Household adaptation matters: The macroeconomic effects of adapting to river-floods at the regional level

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Abstract

Our research evaluates the economic impacts of household inaction versus adaptation to river floods, utilising the EU-EMS regional CGE model. We integrate regional damage data, adaptation cost-effectiveness for future climate scenarios, and household flood damage shares to enhance assessment granularity at the NUTS2 level, revealing indirect climate change effects often obscured in national assessments. Calibrating household expenditure data across income quintiles allows accurate estimation of adaptation impacts. We explore various financing options to inform policymakers at regional and national levels. Additionally, we assess the optimal timing for household adaptation, considering each country's capacity to manage climatic and adaptation challenges. Projected direct river-flood losses in Europe by 2100 are €44 billion annually, reducible to €8.1 billion with adaptation. Without adaptation, household flood damages could increase GDP by 0.15% in 2050 and 0.2% in 2100 due to forced reconstruction efforts. However, combined damages to firms and households reverse this effect. Household adaptation yields higher national and regional GDP compared to the baseline, with a 0.4% GDP increase in 2100, translating to an aggregate. Gains are unevenly distributed, with Denmark, Greece, Italy, Croatia, and Germany benefiting most. A government loan system to support household adaptation

shows significant positive GDP impacts, particularly in countries previously facing negative GDP responses. The timing of household adaptation is crucial; immediate action is beneficial in some countries, while a delayed approach is better for others. Regional analysis reveals significant disparities in national versus regional outcomes, emphasising the need for region-specific adaptation strategies. Our findings provide actionable insights for policymakers to optimise economic outcomes through strategic household adaptation to river floods.

Keywords: keyword1, Keyword2, Keyword3, Keyword4

Discussion

Our research highlights the significant economic impacts of household inaction versus adaptation to river floods, utilising the EU-EMS regional CGE model. By integrating regional damage data, adaptation cost-effectiveness for future climate scenarios, and household flood damage shares, our analysis achieves the required granularity at the NUTS2 level. This approach reveals the indirect effects of climate change often obscured in national assessments. Furthermore, calibrating household expenditure data across income quintiles allows for a more accurate estimation of adaptation impacts. We also explore various financing options for adaptation to provide actionable insights for policymakers at both regional and national levels. Finally, our assessment of the optimal timing for household adaptation considers each country's capacity to manage both climatic and adaptation challenges, offering a comprehensive perspective on effective flood management strategies.

The direct projected river-flood losses in Europe by 2100 are €44(30–61) billion per year (Dottori et al, 2023), that can be reduce to to €8.1(5.5–10.7) billion when adaptation is applied. The indirect projected flood damages can cause regional GDP losses of up to 0.5% in 2050 (Knittel et al, 2024). However these indirect losses focus on damages to the economy through reduction of available capital for firms, ignoring what the flood damages cause to households. We find that flood damages on households (without adaptation) can cause an additional 0.15% GDP increase in 2050 leading to a additional of 0.2% GDP change in 2100. These changes are created since households are damaged from the flood and they are forced to repair by reducing their available

consumption budget and savings in order to finance repairers, thus affecting the total economy. Compared to the firm analysis only, the effects of flood on households seem to have a positive effect on GDP, since the reconstruction actions of households have a net positive effect on the European economy. This result however is reversed when considering both damages to firms and households. In that case, households increase the consumption of Construction, but the sector itself is damaged thus being unable to provide the full extend of services required leading to further reduction in GDP. In our analysis, we look on the households' effects -only- in an effort to understand the economic mechanisms of household adaptation actions. As such, all our results are compared with a baseline that includes the flood damages but no adaptation action.

Our results clearly show that household adaptation leads to higher national and regional GDP compared to the baseline indicating the importance of households' action in CCA. In 2100 the GDP is 0.4% higher when households adapt, leading to a total gain in GDP between 2025 and 2100 of 858 billion euros. These gains form adaptation are equivalent to the EU&UK GDP losses from sea level rise described in Cortés Arbués et al (2024). This result is not equally distributed amongst countries. Denmark(+1.5%), Greece(+1.3%) Italy(+0.7%), Croatia(+0.9%) and Germany(+0.8%) have the highest gains from households adapting to floods. At the country level there are several mechanisms that lead to those results. Initially, different countries are faced with variables flood costs. These costs in our analysis are distributed to households based on the European Spatial Planning Observation Network (ESPON) (2023) data. When households occur damages, they are forced to reconstruct by using the Construction sector and in lesser extend the Industry sector of the economy. Given that Construction is a very productive sector this action by-itself leads to higher GDP. However, households need to finance this reconstruction effort by reducing their consumption of other goods and services on top of reduction of their savings. In our analysis we have given priority to savings reduction. In our CGE

model, decreased household consumption and savings would reduce overall demand, leading to lower production and possibly higher unemployment. Investment drop due to the reduced savings, potentially slowing economic growth further. Government revenues from taxes might decline, affecting public services. This reduction could trigger a negative feedback loop, further dampening economic activity.

