Quantification of Economy-wide Rebound Effects using FAVAR Models

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GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Project ReCap

www.macro-rebounds.org

ReCap
Makro-Rebounds
begrenzen

i|ö|w
INSTITUT FÜR ÖKOLOGISCHE WIRTSCHAFTSFORSCHUNG

GWS

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

FONA
Forschung für Nachhaltige Entwicklung
BMBF

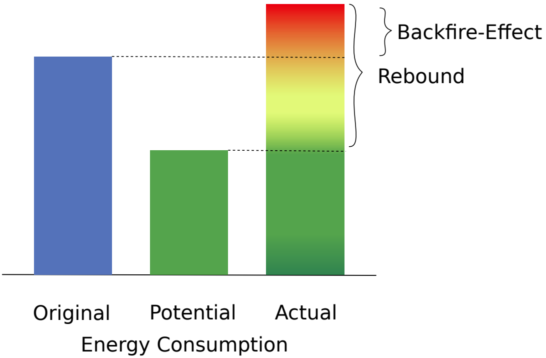
Energy Efficiency Policy

- Save energy and money

1

[1] Source: Synthesis report on the evaluation of national notifications related to Article 14 of the Energy Efficiency Directive

Rebound Effect

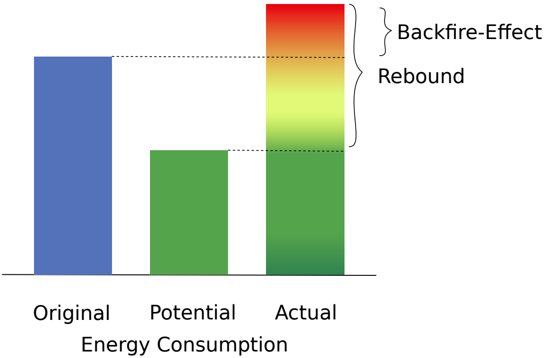


2

$$\text{Rebound Effect} = 1 - \frac{\text{Actual change in Energy Consumption}}{\text{Potential change}}$$

[2] Own representation based on Madlener & Alcott (2011)

Rebound Effect



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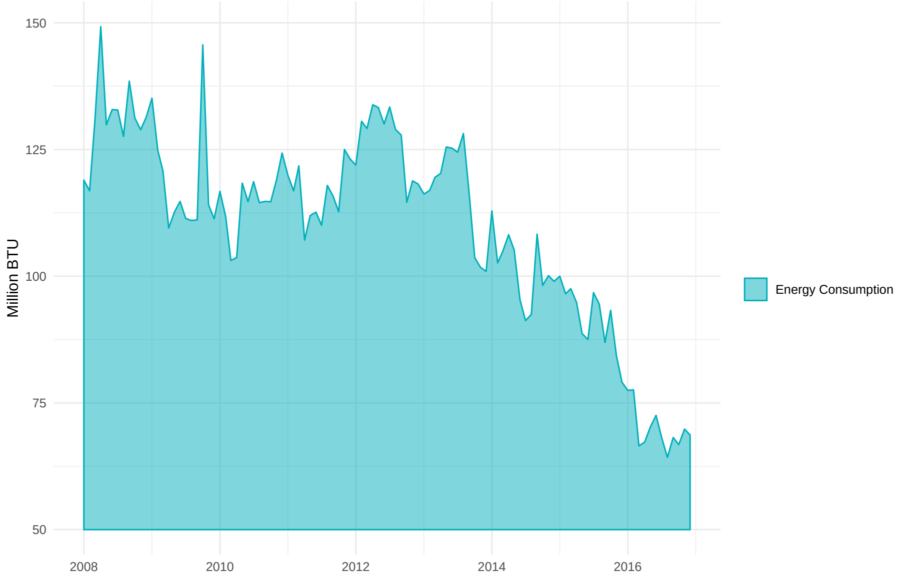
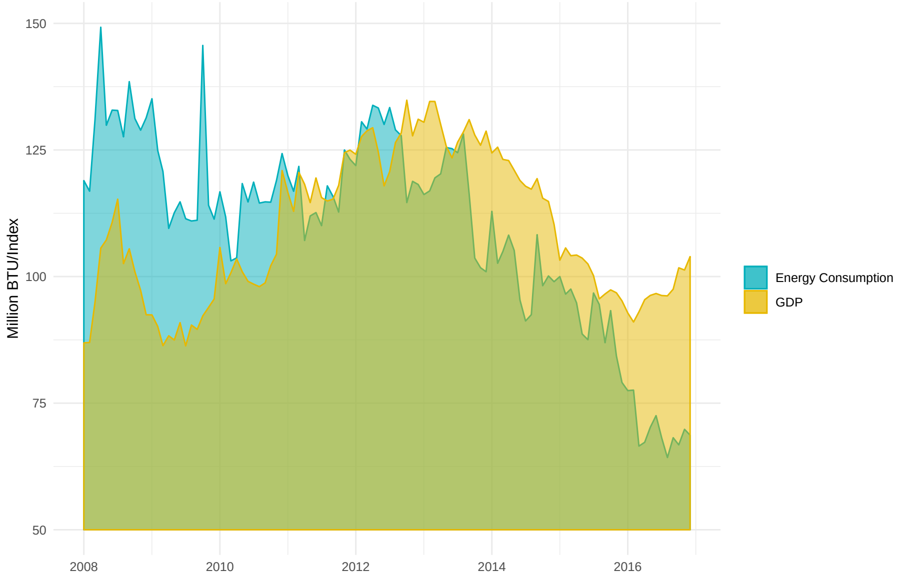
Simultaneity Challenge

