Lost in Aggregation: decomposing the Eurozone's business cycle fluctuations

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Motivation and background

- Business cycle synchronization (BCS) plays a central role in the monetary integration debates
- BCS research was heavily utilizing GDP growth/gaps/business cycle components correlations (Frankel & Rose 1998; Hou & Knaze 2022)
- Dynamic factor models became a popular alternative since seminal work of Kose *et al.* (2003)
- BCS research with factor models
  - mainly utilizes macroeconomic data
  - Models with one factor deliver relatively high BCS in Europe (de Lucas Santos & Delgado Rodriguez 2016)
  - Models with more factors examine different macroeconomic aggregates or/and introduce more supranational factors (Kose *et al.* 2012)
- "Granular" sources of business cycles at national (Acemoglu *et al.* 2012; Gabaix 2011) and international (Di Giovanni *et al.* 2018) level

Literature and novelty

Regional perspective

- BCS research with regional data is mainly based on correlations (Magrini *et al.* 2013) with few exceptions (Gadea *et al.* 2018)
- There are only 3 cases of application of DFMs:
  - for USA states (Owyang et al. 2009)
  - for Chinese provinces (Song & Xia 2018)
  - for the Eurozone (Beck & Okhrimenko 2023)

Sectoral perspective

- BCS research at international level is scarce (Rathke *et al.* 2022)
- There are only 3 cases of application of DFMs
  - for G7 countries (Karadimitropoulou & León-Ledesma 2013)
  - for emerging economies (Karadimitropoulou 2018)
  - for the European Union (Beck 2021)

Our approach: Regional and sectoral perspective

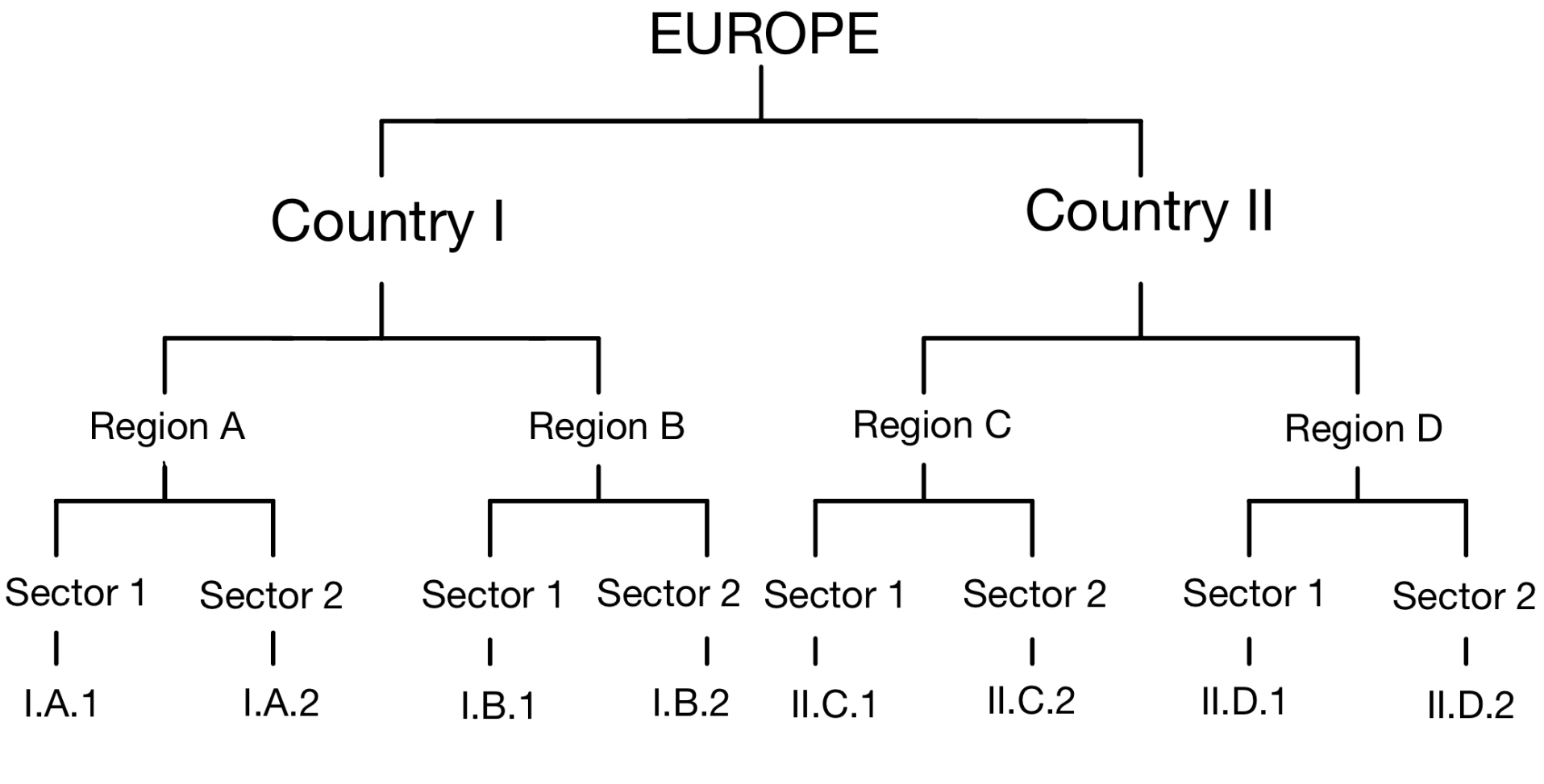
Data

- Time series of real GVA
  - Frequency: annual
  - Period: 1980-2019
  - Country coverage:
    - Austria (3REG), Belgium (3REG), Finland (2REG), France (14REG), Germany (10REG), Italy (5REG), the Netherlands (4REG), Portugal(3REG) , and Spain (7REG)
  - Regional coverage: 51 NUTS1 regions
  - Sector coverage:
    - Agriculture, Industry, Construction, Non-financial services, Financial services, Non-market services
  - Source: Eurostat
- Data was:
  - logarithmized
  - first differentiated
  - demeaned

Description of economic sectors according NACE

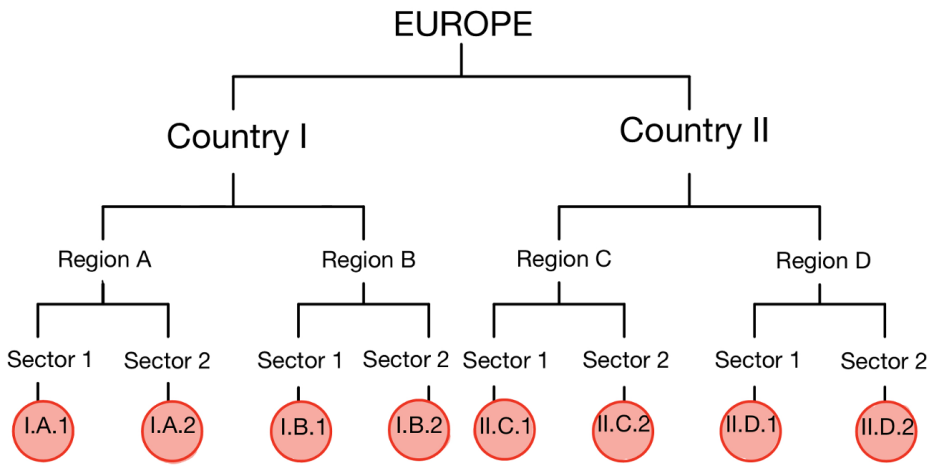
Abbreviation	General Category	Code	Detailed category
A	Agriculture	A	Agriculture
B-E	Industry	B	Mining
		C	Manufacturing
		D-E	Electricity and gas supply
F	Construction	F	Construction
G-J	Non-financial services	G	Wholesale and retail trade
		H	Transportation and storage
		I	Accommodation and food services
		J	Information and communication
K-N	Financial and business services	K	Finance and insurance
		L	Real estate
		M-N	Professional and support services
O-S	Non-market services	O	Public administration
		P	Education
		Q	Health
		R	Arts and recreation
		S	Other services

