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## **D4.1(M18)–D4.2(M24) Report II: International trade and public debt from a network approach**

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## Executive summary

This document presents a description of the current situation of the sovereign public debt relationships among the EU members and its interaction with international trade focusing on the Italian economy. The report includes the up-to-date debt-to-GDP network, the one-step forecast of the countries' cluster membership in the multi-layer trade-debt network to contribute to the evaluation of fiscal stability from a composite risk framework by monitoring the dependence between external and internal deficit equilibria.



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# Report: International trade and public debt from a network approach\*

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## 1 Introduction

This document presents a description of the current situation of the sovereign public debt relationships among the EU members and its interaction with international trade focusing on the Italian economy. The report includes the up to date debt-to-GDP network, the one-step forecast of the countries' cluster membership in the multi-layer trade-debt network to contribute to the evaluation of fiscal stability from a composite risk framework by monitoring the dependence between external and internal deficit equilibria.

The results are based on a flexible Stochastic Block model for multi-layer networks (DSBMM) proposed in [Baltodano López and Casarin \(2023\)](#) and applied to trade flows and public debt in [Baltodano López et al. \(2024\)](#). The topological properties of the debt-to-GDP and trade flow networks are captured by the groups of countries sharing similar connectivity properties in the system. The composition of the clusters and their evolution are inferred using Bayesian methods and the forecast of the probability of belonging to each cluster is estimated as a tool for tracking composite risk. In other words, the DSBMM allows us to jointly consider risks across financial systems and/or between unbalances in the fiscal and external sectors due to a potential twin deficit phenomenon.

In order to extract the debt network and to construct the multilayer structure with trade flows, we use quarterly government debt in percentage of the GDP series and import values of Goods (CIF) in euros aggregated by quarter for all pair of countries in the EU countries during the period 2003–2024 from Eurostat (see [Table 1](#) for further details). The results show negative and positive correlations between countries' public debts, with a core-periphery network structure that emerges during crisis periods evidencing high

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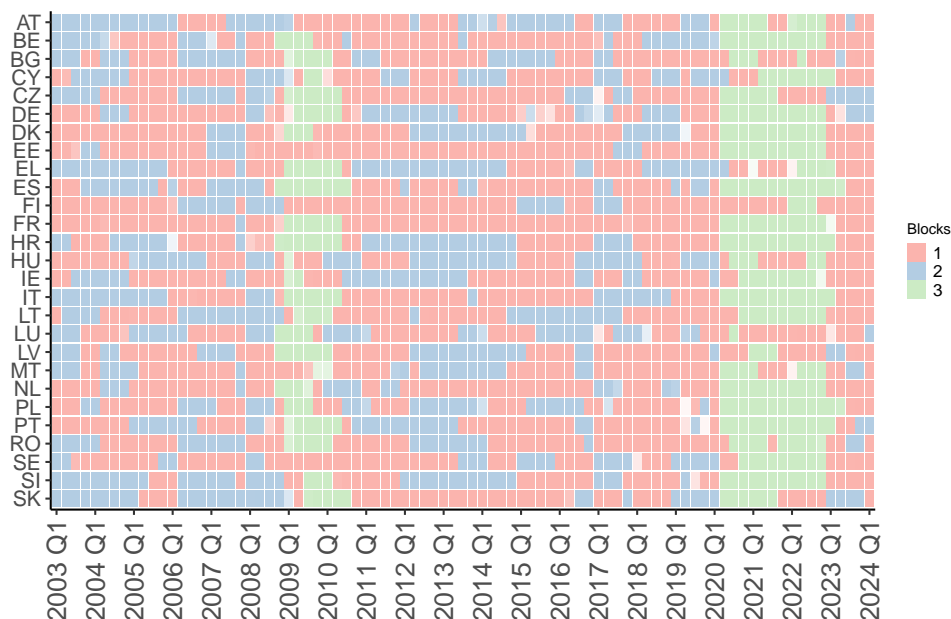
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systemic risks. Comparing 2023Q1 and 2024Q1 there has been an improvement in the network structure, departing from a core–periphery behavior and getting closer to an assortative topology, which is less prone to contagion and spill–over effects. In particular, after COVID–19 some countries experienced three years of high systemic risks, such as Portugal, Poland, and Italy, while the rest of the members such as Austria, Finland, and Germany changed cluster faster towards a less risky state. The new results show that Poland and Spain were the last countries to recover from a high systemic risk situation in 2023Q3, that is no high positive correlation between debt–to–GDP trends. Similarly, Italy recovered in 2023Q2 and the one–step forecast suggests a low probability of returning to a core–periphery structure. Still, there are few negative correlations between the EU members, and most of them are in the same group with a medium positive correlation. Therefore, it can be concluded that most of the system is still in transition toward a lower-risk structure.

