(Re-)Capturing rebounds empirically at the meso and macro level

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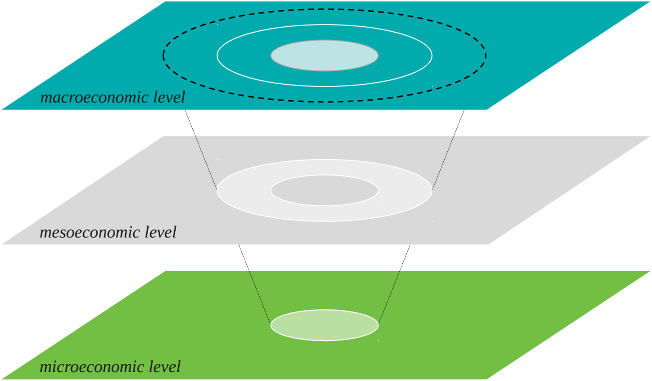
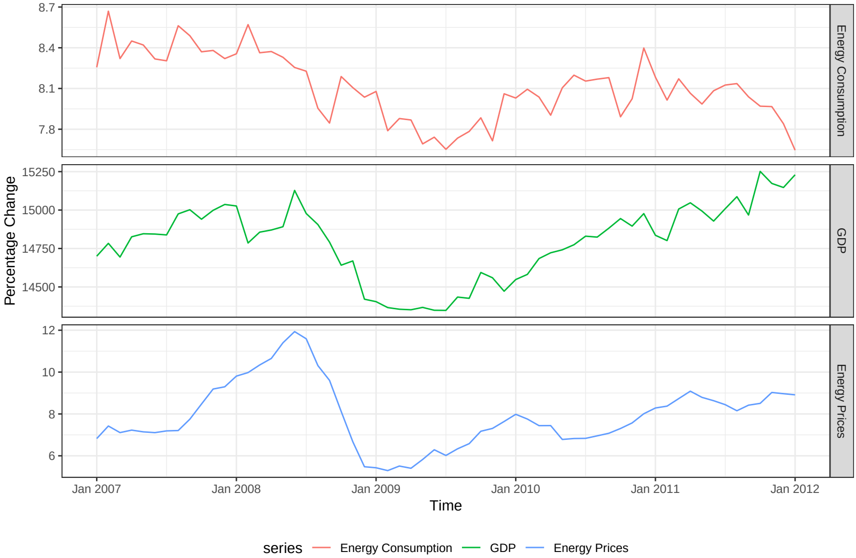

macroeconomic level
mesoeconomic level
microeconomic level

Outline

1. Economy-wide Rebounds using FAVAR Models

2. Rebound Effects at the Sector Level

Macroeconomic Time Series (USA)



General Idea

- Simultaneity-Challenge: Isolate energy efficiency impact on energy consumption from other factors
- Assumption: If E changes, with P and Y constant, then this must be due to a change in the technology A.

$$E = f\ (A, P, Y) \tag{1}$$

where E is the level of energy use, P energy prices and Y is output, A is the state of energy-specific technology

Methodology

SVAR Model

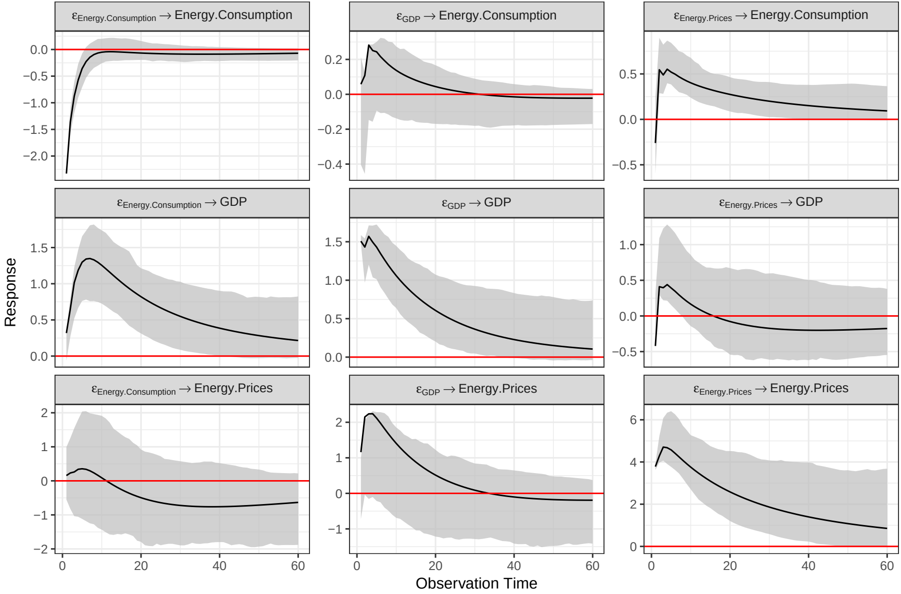
$$A_0 x_t = A_0 \xi_t + \sum_{i=1}^{p} A_0 \Pi_i x_{t-i} + \eta_t \tag{2}$$

