

# **Macroeconomic Impacts of Single and Multi-Hazards across European regions**

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## **Abstract**

Disasters frequently disrupt supply chains, generating cascading effects that propagate across regions and sectors. In this study, we develop a Dynamic Multi-Regional Impact Assessment (DMRIA) model to estimate the temporal evolution of disaster-induced macroeconomic impacts. The DMRIA model builds upon the MRIA model developed by Koks & Thissen (2016) and later extended by Raj et al. (2025). While the MRIA model incorporates regional substitution subject to sectoral production capacities and interregional logistical capacities available, it is formulated as a static model and therefore does not represent the dynamic adjustment of capacities. DMRIA addresses this limitation by taking into account the evolution of production and logistical capacities endogenously, thereby providing a dynamic representation of the macroeconomic consequences.

Using the DMRIA model, we perform a spatial criticality analysis of disaster impacts across NUTS-1 regions of Europe. In this analysis, supply shocks are imposed on individual regions, and the resulting macroeconomic impacts are quantified. The analysis is further extended to multi-hazard scenarios, where shocks to two regions are imposed simultaneously to capture the amplified impacts. Finally, the model will be used to evaluate the effectiveness of economic resilience measures including increased production extension capacities, trade flexibility between regions, inventory capacity, and interregional participation in mitigating the disaster impacts. We believe the results will provide an evidence base for EU policymakers to identify regions of less redundancy, prioritize capacity-building, and design targeted resilience strategies to strengthen regional economic systems.

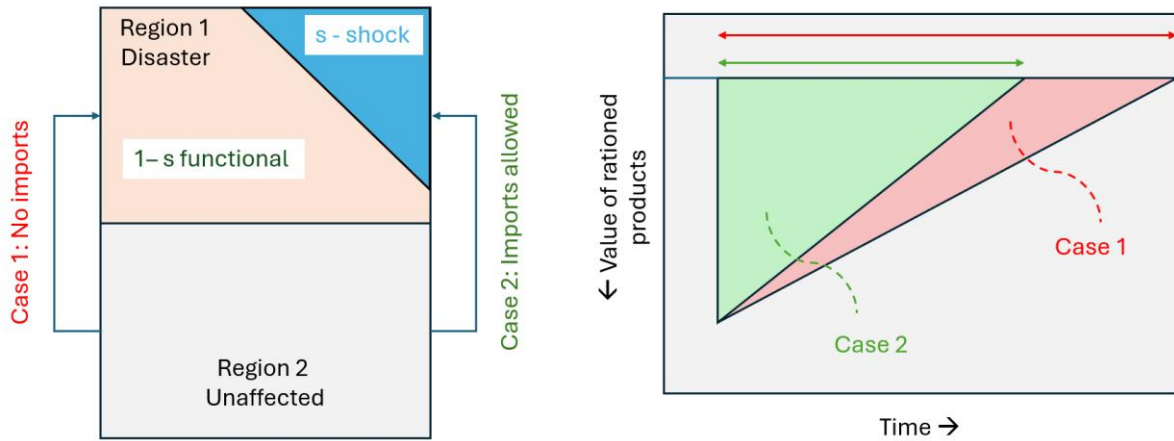
*Keywords: disasters, macroeconomic impacts, economic resilience, input–output analysis, multi-hazard*