Data structure

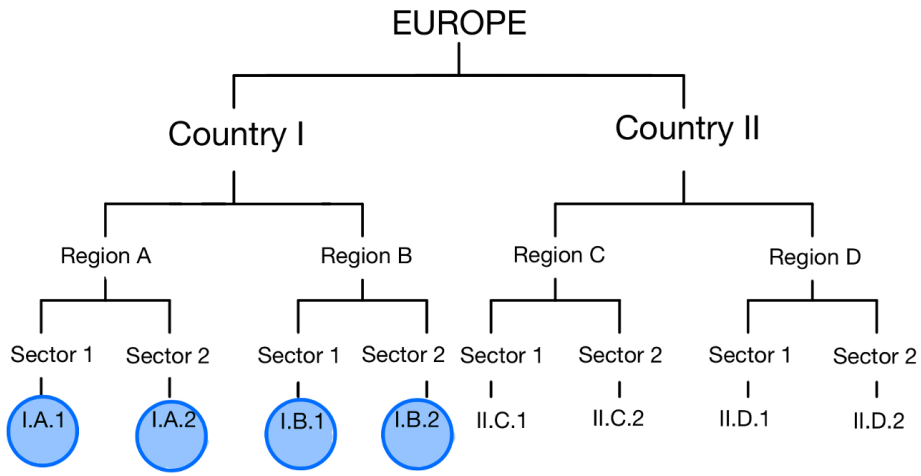


Factor definitions

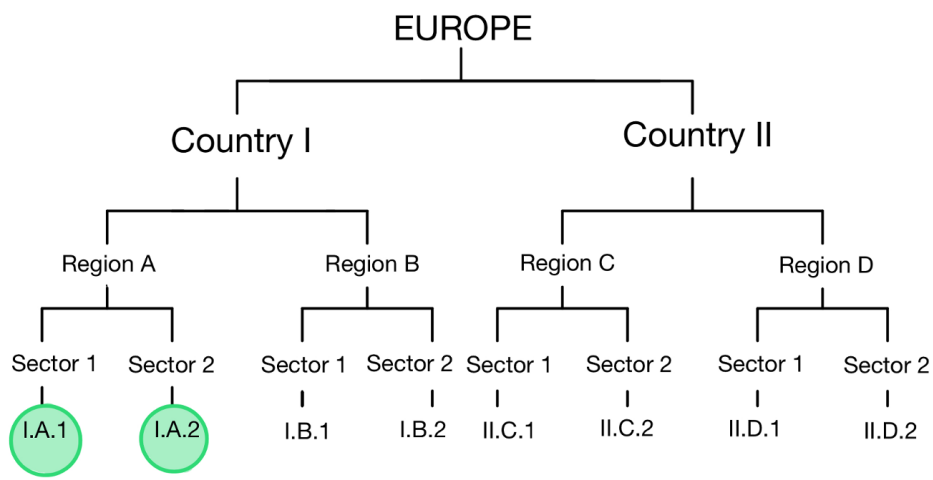
a) European factor



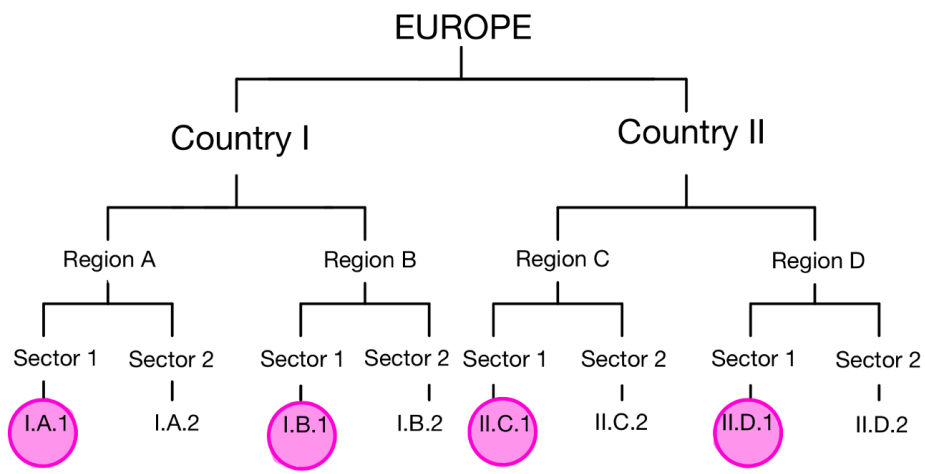
b) Country I factor



c) Region A factor



d) Sector 1 factor



Bayesian Dynamic Factor Model (Otrok & Whiteman 1998; Kose *et al.* 2003)

$$Y_t^{ijk} = \beta_E^{ijk} F_t^E + \beta_C^{ijk} F_{it}^C + \beta_S^{ijk} F_{jt}^S + \beta_R^{ijk} F_{kt}^R + \varepsilon_t^{ijk} \quad (1)$$

$$\varepsilon_t^{ijk} = \phi^{ijk}(L)\varepsilon_{t-1}^{ijk} + e_t^{ijk}, \qquad e_t^{ijk} \sim N(0, \sigma_{ijk}^2) \quad (2)$$

$$F_t^m = \phi^m(L)F_{t-1}^m + \upsilon_t^m, \qquad \upsilon_t^m \sim N(0, \sigma_m^2) \quad (3)$$

i-country; i=1,2,...,I; I=9;

j-sector; j=1,2,...,J; J=6;

k-region; k=1,2,...,K; K=51;

m=1,2,...,1+I+J+K; 1+I+J+K=67;

$E[\varepsilon_t^{jk}, \varepsilon_{t-s}^{j'k'}] = 0$ for $j \neq j' \wedge k \neq k'$.

