An Econometric Model to Assess Residential and Tertiary Electricity and Gas Savings in the EU

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Introduction 1

- In this project the JRC built and test a methodology to evaluate the energy savings produced by energy efficiency measures and programmes (aka policies).
- For policy makers it is crucial that a monitoring and evaluation method is giving good and reliable results on the one hand and is relatively easy and straightforward to use in practice on the other hand.
- The methodology used in this project is a relatively basic econometric model that is used to estimate actual consumption.

Introduction 2

- The economic model includes energy prices, an indicator for the economic situation (e.g. GDP), a variable for weather/climatic conditions (e.g. heating degree days), and the population size. To this variables we add energy efficiency index when available (e.g. the stock of electric appliances - refrigerators).
- Energy demand is then estimated as a function of these factors. Based on the model, we also forecast energy demand for a pre-specified period (2 and 4 years).
- The forecasted consumption is then compared with the actual consumption. The differences between the forecasted and the actual consumption can be interpreted as energy savings
- The models are based on the National Consumption Metrics Models developed by **Marvin Horowitz**.

The database (1)

- In general, the datasets are available for the full timeframe of the analysis from 1990 to 2010. Only the population dataset and the energy consumption datasets are complete for all Member States. All other datasets are incomplete with missing observations for at least one Member State.

- For data on households like the number of households per country, average people per household and average size of dwelling in square meters the datasets are very incomplete and cover only a few countries and short time periods.

The database (2)

- The countries that are being analysed in this project were partly selected because of the high availability and quality of their corresponding datasets. This is true for the four bigger countries, namely France, Germany, Italy, and the United Kingdom.

- There are several ways to deal with missing data. One way to deal with missing data would be to pool countries together to a group and then do a panel analysis. Another way is to estimate the missing data points or extrapolate them.

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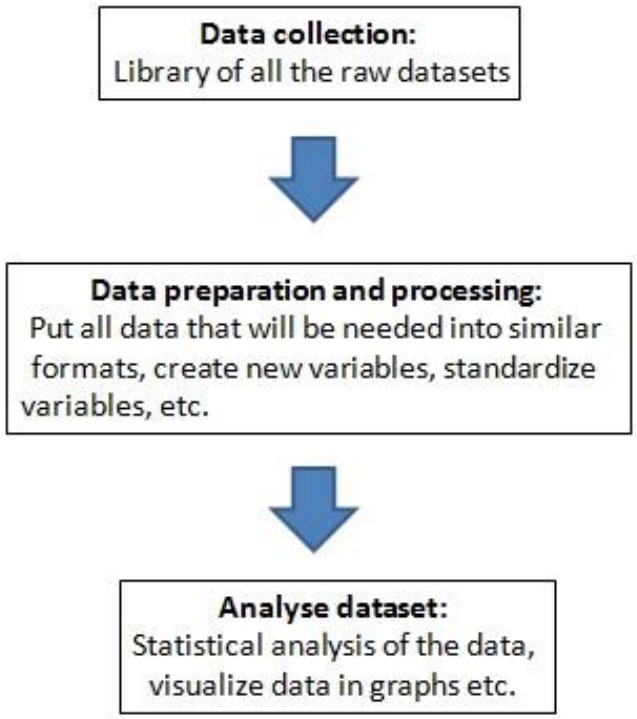
Design of the Database



Overview of available datasets (Res. Sect)

Data Source	Dataset/ Variables
All Sectors	
Eurostat	Actual heating degree days
	Real GDP per capita
	Population
	Value added by economic sectors
	GDP deflator
Odyssee Database	Energy efficiency index
	Final energy intensity
Residential Sector	
Eurostat	Final energy consumption
	Final electricity consumption
	Final gas consumption
	Gas prices
	Electricity prices
	Number of households (per country)
	Average people per household
Odyssee Database	Stock of appliances

The model (1)

- The general econometric model consists of a dependent variable and multiple explanatory variables. In this project the dependent variable is defined as the energy consumption of a single fuel (electricity or gas) divided by population.
- Based on the economic theory of energy demand, the following main factors were identified to influence energy consumption: energy prices, economic situation/development, and weather conditions. These factors are included as explanatory variables in all the models presented in this project.
- For some models, a time trend variable is added, which represents the change in equipment stock and/or other societal trends.
- The model is in log-log form (dependent and explanatory variables are expressed in logarithms) so that the coefficients can be directly interpreted as elasticities.