## 2 DSBMM results

**Figure 1:** *Dynamics of block memberships of countries (colors) and membership uncertainty (transparency) in the debt network from 2003Q1 to 2024Q1.*



The results come from considering the trade growth network and the rolling window correlation between the debt–to–GDP ratio of each pair of countries. For further details see Specification 2 in [Baltodano López et al. \(2024\)](#). The DSBMM results suggest that the EU countries can be divided into three communities according to their connectivity properties in the debt network. Figure 1 show the countries’ (y–axis) membership (colors) across time (x–axis) and its membership uncertainty (transparency). The debt network structurally changes during extreme events increasing systemic risks and it is reflected by community 3 that only emerge during the sovereign debt crisis and COVID–19. Compared to 2023Q1, for the last quarter available, that is 2024Q1, all countries have recovered after COVID–19 and do not present a high positive correlation with other members’ public debt. The last countries to recover were Poland and Spain,

followed by Portugal, Italy, Hungary, Greece, and Cyprus. Although there is no country left in the core group (block 3), implying lower systemic risk, and there is low uncertainty in the current membership (see Table 2), most of the countries belong to block 1 and only four countries to block 2: Czechia, Germany, Luxembourg and Portugal. The block 1 and block 2 exhibit an assortative behavior, that is their members tend to have a positive correlation with other members of the same group and a lower correlation with the rest, but block 1 is inclined to have a higher correlation compared to 2. Therefore, since most of the countries belong to the group with the second highest within-group correlation, from a systemic point of view the situation is still in transition towards a more stable state, such as in 2003Q1 or pre-COVID period.

**Figure 2:** *Italy's links in the extracted public debt network, node's membership (node color) and sign of the correlations (edge color) for 2003Q1, 2009Q1, 2023Q3 and 2024Q1.*