## **Introduction**

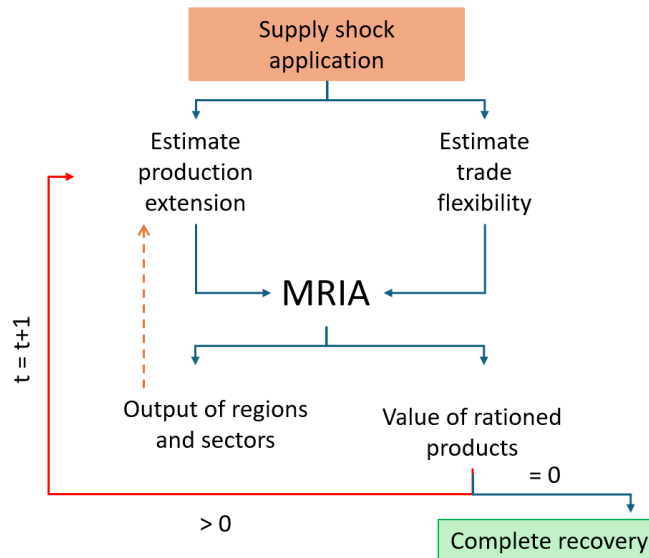
With climate change intensifying, the frequency and severity of natural hazards are expected to rise. The hazard impacts often extend beyond directly affected areas, cascading through interconnected global supply chains. For instance, tropical cyclones disrupt microchip production in Taiwan and triggering global ripple effects in the electronics sector (Allianz Research, 2024). To capture such multi-regional effects, macroeconomic models such as the Multi-Regional Impact Assessment (MRIA) model are increasingly important (Koks & Thissen, 2016). In this study, we develop an updated Dynamic MRIA model that accounts for the time-dependent evolution of regional substitution capacities. We then apply the model to European regions to assess the impacts to single and simultaneous hazards by inducing supply shocks, and also evaluate how resilience measures, such as inventories and inter-regional substitution can mitigate economic losses.

## **Methods**

Figure 1 illustrates the conceptual framework through which disaster impacts can be mitigated via regional substitution. Consider the case where Region 1 experiences a supply shock of magnitude  $s\%$ . In the absence of interregional trade (Case 1), recovery is solely dependent on Region 1's endogenous capacity restoration, resulting in prolonged demand shortages. In contrast, when Region 2 possesses the ability to expand production and export to Region 1, demand shortages can be reduced rapidly. However, the rate of recovery depends on the rate of production extension and the available logistical capacity in Region 2.



**Figure 1.** Effect of regional substitution in mitigating macroeconomic impacts of disaster



**Figure 2.** DMRIA workflow

Figure 2 illustrates the workflow of the DMRIA model. The analysis begins by introducing a supply shock in the region of interest. Subsequently, the sectoral production extension and interregional trade flexibility of unaffected regions are computed according to the equations summarized in Table 1. These adjusted capacities are then incorporated into the MRIA framework to quantify the residual unmet demand. The iterative process continues until all regional demands are fully satisfied.

Table 1. DMRIA model equations<sup>1</sup>.