The model (2a)

- The general aggregate energy demand function in the models is as follows:

$$Y_{it} = f(RP_{it}, HDD_{it}, RGDP_{it}, POP_{it}, ST_{it}, t)$$

- Where Y_{it} is the aggregated energy demand (electricity or gas), RP_{it} is the real price, HDD_{it} are the actual heating degree days, $RGDP_{it}$ is the real GDP, POP_{it} is population, ST_{it} is the stock of appliances, and t is the year.

The model (2b)

In line with our analysis of the available data and of the factors influencing energy consumption, we specify the following general econometric model:

$$\frac{\ln Y_{ijt}}{N_{ijt}} = \alpha_{ijt} + \beta_{HDD} lnHDD_{jt} + \beta_{RP} \ln RP_{ijt} + \beta_{RGDPPC} \ln RGDPPC_{ijt} + \beta_{ST} \ln ST_{ijt} + \beta_{DT} DT_{jt} + \varepsilon_{ijt}$$

where Y_{ijt} is aggregated energy consumption, N_{ijt} is population or number of employees, HDD_{jt} are the actual heating degree days, RP_{ijt} is the real price per kWh for electricity or per Gj for gas respectively, $RGDPPC_{ijt}$ is the real GDP per capita, ST_{ijt} is the stock of electrical appliances (e.g. refrigerators) DT_{jt} is a series of time dummy variables and ε_{ijt} is the disturbance term all for country j, year t and fuel market i. As energy consumption and the regressors are in logarithms, the coefficients are directly interpretable as demand elasticity.

The model (3)

- We have used two different estimation approaches to estimate the models. The first approach is to estimate individual time series models with OLS. The second approach is to estimate a panel model with country fixed effects (LSDV) including either all 27 EU Member States or, alternatively, a sub-group of countries.

- The individual time series models generally deliver more precise results and smaller forecast errors whereas the panel models have more observations and hence deliver more stable coefficients less affected by multi-colinearity and outliers.

The model (4)

- Different models for each of the four countries were created by changing the cut-off period, the explanatory variables, and also the estimation method (panel and individual time series models).
- The models were compared according to forecast results, forecast percentage errors, goodness of fit of the estimated regression, and significance level of the regression coefficients.

The model (5)

- The general model is valid for all countries, sectors, single fuels and estimation methods. Panel data models (with all 27 EU Member States and with only a small group of countries) and individual time series models were estimated.

- Since the data availability is best for the residential electricity consumption models, a panel-27 model, two sub-panel models (one with four countries (DE, FR, IT, UK), and individual time series models for Germany, France, Italy, and the United Kingdom were estimated.

- The reason for the different models is to try out under which setting the model works best and to get the most precise saving estimates.

The residential models - summary

	Residential electricity
Panel 27 (y/pop, gdp)	**x**
Panel 27 (y/employees, value added)	
Sub-panel (DE, FR, IT, UK)	**x**
Sub-panel (BG, RO)	**x**
Individual time series (3 variables)	**x**
Individual time series (4 variables, incl. fridge)	**x**

Energy Savings (1)

- The difference between actual and forecasted consumption is largely driven by the omitted variable in the model: energy efficiency policy.
- Results show an impact of energy efficiency policies on energy consumption. The impact varies between sectors and fuels.
- The most significant results can be seen in the residential electricity sector where the models estimated savings for the majority of countries.
- Although the models do not show the contribution due to energy policy and the one related to other factors influencing the residual is (e.g. caused by measurement error, a wrong function form or temporary random events), the models have a general good fit, and deliver precise results with small forecasts errors.

Energy Savings (2)

- The difference between actual and forecasted consumption is mainly due to energy efficiency policies. The forecasts are produced based on the energy consumption models estimated.