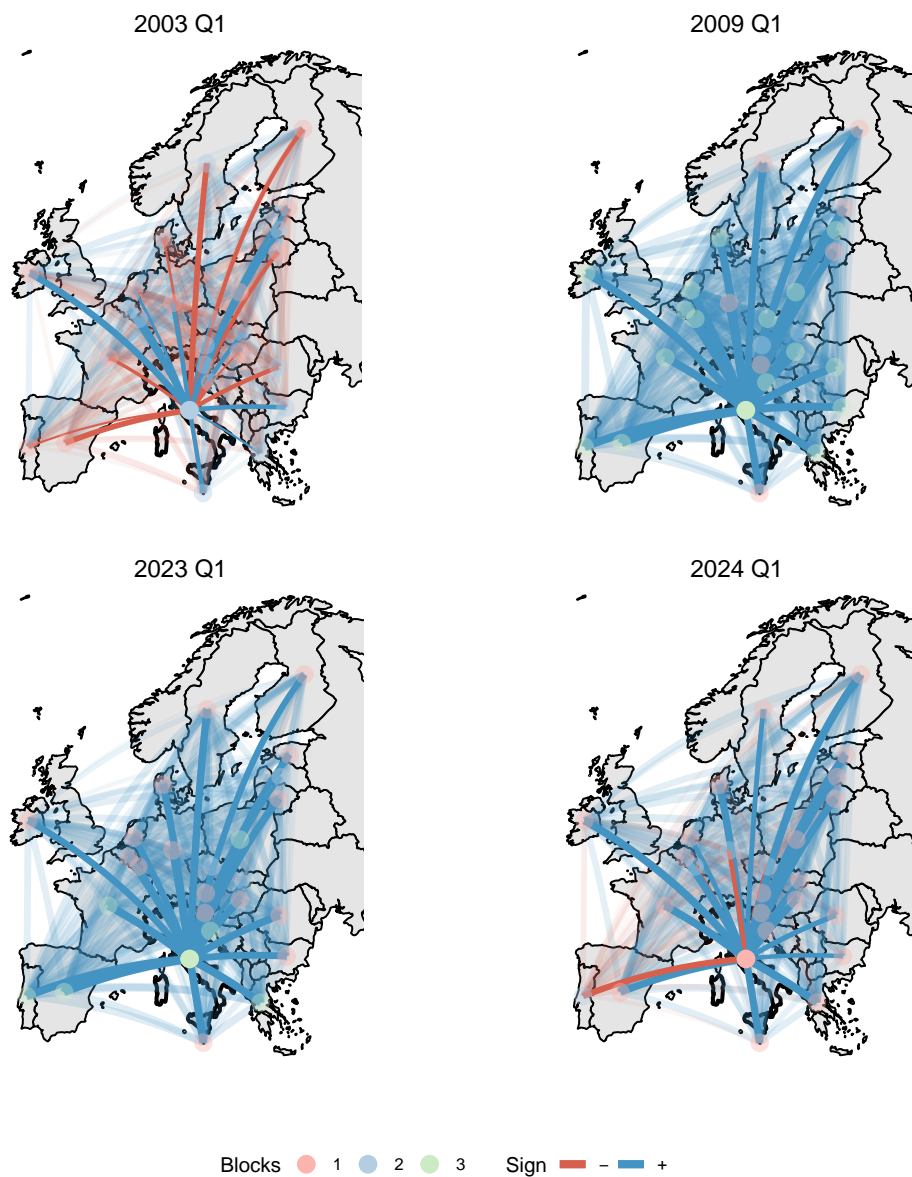
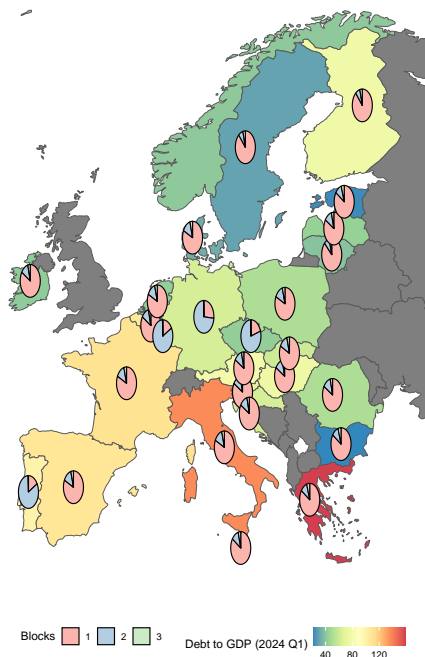


Figure 2 presents the case of Italy and its debt linkages with other countries. The edges represent an active dependence between the countries involved, the width of the links is proportional to the strength of the correlation, and the color (red) blue is a (negative) positive relationship. As discussed before, Italy



**Figure 3:** One-step forecast for the transition probabilities of the countries' memberships (pie charts) for 2024Q2 and the level of debt 2024Q1 (colors in the map)



does not belong anymore to the core, a group of countries with high risk, this is evidenced by the change of membership (the color red of the node in 2024Q1 compared to the color green in 2023Q1) and the reduction in number of edges and their strength, implying lower correlations with the rest of the network, but still no the level of dependence in 2003Q1.

