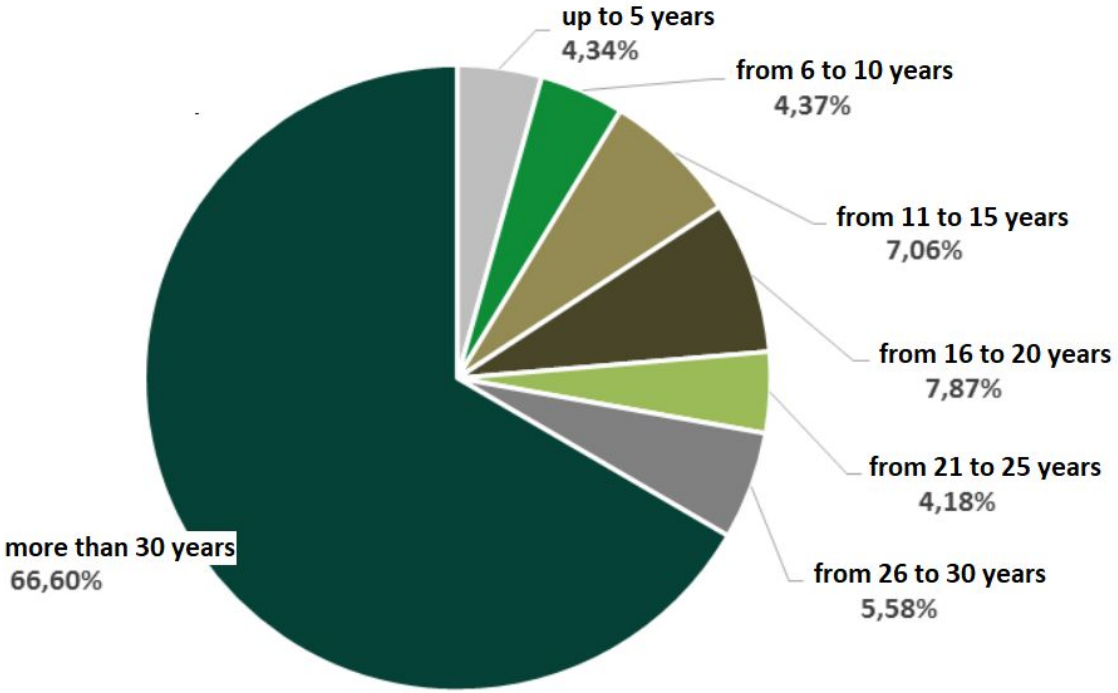
Power plant type:	Installed capacity [in MW]	%share	Electricity generation [in GWh]	%share
hard coal	20 247	46.6	79 868	48.2
lignite	9 352	21.5	51 983	31.3
natural gas	2 341	5.4	7 172	4.3
captive	2 813	6.5	10 057	6.1
hydropower	2 328	5.4	2 767	1.7
wind and other renewables	6 341	14.6	14 005	8.4
TOTAL	43 422	100.0	165 852	100.0

Source: PSE S.A. (Polish Electricity Networks Inc.) Databases.

6. Investments in the energy sector – facts, ideas, threats

Facts:

Pic. 3. Age structure of the power plant blocks [with respect to their installed capacity] at the end of 2015



Tab. 5. Scenarios for disabling the obsolete power plant blocks [power loss in MW]

	2020	2025	2030	2035
„Modernization" scenario	3000	3200	5700	13900
"Turn off" scenario	6600	9900	17300	20300

Source: PSE S.A. (Polish Electricity Networks Inc.) Databases.

6. Investments in the energy sector – facts, ideas, threats

Ideas:

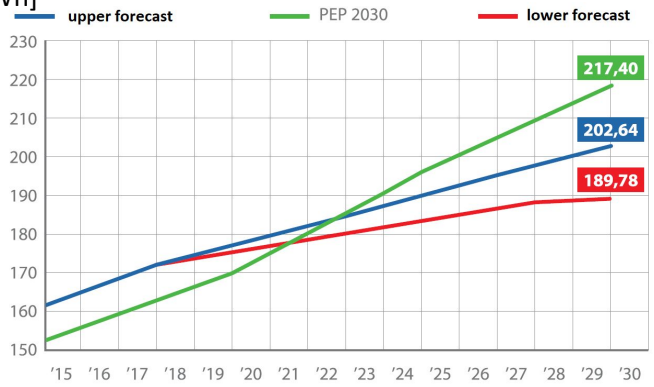
- In the public debate, there exists a lot of ideas how the future of Polish energy sector should develop, but…
- … policy makers still are not determined to choose the main path of development.