- A series of different models (individual time series models and panel models) with different specifications (i.e. varying explanatory variables) are estimated and the estimated energy savings for the same countries differ between the models.

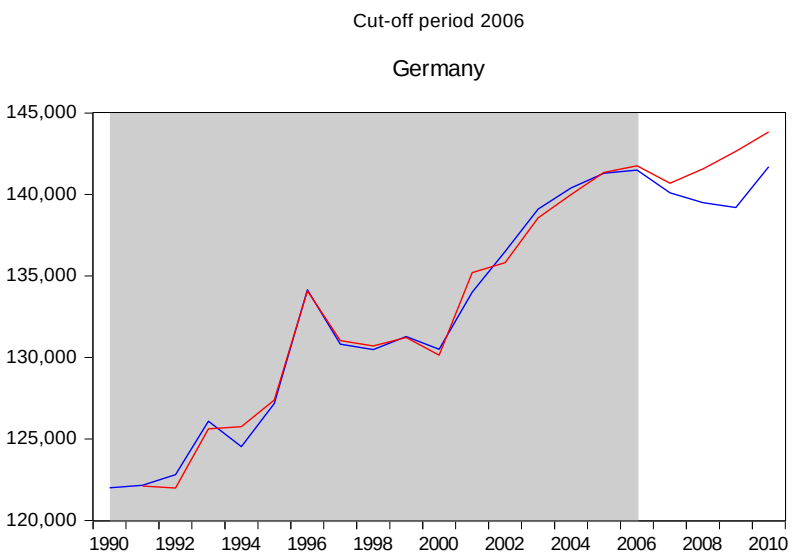
- The highest energy savings have been realized in residential electricity consumption showing that energy efficiency policies have already been successful there.

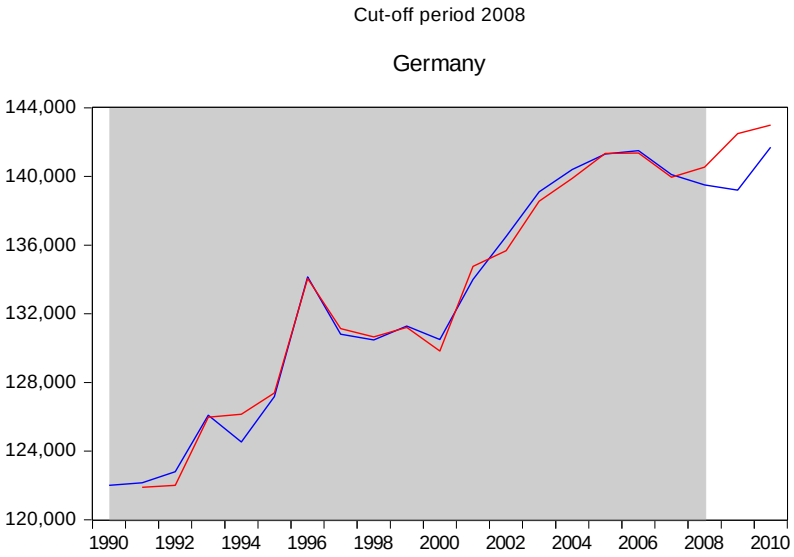
Energy Savings (3)

- In the panel model for residential electricity consumption with all 27 EU Member States almost no energy savings are visible. The actual consumption lies above forecasted consumption for the countries analysed.
- The sub-panel models and individual time-series models show significant savings for most countries and periods analysed. The individual time series models estimated for FR, GE, IT and the UK show savings in residential electricity consumption for all countries and periods except for FR in the year 2010.
- The percentage errors of the forecast for the individual time series models are generally lower than for the panel models.
- Savings lie between 0.42% and 11.34% per year in these models.