- x_t is the vector of the three variables
- Π captures lag cross-correlations between energy use, GDP and the energy price, where u_t is a noise/shock process
- $\eta_t = A_0 u_t$ and $var(\eta_t) = 1$
- A_0 captures contemporaneous effects of the endogenous variables on each other $\rightarrow$ **Identification problem**
- Data-driven Independent Component Analysis (ICA) techniques to estimate A_0

Data for Europe

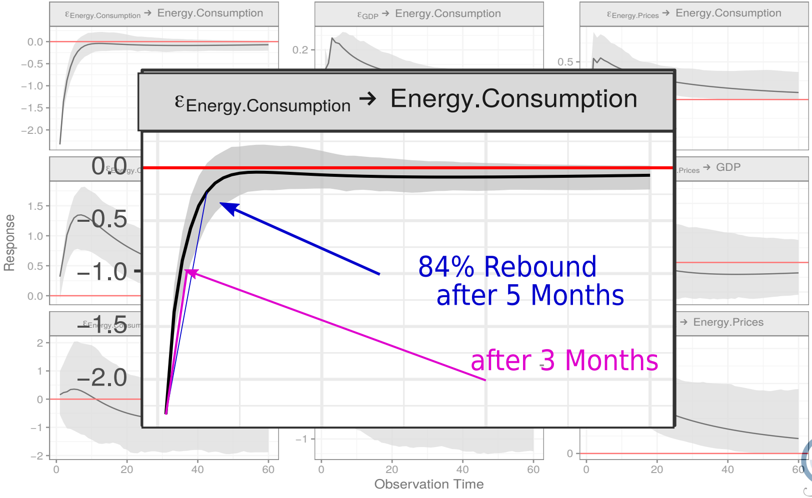
- Monthly data from January 2008 to December 2016
- Gross inland energy consumption: Quantity of energy necessary to satisfy inland consumption of the country
- Harmonized consumer price indices (Solid and liquid fuels, electricity and gas)
- GDP approximated via industrial production

Impulse Response Analysis - Germany



Rebound Effect

$$R = 1 - \frac{\Delta e_i}{\Delta \widehat{e}} = 1 - \frac{\text{actual change}}{\text{potential change}} \quad (3)$$



Rebound effect after 5 months

Country	Lower CI	**Estimate**	Upper CI
Austria	87.83	**89.57**	150.17
Belgium	65.31	**70.16**	79.91
Czechia	81.24	**85.47**	95.51
Germany	70.43	**84.62**	94.56
Denmark	83.79	**97.29**	107.40
Greece	55.31	**69.31**	70.84
France	60.38	**67.98**	75.34
Italy	65.54	**70.11**	78.07
Poland	81.04	**97.15**	105.47
Portugal	99.98	**113.87**	127.20
Sweden	49.14	**85.13**	100.07
UK	5.14	**19.16**	31.21

FAVAR - because three is not enough

- Extreme rebound effect - might have omitted variables
- Evidence that large data sets include relevant information (Stock & Watson, 2016, 2005; Bernanke, Boivin, & Eliasz, 2005)
- Idea: Use a small set of estimated factors to summarize large amount of information about the economy
  1. Core variables of interest Y_t and latent Factors F_t drive the common dynamics of the large informational dataset:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t$$