BDFM: Identification and Priors (Kose *et al.* 2003)

- Rotational indeterminacy:
  - **sign identification:**
    1. European (positive for Industry in the biggest region - Hessen);
    2. Country (positive for Industry in the biggest region);
    3. Sectoral (positive for each sector in the biggest region);
    4. Regional (positive for Construction in a given region).
  - **scale identification:** σ_m^2 are assumed to be constant
- Priors
  1. on factor loadings: $N(0, 1)$
  2. on variance innovations in observable equation: $IG(6, 0.001)$
  3. on autoregressive polinomials: $N(0, \Sigma)$ with

$$\Sigma = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0.25 \end{bmatrix} \tag{4}$$

BDFM: Estimation (Otrok & Whiteman 1998)

- **Gibbs sampling** - MCMC method approximating joint and marginal distributions by sampling from conditional distributions:
  1. Conditional on a draw for F^E, F^C, F^S, and F^R simulate the AR coefficients and the variance of the innovations
  2. Conditional on a draw for F^E, F^C, F^S, and F^R draw the factor loadings $\beta^E, \beta^C\ \beta^S$, and β^R
  3. Simulate $F^E, F^C\ F^S$, and F^R conditional on all parameters above
- **Burn-ins:** 100000
- **Iterations:** 200000

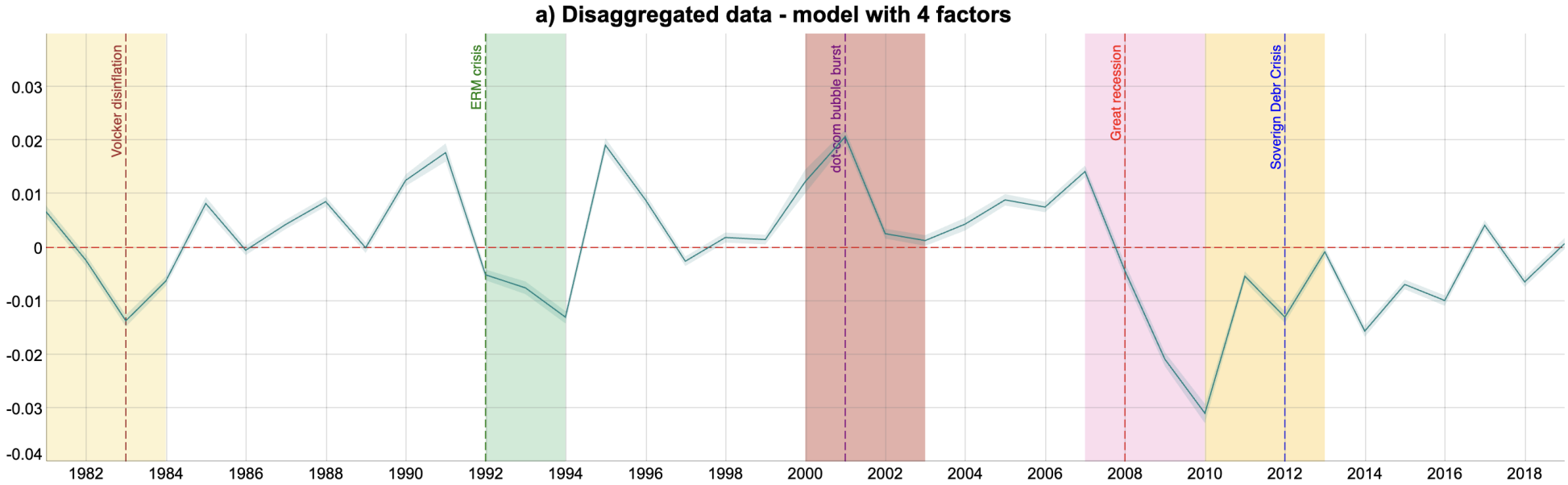
Variance decomposition

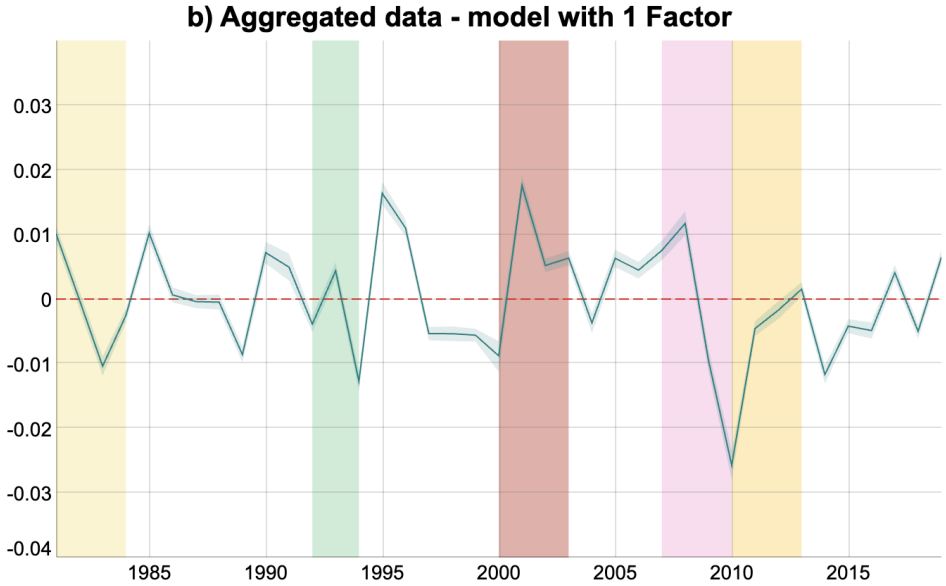
$$
\begin{aligned}
var(Y_t^{ijk}) = \\
&(\beta_E^{ijk})^2 var(F_t^E) + \\
&(\beta_C^{ijk})^2 var(F_{it}^C) + \\
&(\beta_S^{ijk})^2 var(F_{jt}^S) + \\
&(\beta_R^{ijk})^2 var(F_{kt}^R) + \\
&var(\varepsilon_t^{ijk})
\end{aligned}
\tag{5}
$$

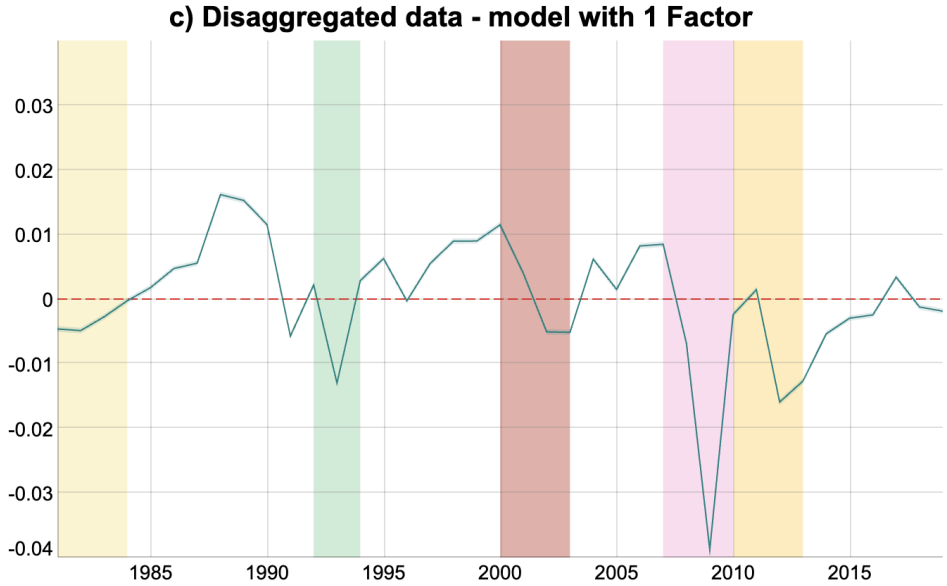
Share of variance attributable to factor **z** is calculated as:

$$
\frac{(\beta_z^{ijk})^2 var(F_{mt}^z)}{var(Y_t^{ijk})} \tag{6}
$$

The Eurozone factor







Variance decomposition - country perspective (1981-2019)