Results Germany – Res Elect

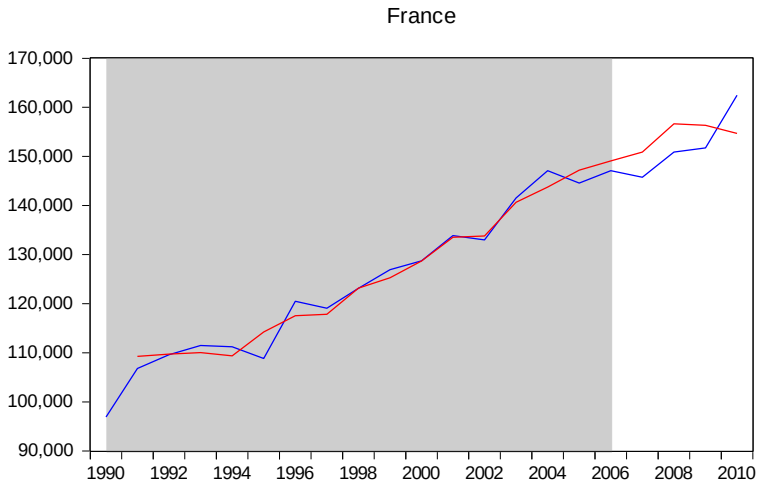
Individual time series models, four expl. variable (incl. fridges)

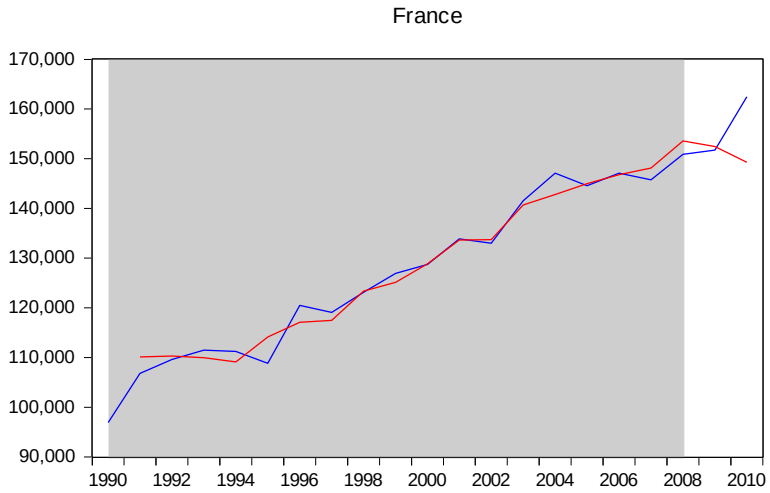




Results France – Res Elect

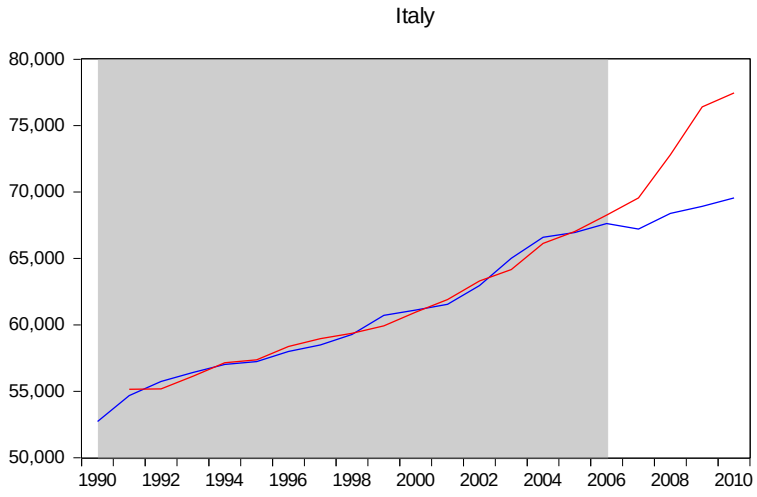
Individual time series models, four expl. variable (incl. fridges)