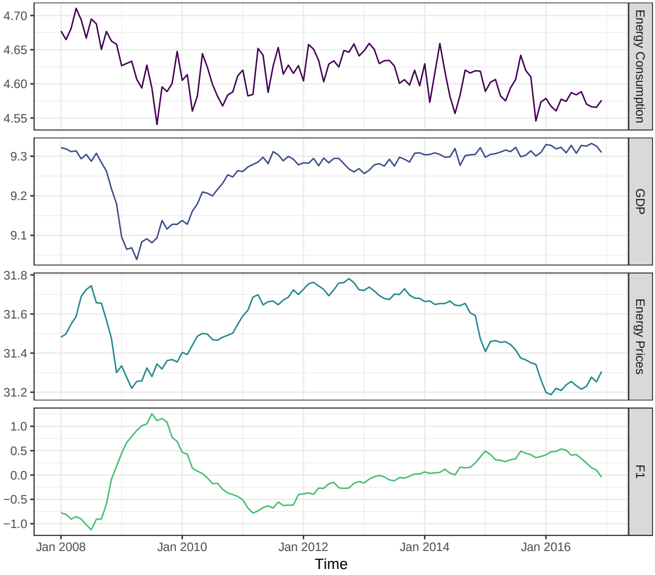
  2. Augment system

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} \sim VAR(d) \tag{4}$$

Factor Estimation

- Approach: Two-step procedure (Stock & Watson, 2005)
  1. Common components, C_t, are estimated using the first principal components of X_t
     $\rightarrow \hat{F}_t$ is space covered by C_t that is not covered by Y_t
  2. FAVAR-equation is estimated by standard methods, with $\hat{F}_t$
- Data: Large monthly macroeconomic data set by OECD (MEI)
  - ⋆ Money and Credit
  - ⋆ Consumption, orders, and inventories
  - ⋆ Import/Export
  - ⋆ Labour Market
  - ⋆ Output and Income
  - ⋆ Prices
  - ⋆ Stock Market

Factor Analysis - Preliminary Results



Conclusions

- Rebound effect in all analyzed countries pretty high
- Bottom-up approach to understand differences between countries

The Status Quo regarding Rebound Data Sources

- German data regarding energy consumption quite scare
  - Short-time spans
  - Mostly restricted to single sectors or just case studies
  - Few datapoints

A New Data Source for Analysing Rebound Effects

Panel der Kostenstrukturerhebung im Verarbeitenden Gewerbe des Stat. Bundesamtes

- Number of firms: ∼16.000
- Timespan: 11 years
- Breadth of firm-specific variables
  - Revenue data
  - Energy consumption data
  - Detailed sector association
  - ...

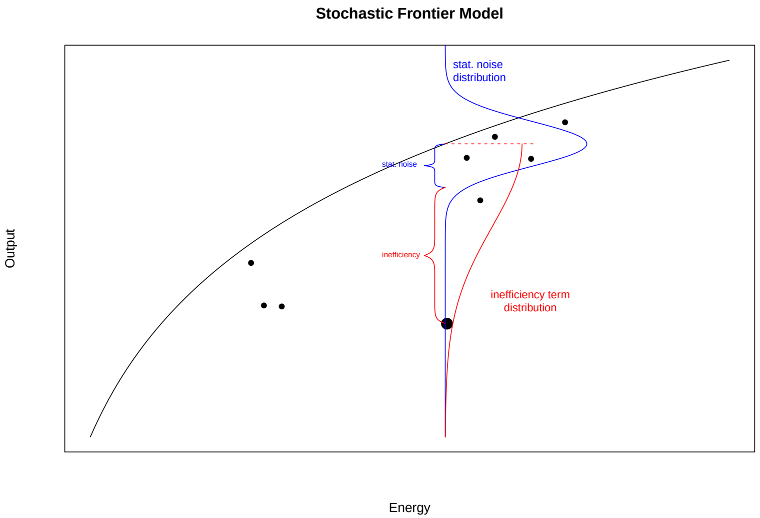
Aim: Use this detailed data source for empirically analysing rebound effects in Germany

A New Data Source for Analysing Rebound Effects

Panel der Kostenstrukturerhebung im Verarbeitenden Gewerbe des Stat. Bundesamtes

- Problem I: Lack of reliable physical output data
  - Merging data with AFID panel
- Problem II: Lack of technical energy efficiency data
  - Augment technical efficiency data by SFA
  - Augment technical efficiency data by SADR