	Aggregated		**Disaggregated**		**4 Factor model**				
Factor	E	I	E	I	E	C	S	R	I
Austria	64.6%	35.4%	23.1%	76.9%	8.8%	62.2%	22.2%	7.6%	8.8%
Belgium	67.4%	32.6%	22.4%	77.6%	6.7%	76.2%	17.4%	0.1%	12.0%
Finland	68.0%	32.0%	33.3%	66.7%	7.4%	15.4%	18.6%	22.5%	31.9%
France	80.9%	19.1%	25.9%	74.1%	8.2%	3.6%	27.5%	33.6%	29.8%
Germany	45.4%	54.6%	29.9%	70.1%	9.5%	0.8%	28.4%	74.0%	8.1%
Italy	76.1%	23.9%	26.1%	73.9%	8.9%	4.0%	23.6%	44.1%	20.3%
Netherlands	72.1%	27.9%	22.6%	77.4%	8.8%	7.1%	13.9%	31.6%	38.8%
Portugal	52.9%	47.1%	31.9%	68.1%	17.3%	12.1%	18.6%	19.9%	30.4%
Spain	73.3%	26.6%	29.2%	70.8%	14.6%	5.8%	16.5%	27.7%	34.5%
Mean	66.7%	33.3%	27.1%	72.9%	10.0%	20.8%	20.7%	29.0%	23.8%

Notes:
E - Eurozone factor;
C - country factor;
S - sectoral factor;
R - regional factor;
I - idiosyncratic component.

Variance decomposition - sectoral perspective (1981-2019)

Factor	E	C	S	R	I
Agriculture	1.1%	3.7%	20.9%	9.1%	64.3%
Industry	6.1%	5.7%	50.9%	29.2%	18.3%
Construction	24%	8.3%	18%	43.9%	22.9%
Non-financial S.	8.8%	10.1%	15.5%	55.4%	16.8%
Financial S.	12.9%	8.9%	18.3%	39.1%	27.2%
Non-market S.	5.8%	11.2%	15.8%	50.4%	19.8%
Mean	9.8%	8%	23.2%	37.9%	28.2%

Notes:
E - Eurozone factor;
C - country factor;
S - sectoral factor;
R - regional factor;
I - idiosyncratic component.

Variance decomposition - country perspective (sub-periods)

Period	1981-1999 (in %)				2000-2019 (in %)				Change (in pp)			
Factor	E	C	S	R	E	C	S	R	E	C	S	R
Austria	4.9	76.5	6.3	12.3	18.9	3.1	51.9	26.1	14	-73.4	45.6	13.8
Belgium	22.8	49.8	23.3	4.0	22.5	29.8	43.4	4.3	-0.3	-20.0	20.1	0.3
Finland	18.4	24.9	7.3	49.3	19.5	10.6	57.1	12.8	1.1	-14.3	49.8	-36.5
France	20.4	10.4	27.3	41.8	24.9	1.4	32.9	40.8	4.5	-9.0	5.6	-1.0
Germany	12.4	5.1	11.9	70.7	11.1	6.4	41.3	41.1	-1.3	1.3	29.4	-29.6
Italy	13.9	11.0	9.2	65.8	18.4	1.4	40.6	39.6	4.5	-9.6	31.4	-26.2
Netherlands	7.9	30.5	15.7	46	25.9	2.6	50.6	21.0	18.0	-27.9	34.9	-25.0
Portugal	20.8	69.5	4.6	5.0	14.3	6.8	40.4	38.5	-6.5	-62.7	35.8	33.5
Spain	24.3	31.2	16.4	28.2	16.2	12.7	49.4	21.7	-8.1	-18.5	33.0	-6.5
Mean	16.2	34.3	13.6	35.9	19.1	8.3	45.3	27.3	2.9	-26.0	31.7	-8.6

Notes:
E - Eurozone factor;
C - country factor;
S - sectoral factor;
R - regional factor.

Variance decomposition - sectoral perspective (sub-periods)

Period	1981-1999 (in %)				2000-2019 (in %)				Change (in pp)			
Factor	E	C	S	R	E	C	S	R	E	C	S	R
Agriculture	8.7	21.2	48.2	21.8	10.2	9.9	41.7	38.2	1.5	-11.3	-6.5	16.4
Industry	16.3	11.8	25.8	46.0	12.5	3.9	52.2	31.4	-3.8	-7.9	26.4	-14.6
Construction	25.5	17.4	19.9	37.2	10.9	2.1	31.9	55.1	-14.6	-15.3	12.0	17.9
Non-financial Services	11.2	21.4	5.5	61.9	22.8	6.8	41.4	29.0	11.6	-14.6	35.9	-32.9
Financial Services	20.6	18.4	19.1	42.0	16.8	5.1	47.6	30.6	-3.8	-13.3	28.5	-11.4
Non-market Services	12.4	18.0	9.8	59.8	27.1	5.2	22.7	44.9	14.7	-12.8	12.9	-14.9
Mean	15.8	18.0	21.4	44.8	16.7	5.5	39.6	38.2	0.9	-12.5	18.2	-6.6

Notes:
E - Eurozone factor;
C - country factor;
S - sectoral factor;
R - regional factor.

Shift share analysis

$$\Delta VD_i^z = \sum_{b=1}^{B_i} (SS_{1981-1999}^{ib} * \Delta VD_{ib}^z + \Delta SS^{ib} * VD_{ib,1981-1999}^z + \Delta VD_{ib}^z * \Delta SS^{ib}) \quad (7)$$