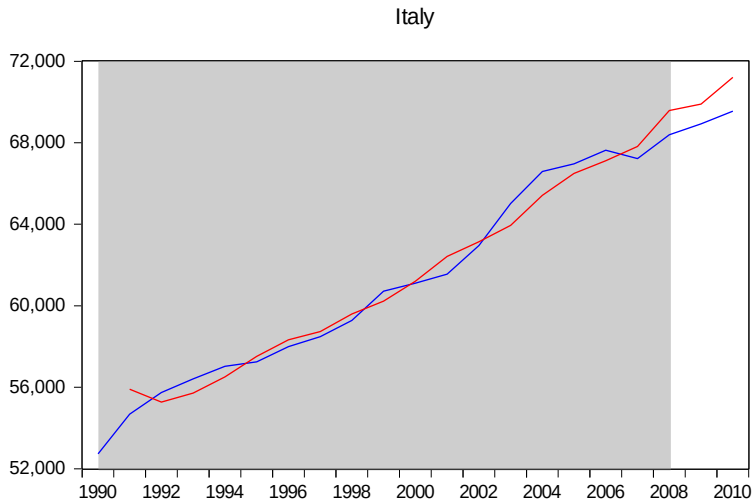




Results Italy – Res Elect

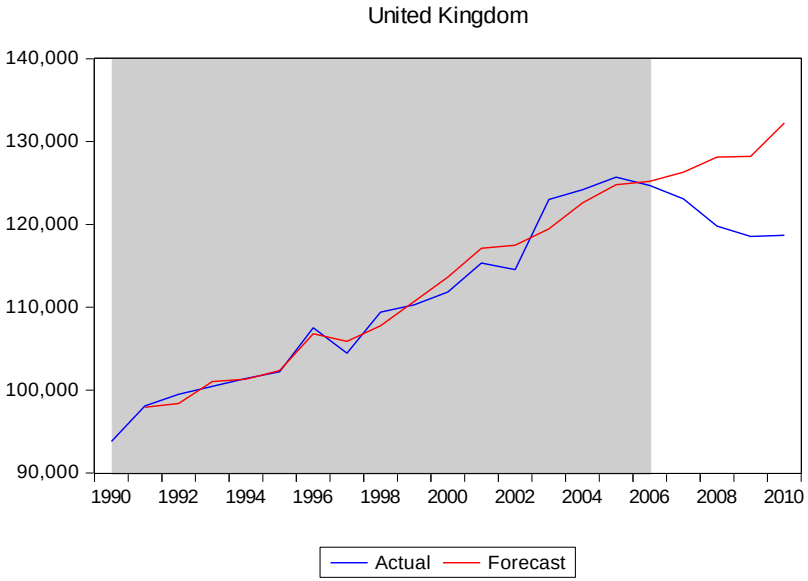
Individual time series models, four expl. variable (incl. fridges)

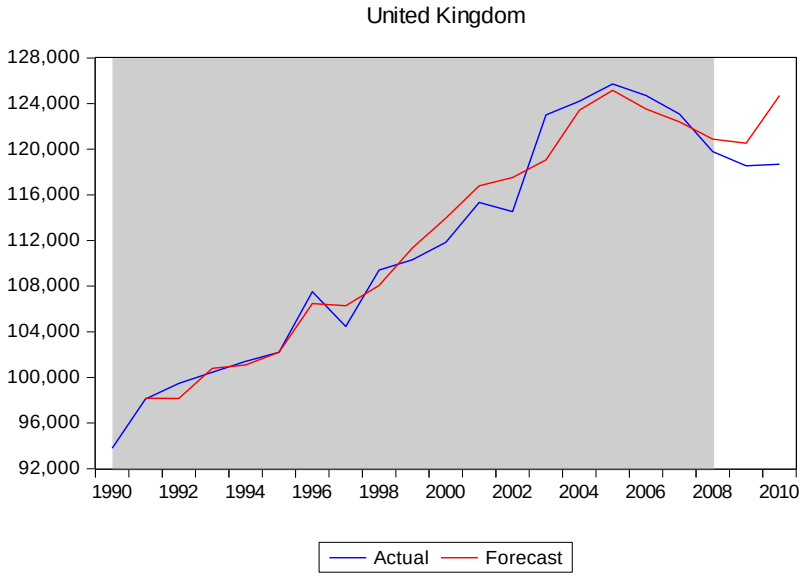




Results UK – Res Elect

Individual time series models, four expl. variable (incl. fridges)