Tab. 6. The example of the paths of the energy system development from domestic documents

Public		Private (think tank)
Polish Energy Policy (PEP) 2050 (2014)	National Programme for the Development of a Low-emission Economy (2015)	*Polish Energy sector 2050. 4 scenarios*
• Balanced scenario • Nuclear scenario • „Natural Gas+RES" scenario	• Central scenario • High scenario • Low scenario	• Hard coal scenario • Diversified scenario (with the nuclear power) • Diversified scenario (without the nuclear power) • Renewable scenario

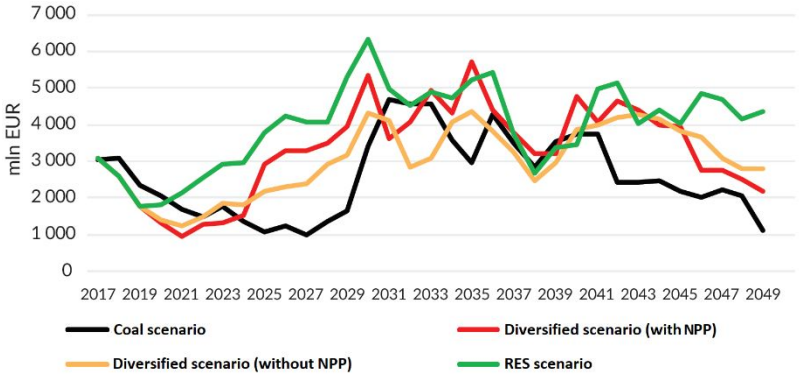
Source: Own research.

Pic. 4. Electricity annual demand forecast up to 2030 [in TWh]



Source: The Friendly State Fundation (2018), *Polish power engineering,* p. 10.

Pic. 5. Annual investment expenditures according to 4 scenarios



Source: P. Mikusek ed. (2017), *Polish Energy sector 2050. 4 scearios,* Energy Forum, p. 7.

6. Investments in the energy sector – facts, ideas, threats

Threats:

Hard coal	Nuclear power
• delays in the diversification of Polish energy system; • low elasticity of installed capacity; • strong dependence on world CO_2 emission allowance prices, • the necessity of import of a high amount of coal in the future.	• the increase in electricity prices; • delays in construction schedule due to high investment cost • problems with balancing the installed power (in case of a breakdown)
Shale gas	**RES**
• possibility of overestimating an amount of the resources; • high degree of the devastation of the natural environment; • the increase of the mining costs over the time.	• problems connected with energy storing and system stability. • strong dependence on future weather conditions.

Source: own elaboration.

7. Summary and directions of further research

SUMMARY

I. Modelling investment on the high disaggregation level is associated with limited selection of the determinants (data availability).

II. Estimation results indicate that in many sectors better results are achieved by including the macroeconomic business cycle.

III. Individual approach is time-intensive but allows the researcher to deal with the specificity of the sector's performance and helps with obtaining better quality of the structural and stochastic parameters of the model.

IV. Polish energy sector needs one clear scenario of development, where investments made will contribute to shift the economy to the low-emission growth path.

DIRECTIONS OF FURTHER RESEARCH:

I. Determining the shape of the energy block, which will be a part of MMM.

II. Giving the multisectoral energy model a purpose – conducting simulations of future energy carriers usage and its emissions levels on the basis of various scenarios of the development of Polish energy sector.

Chosen literature

- Almon C. (2017), *The Craft of Economic Modeling*. Boston: Ginn Press, Third, Enlarged Edition.
- Domar E.D. (1962), *Szkice teorii wzrostu gospodarczego*, Warszawa: PWN.
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