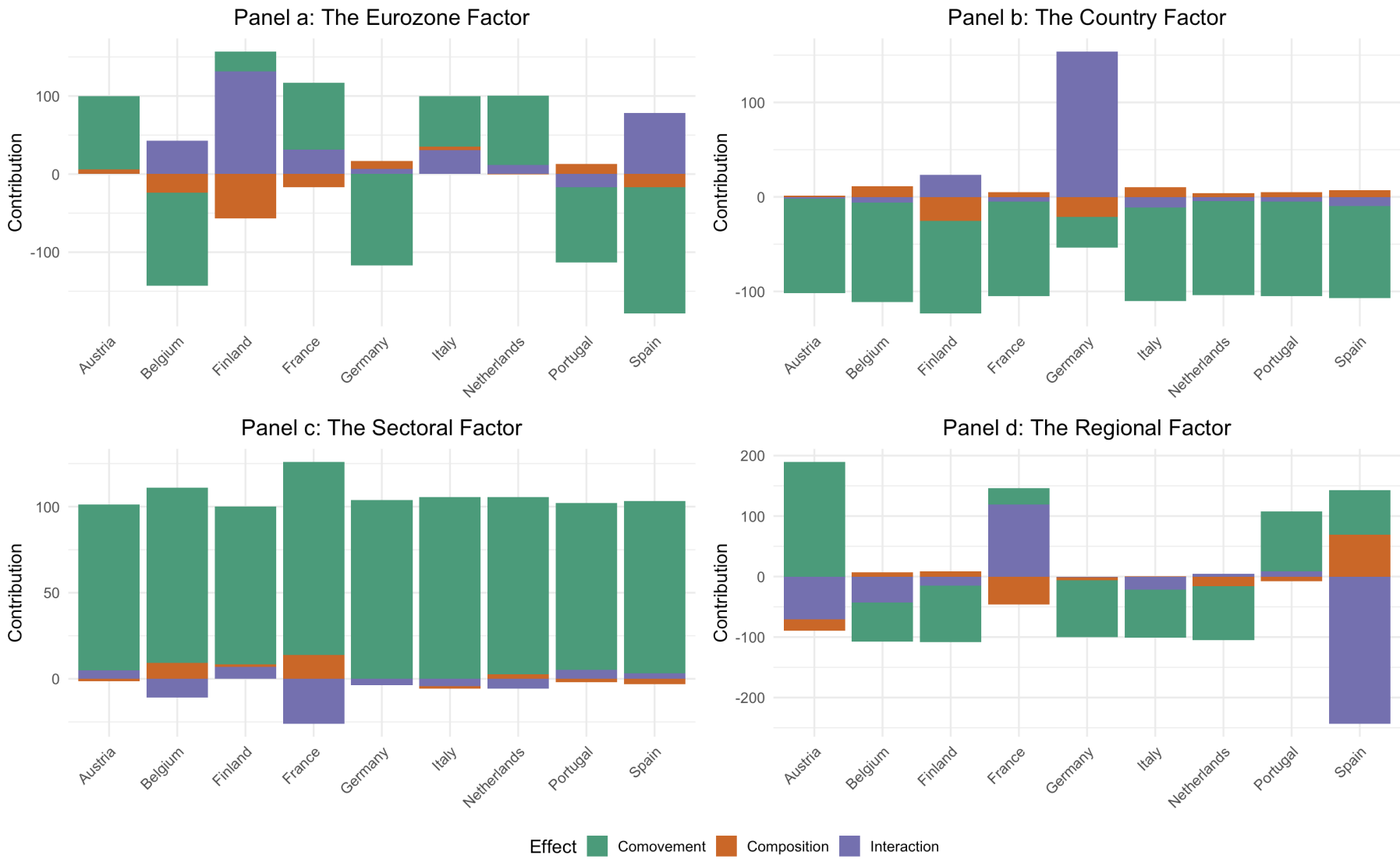
Comovement Effect (CE): $\sum_{b=1}^{B_i} (SS_{1981-1999}^{ib} * \Delta VD_{ib}^z)$

Structural Composition Effect (SCE): $\sum_{b=1}^{B_i} (\Delta SS^{ib} * VD_{ib,1981-1999}^z)$

Interaction Effect (IE): $\sum_{b=1}^{B_i} (\Delta VD_{ib}^z * \Delta SS^{ib})$

Notes:
SS - structural share;
Bi - number of sectors times number of regions in country *i*

Shift share results (in %)



FEVD

The extracted factors are used to estimate a VAR, following Baumeister & Hamilton (2018). The structural form of the model is given by:

$$AF_t = BF_{t-1} + u_t \tag{8}$$

where
F_t is an $(n \times 1)$ vector of observed factors at time t,
A is an $(n \times n)$ matrix of contemporaneous structural relations,
F_{t-1} is an $(np + 1 \times 1)$ vector of lagged factors with a constant,
and u_t is a vector of noise innovations.

FEVD

The reduced form of this model is given by:

$$F_t = \Phi F_{t-1} + \varepsilon_t \tag{9}$$

$$\Phi = A^{-1}B \tag{10}$$

$$\varepsilon_t = A^{-1}u_t \tag{11}$$

Φ and the variance-covariance matrix $E[\varepsilon_t \varepsilon_t']$ are estimated with OLS.

FEVD

To identify the structural shocks u_t, we impose a recursive identification scheme by restricting the matrix A to be lower triangular:

$$A = \begin{bmatrix} a_{11} & 0 & \cdots & 0 \\ a_{21} & a_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{12}$$

F_t **includes**:

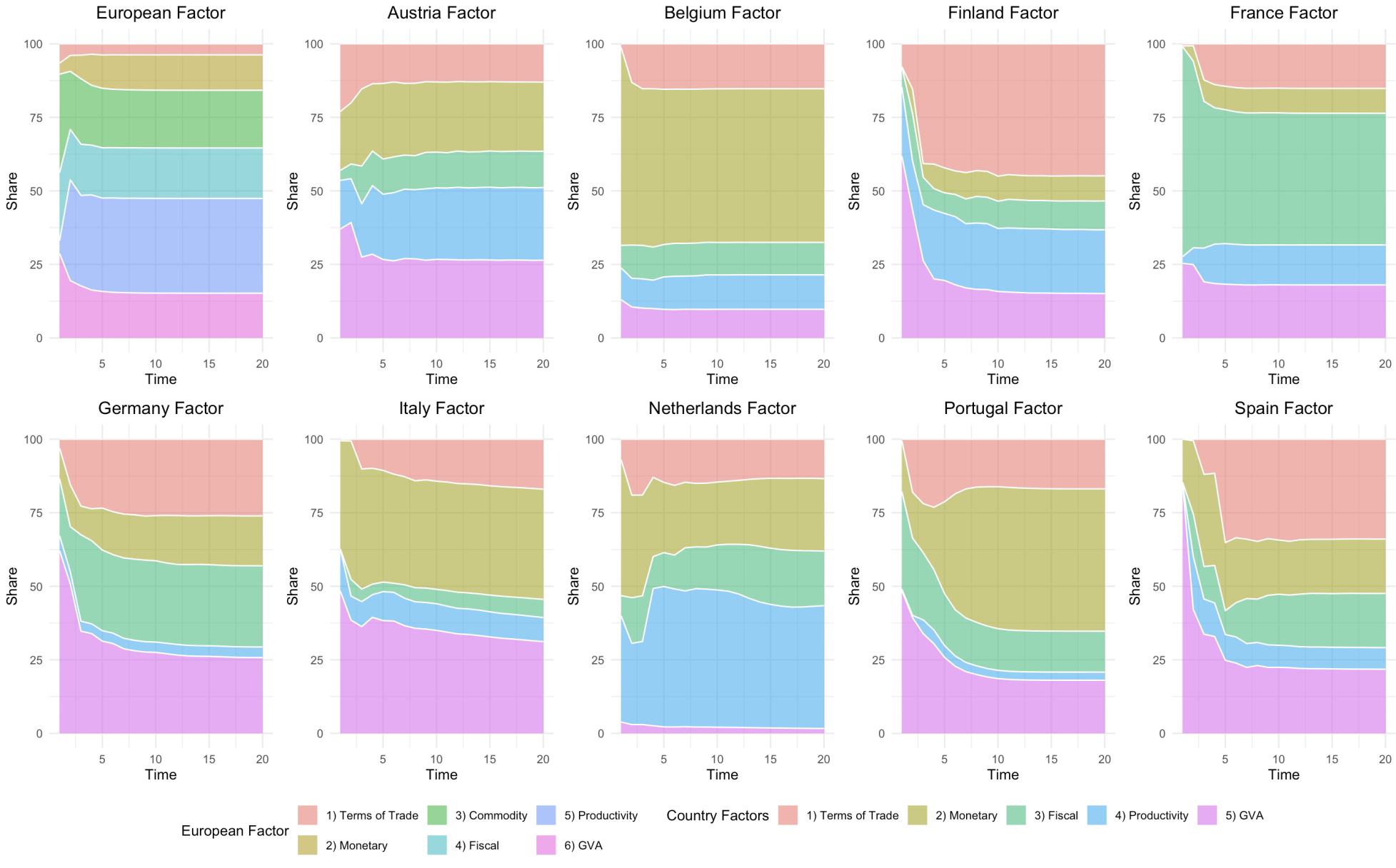
a) for the Eurozone factor:

- terms of trade
- monetary policy
- commodity prices
- fiscal policy
- productivity
- gross VA

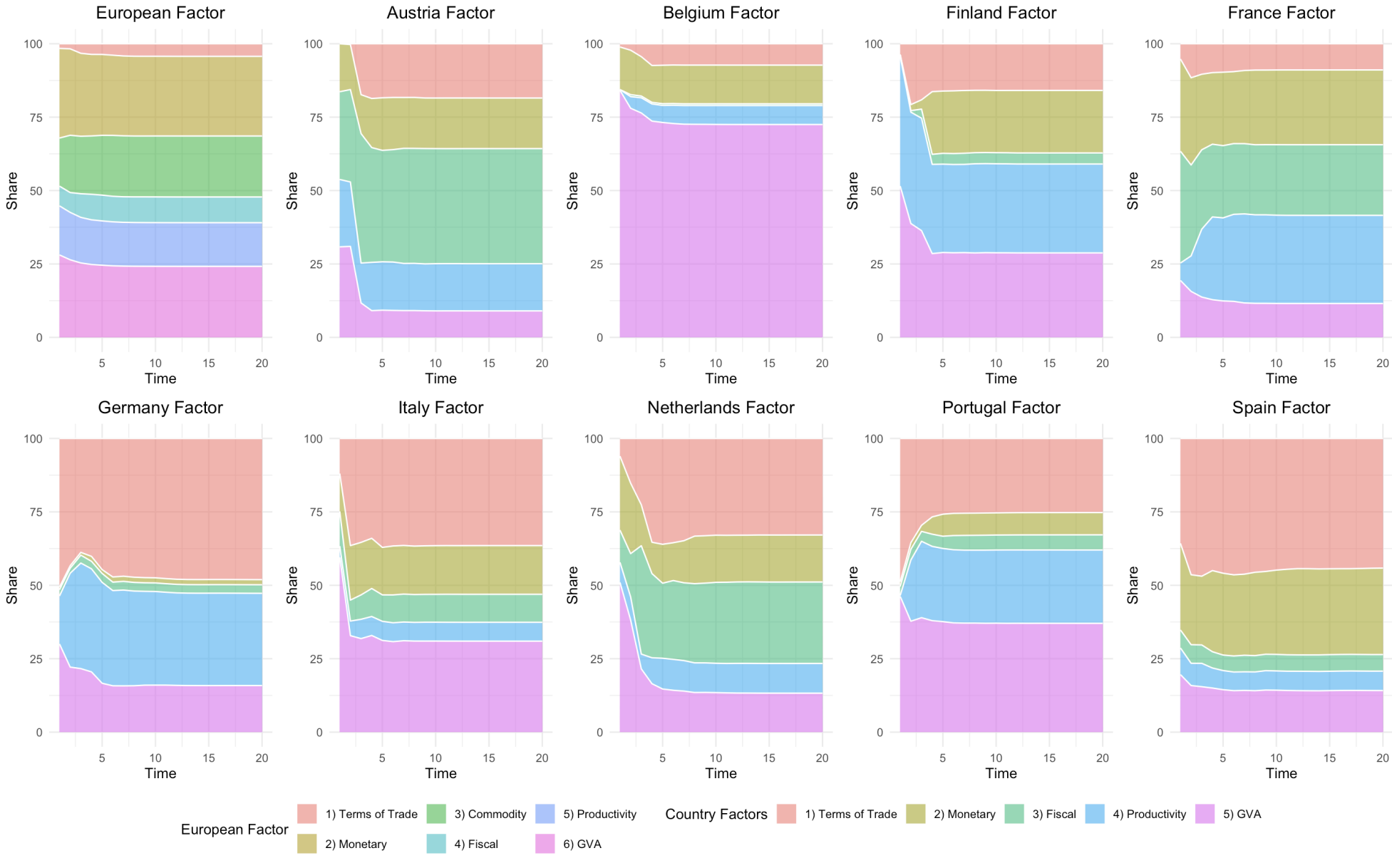
b) for the country factors:

- terms of trade
- monetary policy
- fiscal policy
- productivity
- gross VA

FEVD for the 1981-1999 period



FEVD for the 2000-2019 period



Conclusions

- Aggregation and usage of the models with just one factor lead to overestimation of the common factor
- European factor accounts for a small portion of the comovement in Europe
- Sectoral factor explains over 30% of the business cycle comovement in the Eurozone
- Industry and financial services is the main carriers of the international business cycles
- Business cycles of the European countries converged mostly due to increase in the role of sectoral factors and fall in the role of country factors
- The results provide strong support for "European Comission view"
- WHAT ARE THE CONSEQUENCES FOR THE EURO AREA?

Consequences for the Euro Area

Factor group	International		National	Intranational	
Factor	E	S	C	R	I
Austria	11.7%	32.1%	1.9%	16.1%	36.2%
Belgium	11.9%	23.0%	15.8%	2.3%	35.1%
Finland	12.8%	37.6%	7.0%	8.4%	27.1%
France	22.1%	29.2%	1.2%	36.2%	19.3%
Germany	8.3%	30.8%	4.8%	30.6%	24.1%
Italy	17.3%	38.1%	1.3%	37.2%	11.0%
Netherlands	19.0%	37.2%	1.9%	15.4%	23.5%
Portugal	11.7%	33.1%	5.6%	31.5%	17.5%
Spain	12.0%	36.6%	9.4%	16.1%	20.8%
Mean	14.1%	33.1%	5.4%	21.5%	23.8%
Sums	**47.2%**		**5.4%**	**45.3%**	

Notes:
E - European factor;
C - country factor;
S - sectoral factor;
R - regional factor;
I - idiosyncratic component.