Decrease in Energy Consumption in the UK



What about Causality?



Methodology

1. "Ex ante" via Partial/Computable General Equilibrium Models e.g. Turner (2013); Koesler (2013)

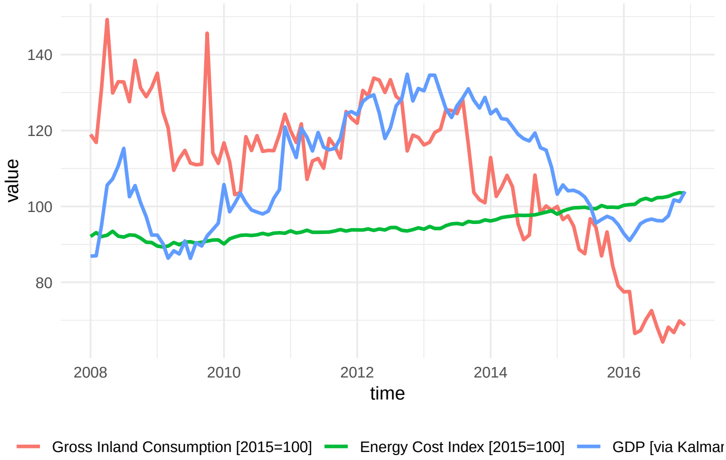
2. "Ex post" via econometric general equilibrium model
   - Partial equilibrium econometric estimates do not credibly identify causal effect, e.g. Saunders (2013); Orea, Llorca, and Filippini (2015)

   - **Our approach:** Structural Vector Autoregressive (SVAR) model
   - Empirical identification with minimum number of assumptions

Methodology

Idea: Isolate energy efficiency impact on energy consumption:

$$E = f\ (\text{Energy Efficiency, Price, GDP, X}) \tag{1}$$



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**

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Identification Problem

Data-driven Independent Component Analysis (ICA) techniques to estimate A_0

[3]

[3] Source: https://www.deichstube.de

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)
- Monthly GDP approximated via Kalman Filter (Uhlig (2005)