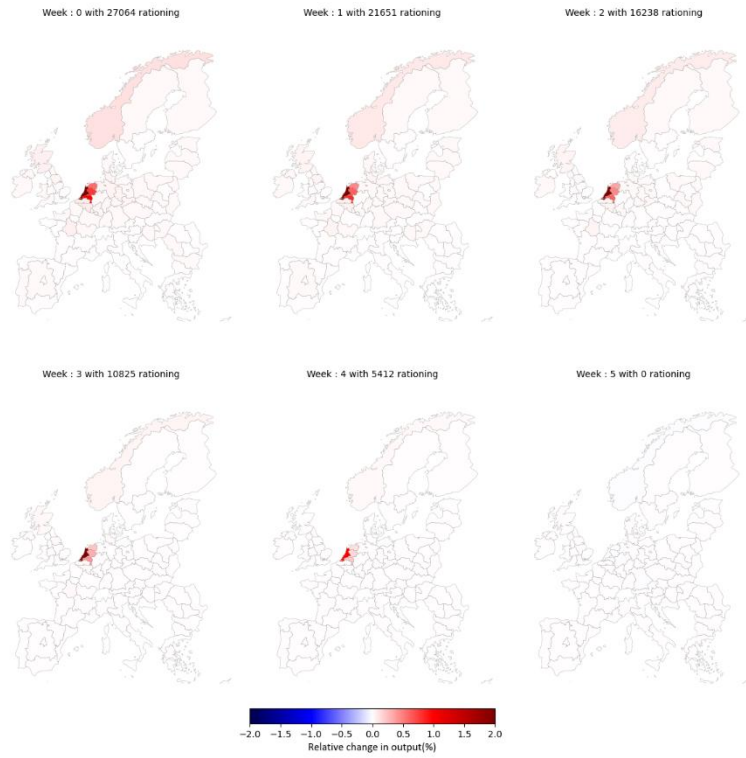
Equations	Symbols	Description
If $r$ is disaster struck,	$\gamma_d$	Production extension rate – <i>intra regional resilience</i>
$\bar{X}_{r,s}^{t+1} = \min(X^{base}, X_{r,s}^t \times \gamma_d)$	$\gamma_u$	Production extension rate – <i>inter regional resilience</i>
else	$\gamma_t$	Trade flexibility extension rate
$\bar{X}_{r,s}^{t+1} = \min\left(\delta^{\max} \times X_{r,s}^{base}, X_{r,s}^t \times \left[\frac{\gamma_u}{e^{-\theta}}\right]\right)$	$\bar{X}$	Upper bound for sectoral output $X$
	$\theta$	Decay parameter defining regional participation
	$\delta^{\max}$	Permissible production extension
$\phi_{r1,r2,p}^{t+1} = (\phi_{r1,r2,p}^t \times \gamma_t) + \phi_{\min}$	$\Phi_{r1,r2,p}$	Trade flexibility between regions $r1,r2$ for the product $p$

### Preliminary results<sup>2</sup>

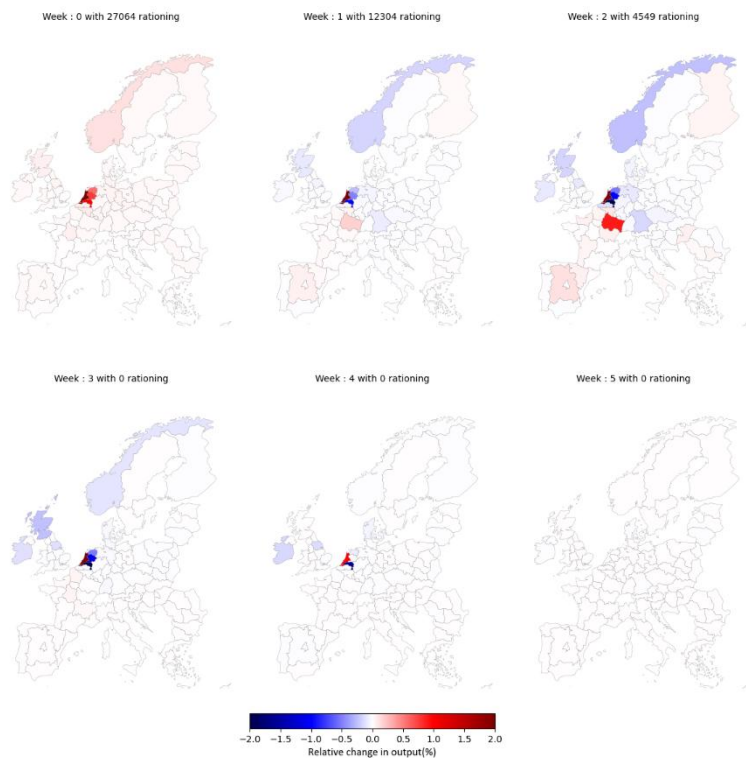
Figures 3a and 3b present the relative change in regional output across the EU in response to a 5% supply disruption in West Netherlands (NL3), under scenarios of zero and enhanced substitution capacities (with 1% production extension and 10% trade flexibility extension per week), respectively. In the absence of interregional flexibilities, all regions experience persistent negative impacts throughout the time period. By contrast, when substitution mechanisms are enabled, neighboring trading partners exhibit positive output effects, reflecting compensatory and redistributed production to mitigate the initial disruption.