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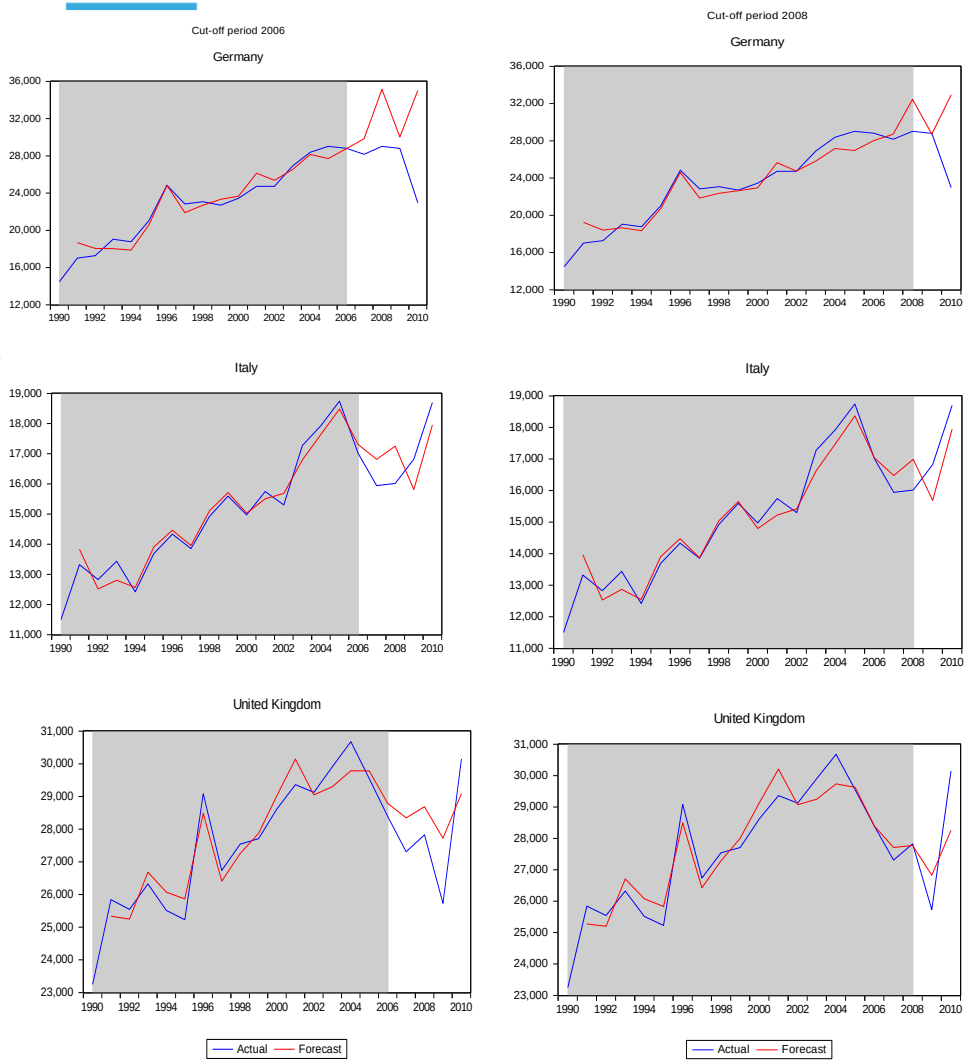
Energy Savings Gas

- Due to incomplete datasets only three countries have been included in the gas consumption models. For gas consumption, the models show savings for some of the countries analysed. The savings are not in the expected range. Many countries analysed achieved substantial savings in gas consumption whereas the models only show small savings. Together with high average foresting errors, the models might not capture the real development in gas consumption.

- This is to a great extent caused by an overall lower quality of the data for this sector compared to the data for residential electricity consumption. Some variables included in the residential electricity consumption models (i.e. stock of electricity consuming appliances) are not are available for gas consumption such as the stock of energy consumption appliances.