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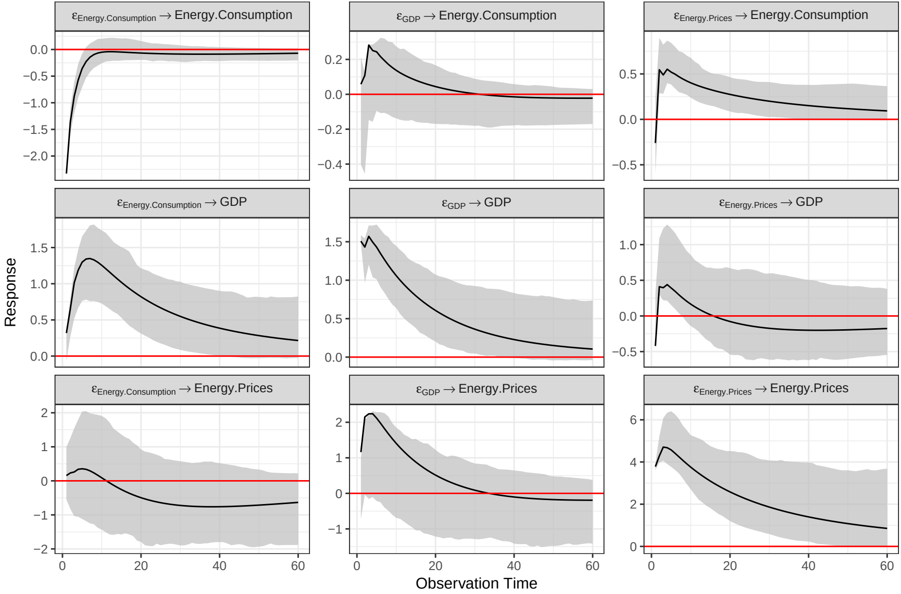
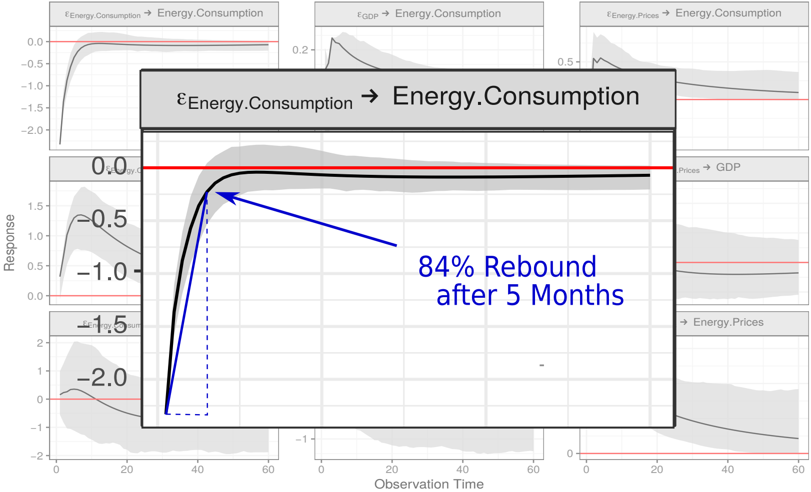
Impulse Response Analysis - Germany

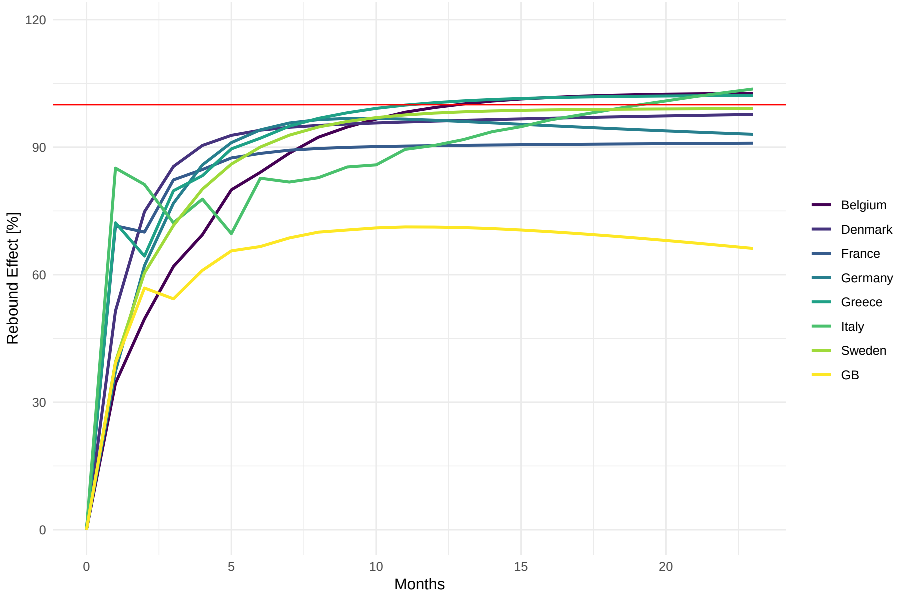


Rebound Effect

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



Rebound Effects in Europe



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
  $\rightarrow$ Large monthly macroeconomic data set by OECD (MEI)
  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

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

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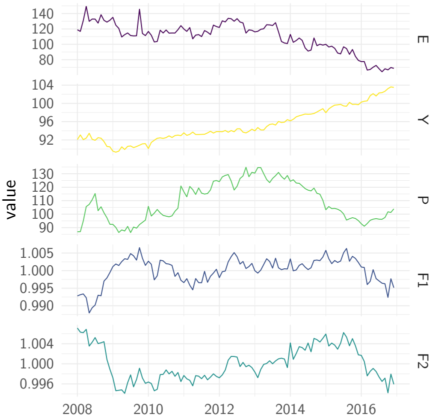
Factor Estimation for the UK