Using SFA to obtain Technical Efficiencies



Using SADR to obtain Technical Efficiencies

- Estimate the whole conditional distribution not just its expectation

▷ $Y_i = \mathbb{E}(Y_i) + \varepsilon_i$

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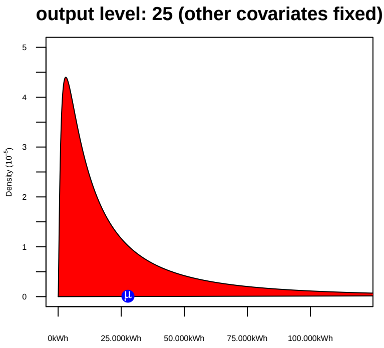


▷ Parametric distribution assumption

$\Rightarrow Y|X \sim \mathcal{D}(\boldsymbol{\theta}(X))$

▷ Additive predictors for each distribution parameter

$\Rightarrow \eta^{\theta_k} = \sum_{l=1}^{L} f_l(x_l)$

Using SFA/SADR to obtain Technical Efficiencies

- Estimate stochastic frontier / conditional distributions firms with given characteristics X:
- Assess energy efficiency of any given firm by distance to frontier / quantile-position in distribution

Our Modelling Approach to Assess Rebound Effects

- Use structured equation models to assess role of energy efficiency (or relative energy efficiency) on energy consumption:

$$\Delta \log(PO_{i,t}) = \gamma_0 + \beta_2 \log(\Delta \mathsf{EnEff}_{i,t}) + \epsilon_{SEM1,i,t}$$
$$\Delta \log(EV_{i,t}) = \tilde{\beta}_0 + \tilde{\beta}_1 \Delta \log(PO_{i,t}) + \tilde{\beta}_2 \Delta \log(\mathsf{EnEff}_{i,t}) + KV_{i,t} + \epsilon_{SEM2,i,t}.$$

Questions?

Literature I

Bernanke, B. S., Boivin, J., & Eliasz, P. (2005). Measuring the effects of monetary policy: A factor-augmented vector autoregressive (FAVAR) approach. *Quarterly Journal of Economics*, *120*(1), 387–422.

Lange, A., Dalheimer, B., Herwartz, H., & Maxand, S. (2018). svars: Data-driven identification of svar models [Computer software manual]. Retrieved from `https://CRAN.R-project.org/package=svars` (R package version 1.2.1)

Lanne, M., Meitz, M., & Saikkonen, P. (2017, feb). Identification and estimation of non-Gaussian structural vector autoregressions. *Journal of Econometrics*, *196*(2), 288–304.

Matteson, D. S., & Tsay, R. S. (2017). Independent Component Analysis via Distance Covariance. *Journal of the American Statistical Association*, *112*(518), 623–637.

Literature II

Stock, J. H., & Watson, M. W. (2005). An empirical comparison of methods for forecasting using many predictors. *Manuscript, Princeton University*.

Stock, J. H., & Watson, M. W. (2016). Dynamic factor models, factor-augmented vector autoregressions, and structural vector autoregressions in macroeconomics. In *Handbook of macroeconomics* (Vol. 2, pp. 415–525). Elsevier.

Identification

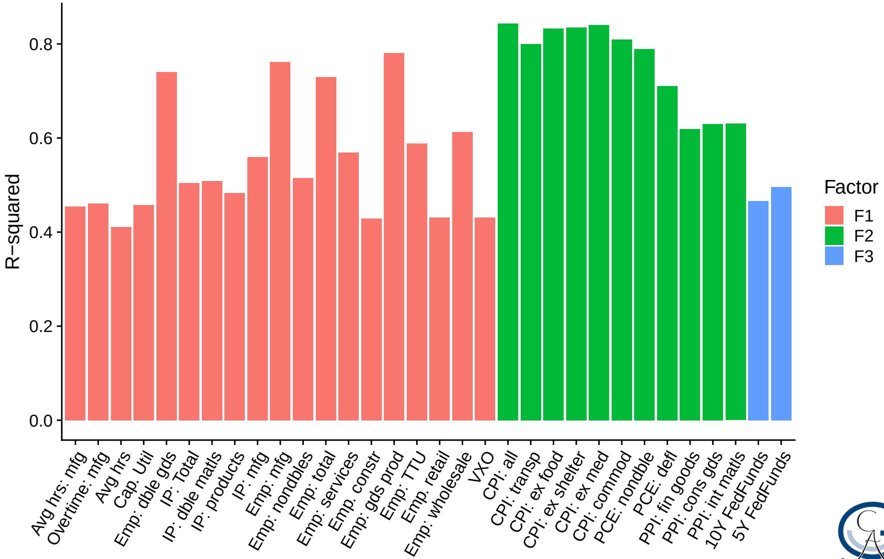
Independent component analysis (ICA) techniques to estimate A_0