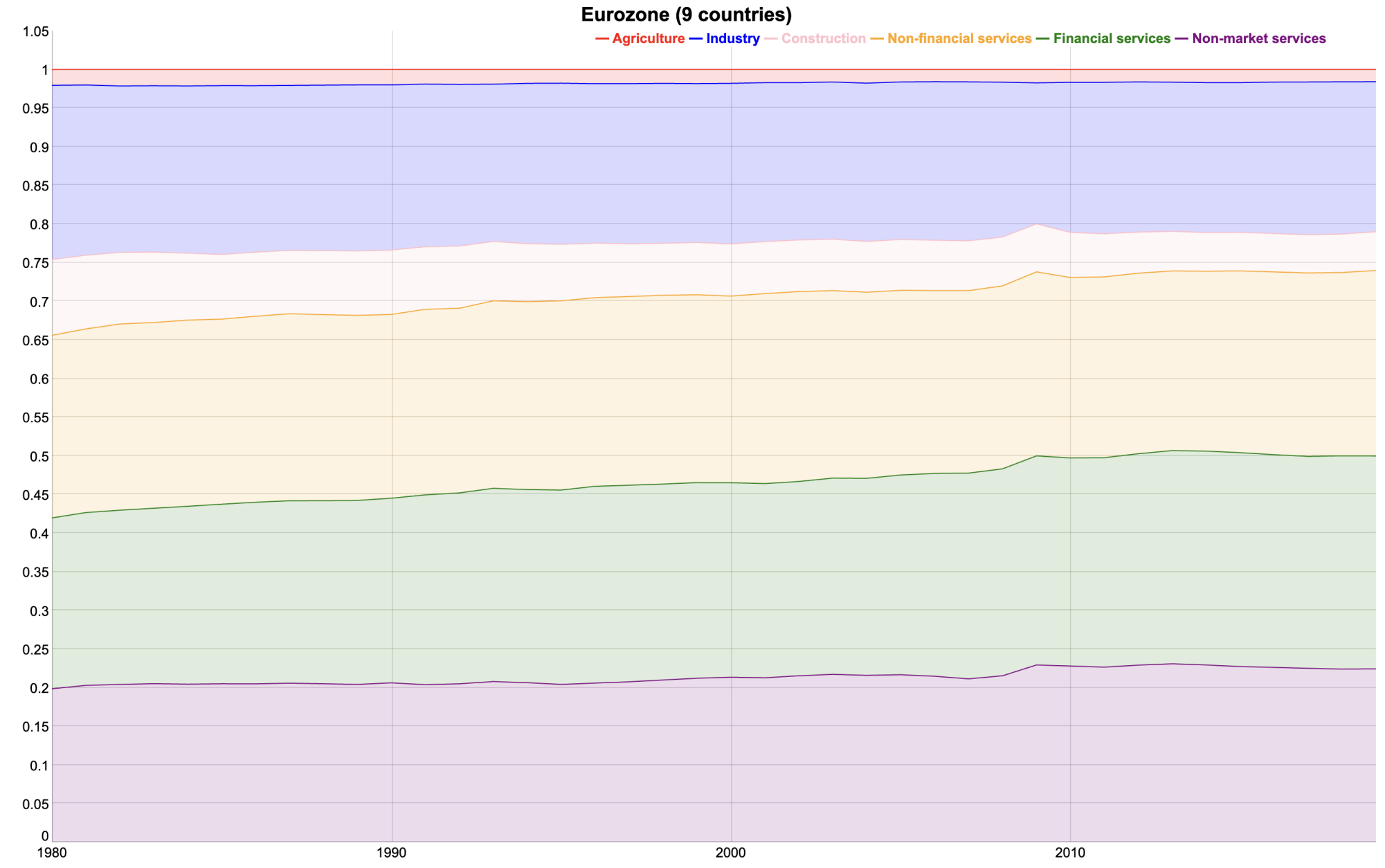
- Friedrich Nietsche:
  "He who fights with monsters might take care lest he thereby become a monster. And if you gaze for long into an abyss, the abyss gazes also into you."
- Paraphrazing the words of Great Nietsche:
  "If you gaze for long into macroeconomic data, the macroeconomic data gazes also into you."

Thank you for your attention

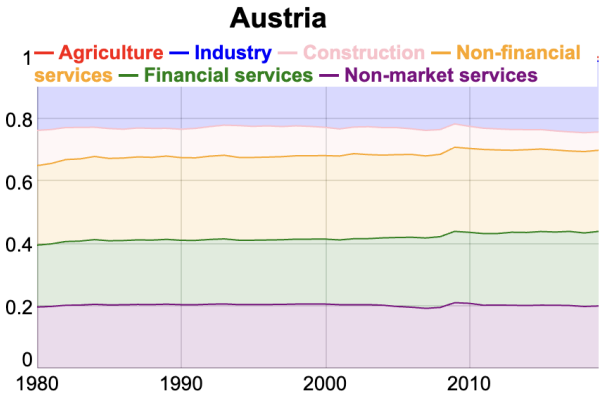
Tests for the number of factors

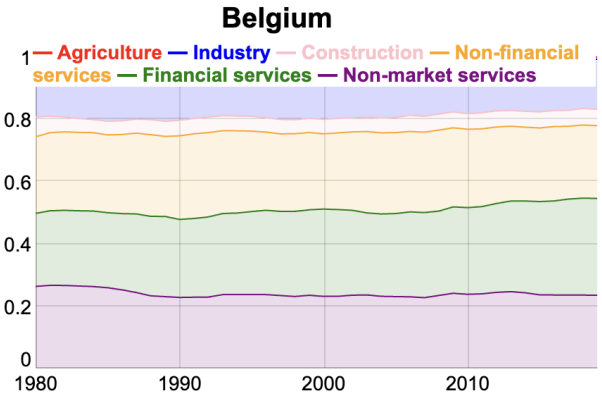
1. Bai and Ng (2002) test: 4 factors
2. Onatski (2010) test: 5 factors
3. Test for the number of global factors Choi *et al.* (2023)
    1. Canonical correlations difference test: 1 global factor
    2. Modified canonical correlations test: 2 global factors