Results Res Gas

Individual time series models (DE, IT, UK), three regressors

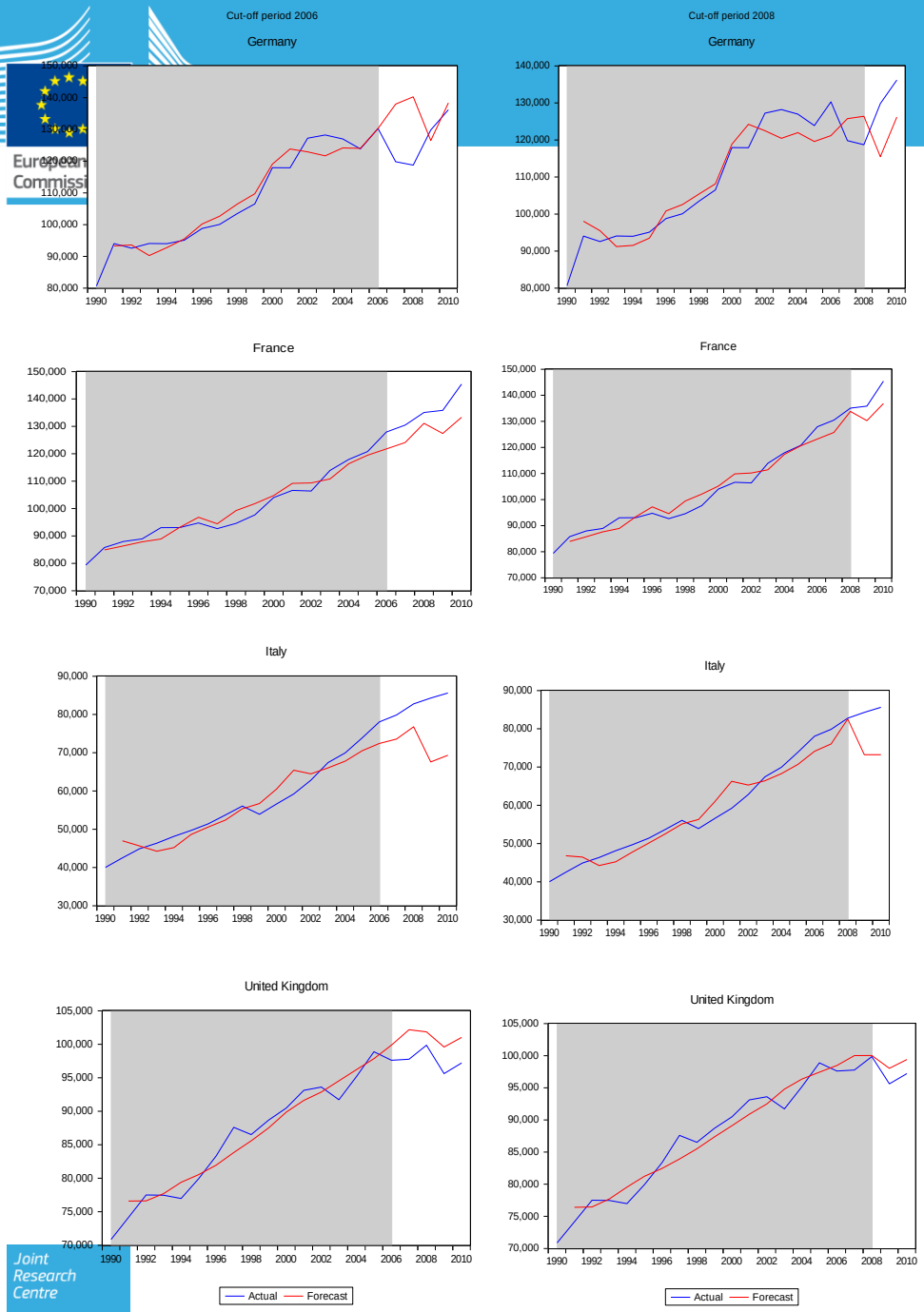


Energy Savings Tert. Sector Elec and Gas

- The most precise results are gained from the residential electricity consumption models, whereas the tertiary electricity and gas consumption models deliver less precise forecasts.
- This is to a great extent caused by an overall lower quality of the data for these sectors compared to the data for residential electricity consumption.
- Furthermore, some variables included in the residential electricity consumption models (i.e. stock of electricity consuming appliances) are not are available for tertiary sector and gas consumption such as the stock of energy consumption appliances.