<sup>1</sup> The equations relevant solely to the dynamics of the model is presented here. For complete set of equations defining the model refer Raj et al. (2025)

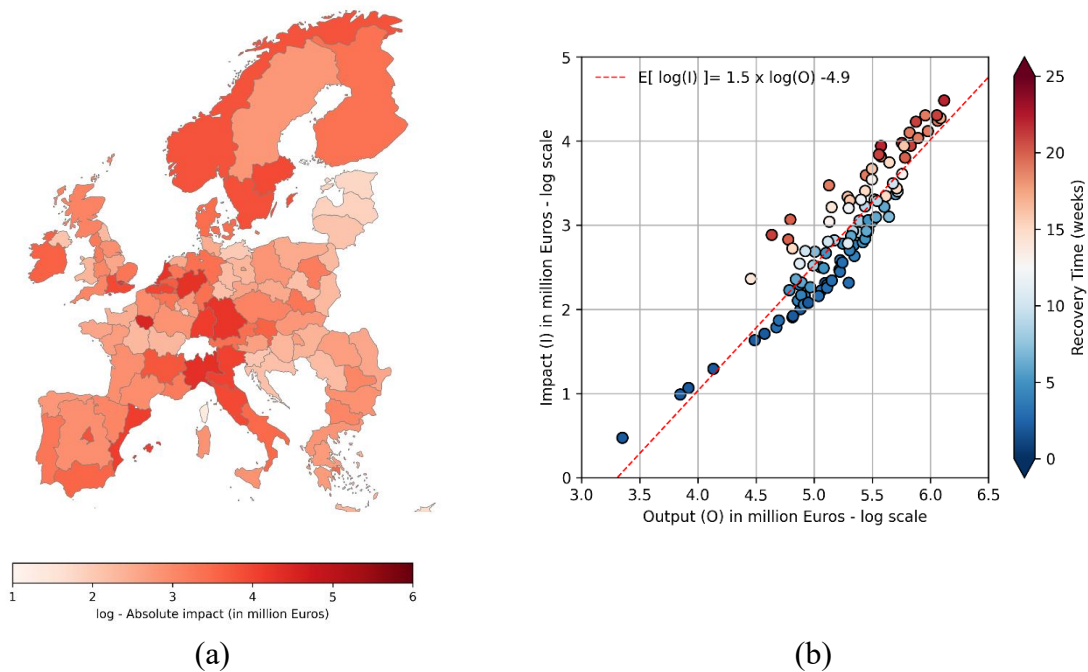
<sup>2</sup> The work is currently under preparation and the results are outcomes of the preliminary test runs.



**Figure 3a.** Relative change in regional outputs to 5% disruption to West-Netherlands (NL3) under zero production extension and trade flexibility capacities



**Figure 3b.** Relative change in regional outputs to 5% disruption to West-Netherlands (NL3) with 1% production extension and 10% trade flexibility extension per week



**Figure 4.** a) Impact across EU regions b) Regional economic output Vs the Observed macroeconomic impact

Figure 4a illustrates the absolute economic impacts across all EU regions under a 5% supply disruption. The impacts exhibit substantial regional heterogeneity, with major economies experiencing relatively higher absolute losses. Figure 4b compares regional economic output with the corresponding observed impacts, revealing an approximately linear relationship. However, smaller regions with limited trade connectivity can experience impacts equivalent to the impacts observed in major economies (of 5–8 times higher output), highlighting their vulnerability to supply shocks. In subsequent analyses, we will assess the effectiveness of various economic resilience measures and examine regional responses to these interventions.

## Conclusion

This study introduces a Dynamic Multi-Regional Impact Assessment (MRIA) model to analyze the macroeconomic consequences of disasters across EU regions. Preliminary results show that regional substitution can significantly reduce impacts, while regional responses vary by both its size and trade connectivity. The role of economic resilience measures will also be explored.

## References

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