Although some countries are faced with losses, like Poland(-0.6%), Cyprus(-0.5%), Romania(-0.4%) and Czech Republic(-0.2%) in 2100 compared to the baseline. In these countries, the gains from adapting are not enough to counteract the changes happening in the economy from the combination of adaptation action and flood reconstruction. In our CGE model, counties experiencing lower GDP with adaptation compared to the baseline (flood damages only) likely face higher immediate costs of reconstruction. These costs divert funds from other productive investments and consumption, reducing overall economic activity. Additionally, resource reallocation to reconstruction may lead to inefficiencies and short-term economic disruptions, outweighing the long-term benefits of adaptation. Cyprus is a special case where the flood costs are very small compared to the total economic changes from adapting (starting at 2025) even though it is cost-effective to adapt indicating that special attention is required in countries where the damages are rather small.

Introducing a government loan system to aid household adaptation can alleviate the immediate financial burden on households, allowing them to maintain consumption and savings levels. Households get a loan from the government in order to pay for the adaptation they need, and they repay it in 5 year with a 3% interest rate. This financial support helps sustain demand for goods and services, mitigates economic disruptions, and promotes a quicker recovery. By spreading the reconstruction costs over time, the economy can stabilise, supporting higher GDP levels and more efficient resource allocation during the adaptation process. Our results indicate that the loan system has a very positive effect on GDP for all countries. In this case all countries see

an increase in their 2100 GDP relative to the baseline, with a maximum increase in Greece(+6%) and Croatia(+2.3%). The countries that had a negative GDP response from adapting now see also a positive effect such as Romania(+1.1%), Cyprus(+0.9%) Poland(+0.6%) and Czech Republic(+0.2%). As it seems, a government loan is a significant tool for supporting the adaptation effort of households that has the ability of further stimulating the economy. Policy makers should use this option to promote household adaptation given the small effect this action would have on the government budget and the significant gains to GDP relative to no-government intervention.

With or without government intervention, the timing of households' investment in adaptation is crucial. While it might be logical to invest in adaptation when the benefit-cost ratio (BCR) is ideally above 1, the economy's capacity to finance this action or its ability to support the necessary construction remains uncertain without government support. Our analysis examines the effects of delayed household adaptation (beginning in 2035) compared to earlier action (starting in 2025). Our results indicate that in countries like Denmark, Latvia, Belgium, and Germany, delaying household adaptation is highly detrimental, highlighting the need for immediate action. Countries such as Portugal, Cyprus, Poland, and Greece, postponing adaptation by a decade proves beneficial to GDP. However, delaying adaptation by an additional ten years (starting in 2045) results in negative GDP impacts for all countries, underscoring the importance of timely adaptation measures. These findings suggest that while immediate adaptation can strain economies without government support, strategic timing and financial aid are critical for optimising economic outcomes. Out results can be used directly by policy makers to promote household adaptation at the appropriate timing for their region.

By analysing the economic effects of flood damages and household adaptation actions at the regional (NUTS2) level, our results show significant differences between

national and regional outcomes. These disparities highlight the necessity of considering adaptation actions at the regional level. Romania serves as a prime example of why regional analysis is essential. While national-level analysis indicates a 0.4% GDP loss for Romania by 2100, regional analysis uncovers substantial losses in specific areas: Bucureşti-Ilfov (RO32) (-1.5%), Nord-Vest (RO11), and Centru (RO12) both at -0.3%. Conversely, other regions experience positive GDP impacts, such as Sud-Muntenia (RO31) with a 1.3% increase and Sud-Est (RO22) with a 2.0% increase. Our findings emphasise that region-specific characteristics and economic structures must be considered when assessing household adaptation to climate change.

Our analysis is based on several assumptions regarding how households adapt to climate change and rebuild after damages. We assume that all households choose to adapt, regardless of their economic situation. Although income distribution in each region has been considered to estimate the income spent on adaptation, only one aspect of household preferences has been accounted for. Some households might choose not to adapt at all. These choices could be better represented in a detailed micro-simulation or agent-based model (ABM), where the heterogeneity of individual households is explicitly modelled. Similarly, we assume households finance adaptation and reconstruction following a flood 70% from their savings and 30% from their consumption budget. A more detailed CES function for household consumption and savings could better represent these decisions, instead of the simple LES applied in our CGE model in the absence of required data.

5 Appendix

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Table 4: EU-EMS Sectoral Aggregation and corresponding NACE2 Codes

Sector	NACE Rev.2 Codes
Agriculture	A
Industry (Capital)	C26-C33
Industry (Rest)	B, C10-C25
Construction	F
Utilities	D, E36-E39
Logistics	G45-G46, H52-H53
Transport	H49-H51
Private Services	I, J, K, L, M, N
Public Services	O, P, Q, R, S

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