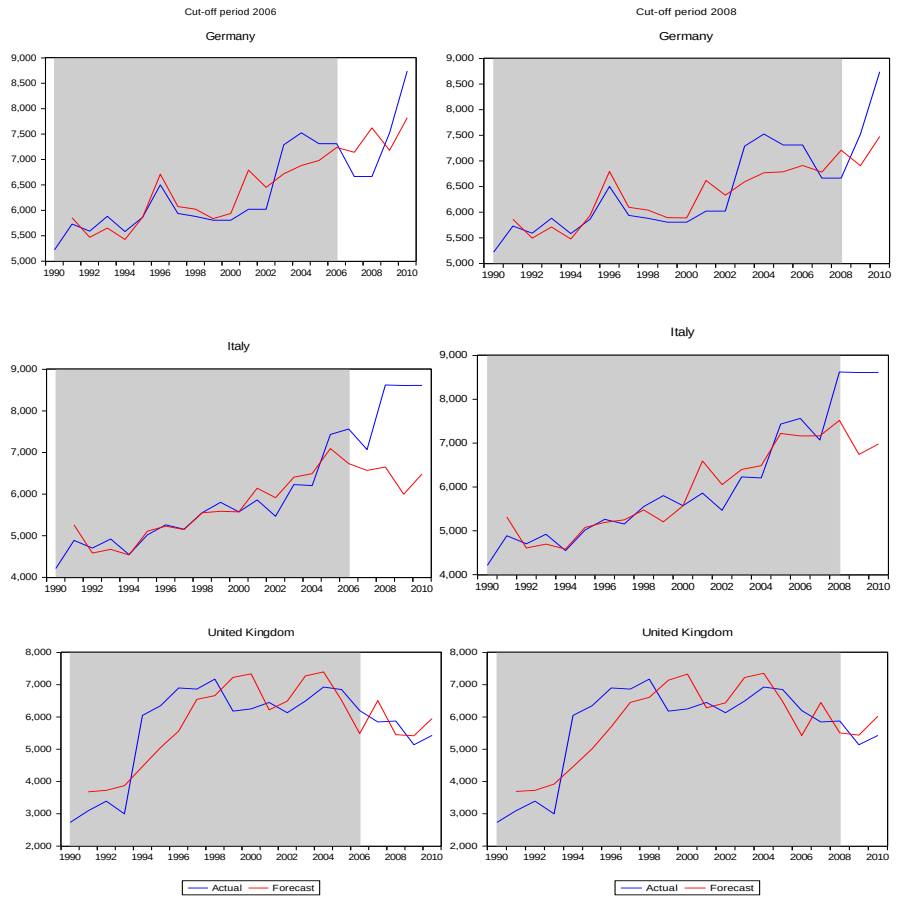
Results Tert. Electr.

Invididual time series models (DE, FR, IT, UK), three regressors



Results Tert. Gas

Individual time series models (DE, IT; UK), three regressors



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Conclusions (1)

- Energy savings has become one of the main policy goals in energy policy in the EU. It is crucial importance for the policy maker to evaluate the impact of the policies.
- In this project we applied a general energy demand model to the residential and tertiary sector to analyse electricity and gas consumption) savings. Based on the econometric model, we estimated the respective energy savings for four selected countries.
- The results show that energy efficiency policies are already starting to be successful and their impact on energy consumption is already visible in some sectors, as for instance in residential electricity consumption, where the majority of the analysed countries achieved important savings in consumption.

Conclusions (2)

- The project shows that generally individual time series models deliver better forecasting results than panel models whereas panel models have a higher number of statistically significant coefficients.

- The project shows that the models that have been used can deliver important and reliable results of energy savings estimates.

Conclusions (3)

- The quality of the models' results depends to a large extent also on the quality and availability of the database. For future research projects, it will be important to expand the now existing database with datasets that are not yet available now but will be maybe in the future.

- The models perform generally well when being used for modelling electricity consumption and less well for modelling gas consumption.

Thank you for your attention

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http://iet.jrc.ec.europa.eu/energyefficiency/