A one step-ahead forecast for the transition probability reveals that this situation is expected to continue for 2024Q2 in Figure 3 for Italy. In the map, the color of the country is related to its level of debt-to-GDP in the first quarter 2024 (2024Q1), and each territories' pie chart represent the membership probabilities for the next period (2023Q2). Italy has a high probability of remaining in community 1 followed far behind by the probability of changing to a more stable situation in community 2. This is consistent with its level of debt-to-GDP, which is the second highest in the network. Other countries have also similar odds even having a lower level of debt, such as Sweden. The one-step forecast does not vary much between the countries of the same community indicating that the trade growth network is not influencing the transitions in the debt network, i.e. no twin deficit risks in the system.

## References

- Baltodano López, O., Billio, M., and Casarin, R. (2024). International trade and public debt: A Network approach.
- Baltodano López, O. and Casarin, R. (2023). A Dynamic Stochastic Block Model for Multi-layer Networks.

# Appendix

**Table 1:** *List of countries and abbreviations*

Austria (AT)	Spain (ES)	Latvia (LV)
Belgium (BE)	Finland (FI)	Malta (MT)
Bulgaria (BG)	France (FR)	Netherlands (NL)
Cyprus (CY)	Croatia (HR)	Poland (PL)
Czechia (CZ)	Hungary (HU)	Portugal (PT)
Germany (DE)	Ireland (IE)	Romania (RO)
Denmark (DK)	Italy (IT)	Sweden (SE)
Estonia (EE)	Lithuania (LT)	Slovenia (SI)
Greece (EL)	Luxembourg (LU)	Slovakia (SK)

**Table 2:** *Communities for 2023Q2–2024Q1*

	2023 Q2		2023 Q3		2023 Q4		2024 Q1	
1	AT(1.000),	BE(1.000),	AT(1.000),	BE(0.998),	AT(0.999),	BE(0.999),	AT(1.000),	BE(1.000),
	BG(0.953),	CY(1.000),	BG(0.989),	CY(1.000),	BG(1.000),	CY(1.000),	BG(1.000),	CY(1.000),
	DK(1.000),	EE(1.000),	DK(1.000),	EE(1.000),	DK(1.000),	EE(1.000),	DK(1.000),	EE(1.000),
	EL(1.000),	ES(0.959),	EL(1.000),	ES(1.000),	EL(1.000),	ES(1.000),	EL(1.000),	ES(1.000),
	FI(1.000),	FR(1.000),	FI(1.000),	FR(1.000),	FI(1.000),	FR(1.000),	FI(1.000),	FR(1.000),
	HR(0.965),	HU(1.000),	HR(0.997),	HU(1.000),	HR(1.000),	HU(1.000),	HR(1.000),	HU(1.000),
	IE(1.000),	IT(1.000),	IE(1.000),	IT(1.000),	IE(1.000),	IT(1.000),	IE(1.000),	IT(1.000),
	LT(1.000),	LV(0.999),	LT(1.000),	LV(0.993),	LT(1.000),	LV(1.000),	LT(1.000),	LV(1.000),
	MT(1.000),	NL(1.000),	MT(1.000),	NL(1.000),	MT(1.000),	NL(1.000),	MT(1.000),	NL(1.000),
	PL(0.959),	RO(1.000),	PL(0.992),	RO(1.000),	PL(1.000),	RO(1.000),	PL(1.000),	RO(1.000),
	SE(1.000),	SI(1.000),	SE(0.992),	SI(1.000),	SE(1.000),	SI(1.000),	SE(1.000),	SI(1.000),
	SK(1.000)		SK(1.000)		SK(1.000)		SK(1.000)	
2	CZ(1.000),	DE(0.670),	CZ(1.000),	DE(1.000),	CZ(1.000),	DE(1.000),	CZ(1.000),	DE(1.000),
	LU(0.981),	PT(1.000)	LU(1.000),	PT(0.996)	LU(1.000),	PT(0.999)	LU(1.000),	PT(1.000)
3								

Note: Membership (rows 1, 2 and 3) by quarter (column). In parenthesis the posterior probability of belonging to its posterior mode (rows 1, 2 and 3).