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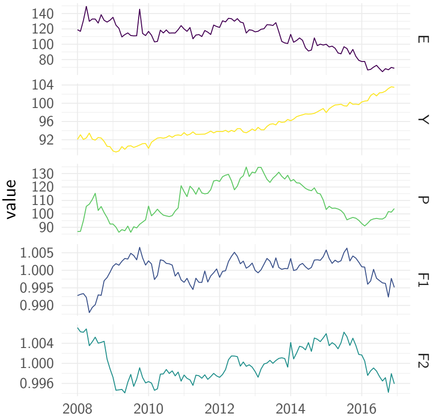

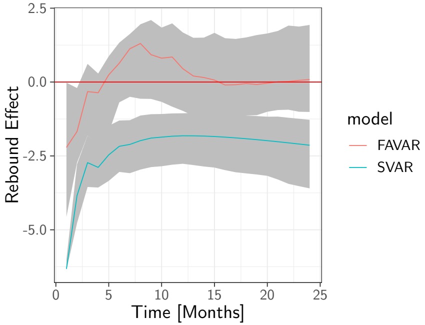

Conclusion

- Rebound effect shockingly consistent
- Approx. 100 % rebound effect in all analyzed countries after 1 year
- Future work:
  - Apply the FAVAR to all EU countries
  - Quality of Energy: Exergy/Divisia Index
  - Sectoral analysis in order to understand drivers of the rebound effect

Thank you for your attention!

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.

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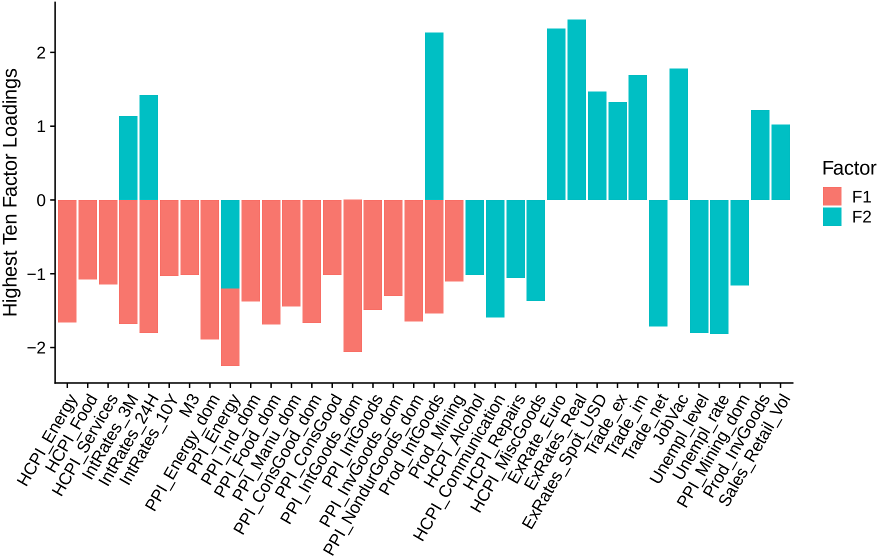
Turner, K. (2013). "Rebound" effects from increased energy efficiency: A time to pause and reflect. *Energy Journal*, *34*(4), 25–42. doi: 10.5547/01956574.34.4.2

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) comparable to McCracken and Ng (2016)
    - ⋆ Money and Credit
    - ⋆ Consumption, orders, and inventories
    - ⋆ Import/Export
    - ⋆ Labour Market
    - ⋆ Output and Income
    - ⋆ Prices
    - ⋆ Stock Market