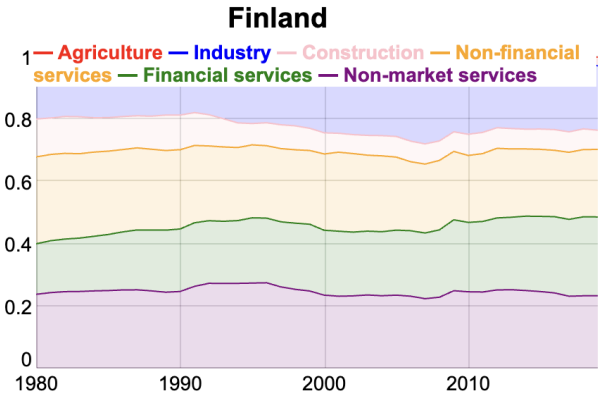
Sectoral composition 1980-2019

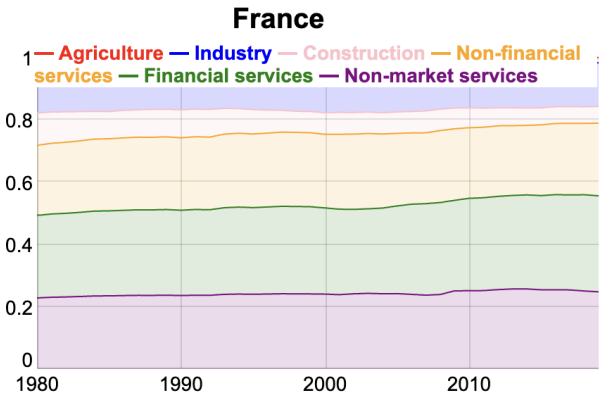


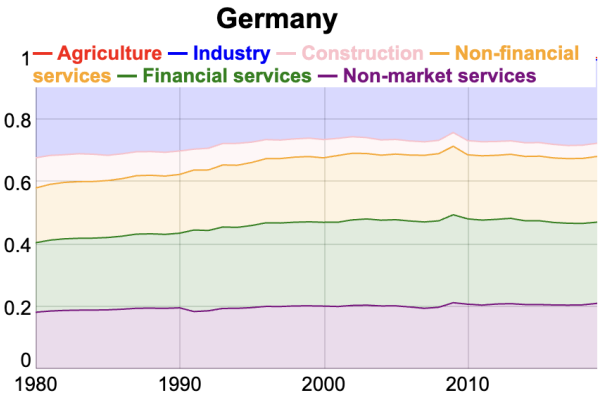
Sectoral composition 1980-2019

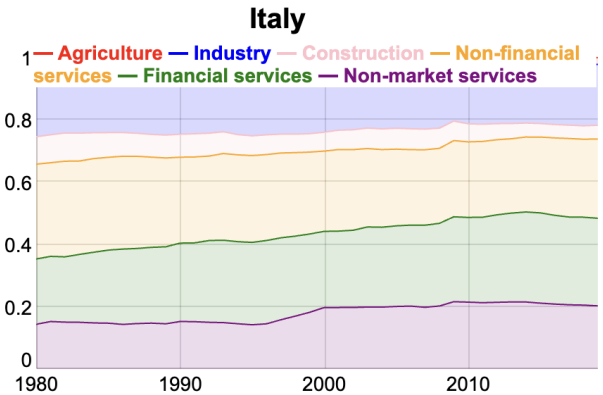


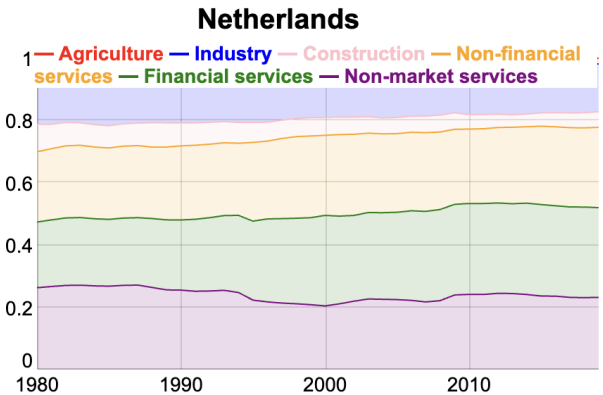


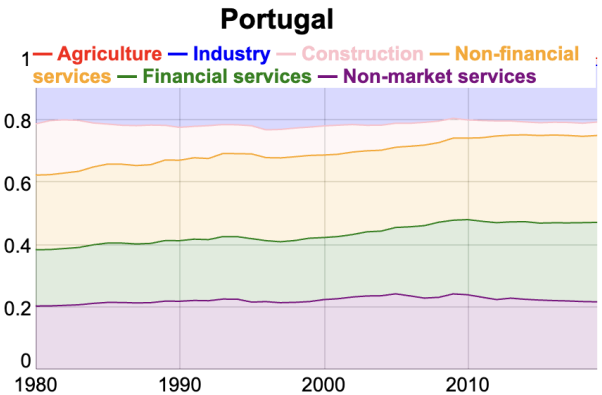


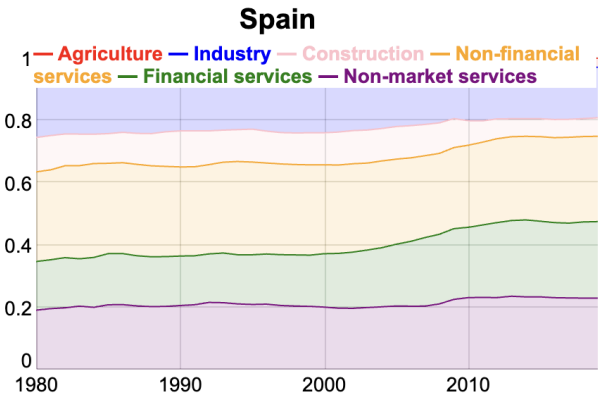












Commodity	Price of Crude oil, Brent	World Bank
	Price of Crude oil, Dubai	World Bank
	Price of Coal, Australian	World Bank
	Price of Natural gas, US	World Bank
	Price of Natural gas, Europe	World Bank
	Price of Liquefied natural gas, Japan	World Bank
	Price of Cocoa	World Bank
	Price of Coffee, Arabica	World Bank
	Price of Coffee, Robusta	World Bank
	Price of Tea, Colombo	World Bank
	Price of Tea, Kolkata	World Bank
	Price of Tea, Mombasa	World Bank
	Price of Coconut oil	World Bank
	Price of Groundnuts	World Bank
	Price of Fish meal	World Bank
	Price of Groundnut oil	World Bank
	Price of Palm oil	World Bank
	Price of Soybeans	World Bank
	Price of Soybean oil	World Bank
	Price of Soybean meal	World Bank
	Price of Barley	World Bank
	Price of Maize	World Bank
	Price of Sorghum	World Bank
	Price of Rice, Thai 5%	World Bank
	Price of Wheat, US SRW	World Bank
	Price of Wheat, US HRW	World Bank
	Price of Banana, US	World Bank
	Price of Orange	World Bank
	Price of Beef	World Bank
	Price of Chicken	World Bank
	Price of Lamb	World Bank
	Price of Shrimps, Mexican	World Bank
	Price of Sugar, EU	World Bank
	Price of Sugar, US	World Bank
	Price of Sugar, world	World Bank
	Price of Tobacco, US import u.v.	World Bank
	Price of Logs, Cameroon	World Bank
	Price of Logs, Malaysian	World Bank
	Price of Sawnwood, Malaysian	World Bank
	Price of Plywood	World Bank
	Price of Cotton, A Index	World Bank
	Price of Rubber, RSS3	World Bank
	Price of Phosphate rock	World Bank
	Price of DAP	World Bank
	Price of TSP	World Bank
	Price of Urea	World Bank
	Price of Potassium chloride	World Bank
	Price of Aluminum	World Bank
	Price of Iron ore, cfr spot	World Bank
	Price of Copper	World Bank
	Price of Lead	World Bank
	Price of Tin	World Bank
	Price of Nickel	World Bank
	Price of Zinc	World Bank
	Price of Gold	World Bank
	Price of Platinum	World Bank
	Price of Silver	World Bank

Fiscal	Public Debt	AMECO
	Budget Deficit	AMECO
	Goverment spending	PWT
Monetary	Effective exchange rate	AMECO
	Exchange rate against US dollar	AMECO
	Short run interest rate	AMECO
	Long run interest rate	AMECO
	Yield curve	AMECO
Productivity	Labor productivity	PWT
	Labor productivity in hours worked	PWT
	TFP at constant national prices	PWT
	Welfare-relevant TFP at constant national prices	PWT
	Real internal rate of return	PWT
Terms of Trade	Commodity Export Price Index, Individual Commodites Weighted by Ratio of Exports to GDP	IMF
	Commodity Export Price Index, Individual Commodites Weighted by Ratio of Exports to GDP	IMF
	Commodity Export Price Index, Individual Commodites Weighted by Ratio of Exports to Total Commodity Exports	IMF
	Commodity Export Price Index, Individual Commodites Weighted by Ratio of Exports to Total Commodity Exports	IMF
	Commodity Import Price Index, Individual Commodites Weighted by Ratio of Imports to GDP	IMF
	Commodity Import Price Index, Individual Commodites Weighted by Ratio of Imports to GDP	IMF
	Commodity Import Price Index, Individual Commodites Weighted by Ratio of Imports to Total Commodity Imports	IMF
	Commodity Import Price Index, Individual Commodites Weighted by Ratio of Imports to Total Commodity Imports	IMF
	Commodity Net Export Price Index, Individual Commodities Weighted by Ratio of Net Exports to GDP	IMF
	Commodity Net Export Price Index, Individual Commodities Weighted by Ratio of Net Exports to GDP	IMF
	Commodity Net Export Price Index, Individual Commodities Weighted by Ratio of Net Exports to Total Commodity Trade	IMF
	Commodity Net Export Price Index, Individual Commodities Weighted by Ratio of Net Exports to Total Commodity Trade	IMF