- Idea: Searching for the linear combinations of the observed data (u_t) that are maximally independent
- Assumptions on elements of η_t:
  1. Independent - mutually and cross-sectionally
  2. Non-Gaussian - with at maximum one exception

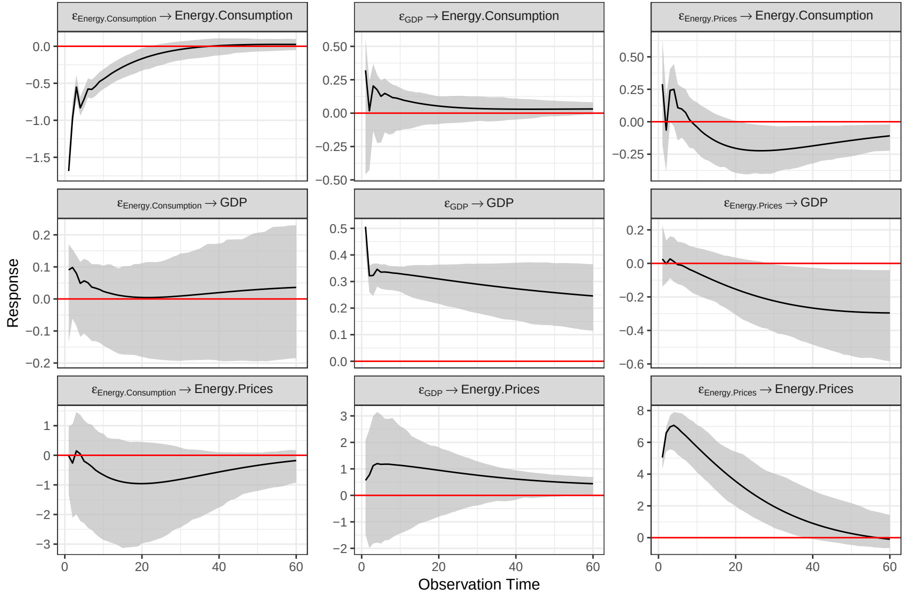
  $\rightarrow$ Invertible matrix A_0^{-1} is "almost identifiable"
- Two techniques applied by using svars-Package (Lange et al., 2018):
  1. Distance covariance approach (Matteson & Tsay, 2017)
  2. Non-Gaussian Maximum Likelihood Estimator (Lanne et al., 2017)

Factor Analysis

$R^2s > 0.4$ of regressing each variable in X_t on the three factors



Svar USA



εEnergy.Consumption → Energy.Consumption
εGDP → Energy.Consumption
εEnergy.Prices → Energy.Consumption
εEnergy.Consumption → GDP
εGDP → GDP
εEnergy.Prices → GDP
εEnergy.Consumption → Energy.Prices
εGDP → Energy.Prices
εEnergy.Prices → Energy.Prices
Response
Observation Time
0
20
40
60

Using SFA to obtain Technical Efficiencies

- Use the following production function to estimate SFA
  - $BPW_{i,t} = TFP * K_{i,t}^{\beta_K} * L_{i,t}^{\beta_L} * E_{i,t}^{\beta_E^\star} * \varepsilon_{i,t}$
  - $\beta_{E,i,t}^\star = \beta_E^{FE} - \beta_{E,i,t}^{ZE}$
  - $\mathsf{EnEff}_{i,t} = \mathsf{EnEff}_{s,t} = \exp(\beta_E^{FE} - \beta_E^{ZE}) / \exp(\beta_E^{FE})$