Factor Loadings



Independent Component Analysis

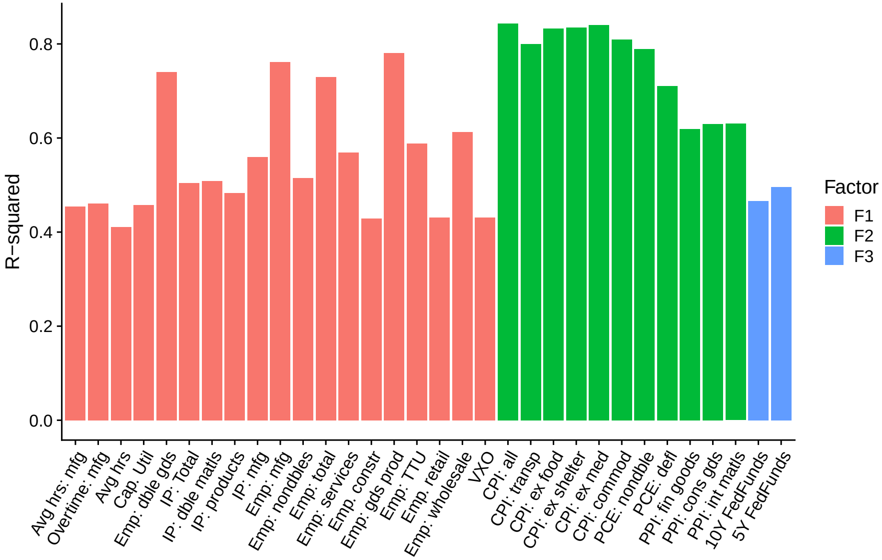
Data-driven Independent Component Analysis (ICA) techniques to estimate A_0

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

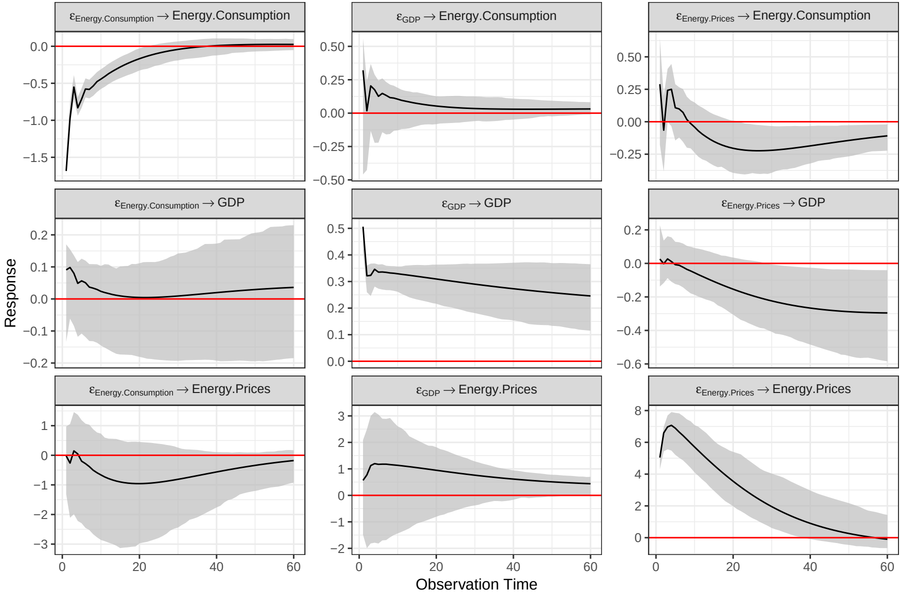
  $\rightarrow$ Invertible matrix A_0^{-1} is "almost identifiable"
- Two techniques applied by using svars-Package (Lange et al., 2018):
  1. Distance covariance approach (Matteson & Tsay, 2017)
  2. Non-Gaussian Maximum Likelihood Estimator (Lanne et al., 2017)

Factor Analysis

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



Svar USA



$\varepsilon_{Energy.Consumption} \rightarrow$ Energy.Consumption
$\varepsilon_{GDP} \rightarrow$ Energy.Consumption
$\varepsilon_{Energy.Prices} \rightarrow$ Energy.Consumption
$\varepsilon_{Energy.Consumption} \rightarrow$ GDP
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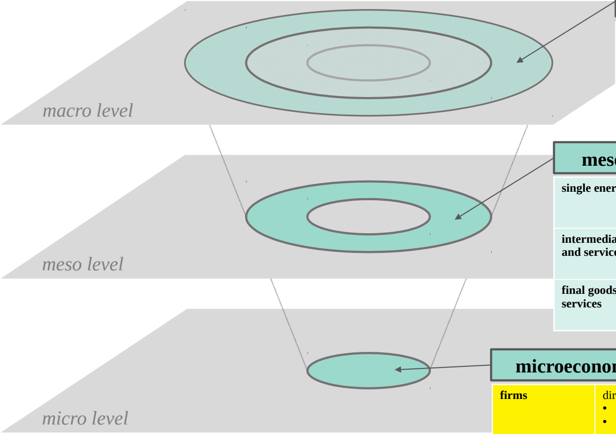
Response
Observation Time

Svar USA



macroeconomic rebound effec

international	international trade and relocation	internationa energy mar
national	general market price of energy	macroecon multiplier

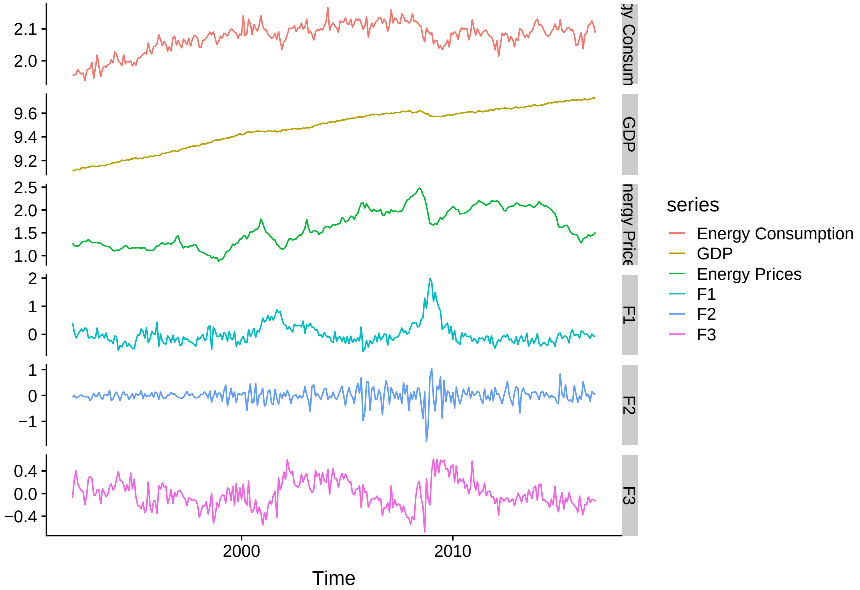
mesoeconomic rebound effects

single energy market	energy price in one energy market
intermediate goods and services	• output • lower prices and higher sales
final goods and services	lower prices and higher sales • income • substitution

microeconomic rebound effects

firms	direct • output • substitution	indirect
housholds	direct • output • substitution	indirect

Factor Analysis - Preliminary Results



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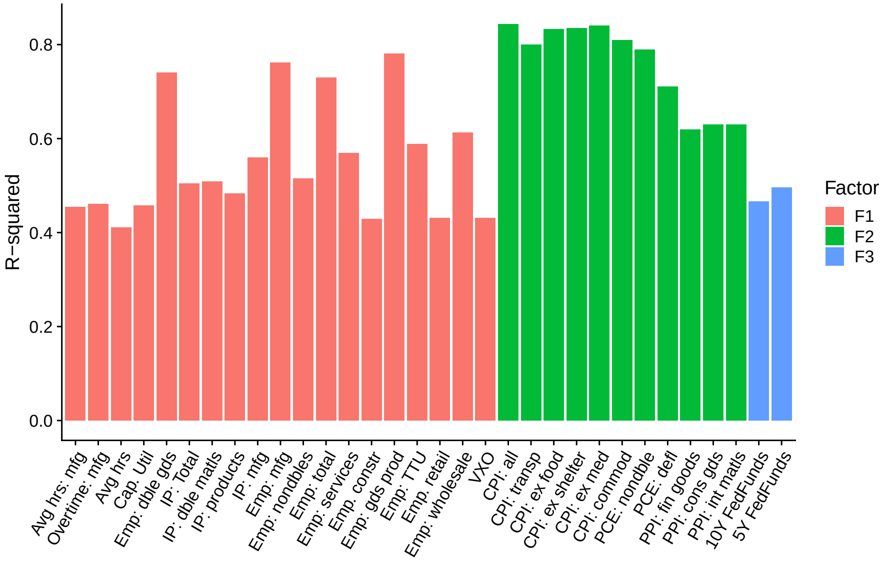

Rebound effect after 5 months

	Country	X1month	X3months	X6months	X12months	CI_90
1	Belgi	49.58	69.41	88.58	100.16	[89.05 11
2	Germa	62.12	85.83	95.68	96.04	[86.9 106
3	Denma	74.80	90.40	94.68	96.31	[95.08 10
4	Greec	64.37	83.30	94.93	100.89	[89.11 10
5	Franc	70.01	84.74	89.29	90.44	[86.75 97
6	Italy	81.22	77.78	81.80	91.76	[79.15 10
7	Swede	60.42	80.12	92.82	98.31	[78.16 10
8	Unite	56.86	61.01	68.65	71.08	[55.09 82