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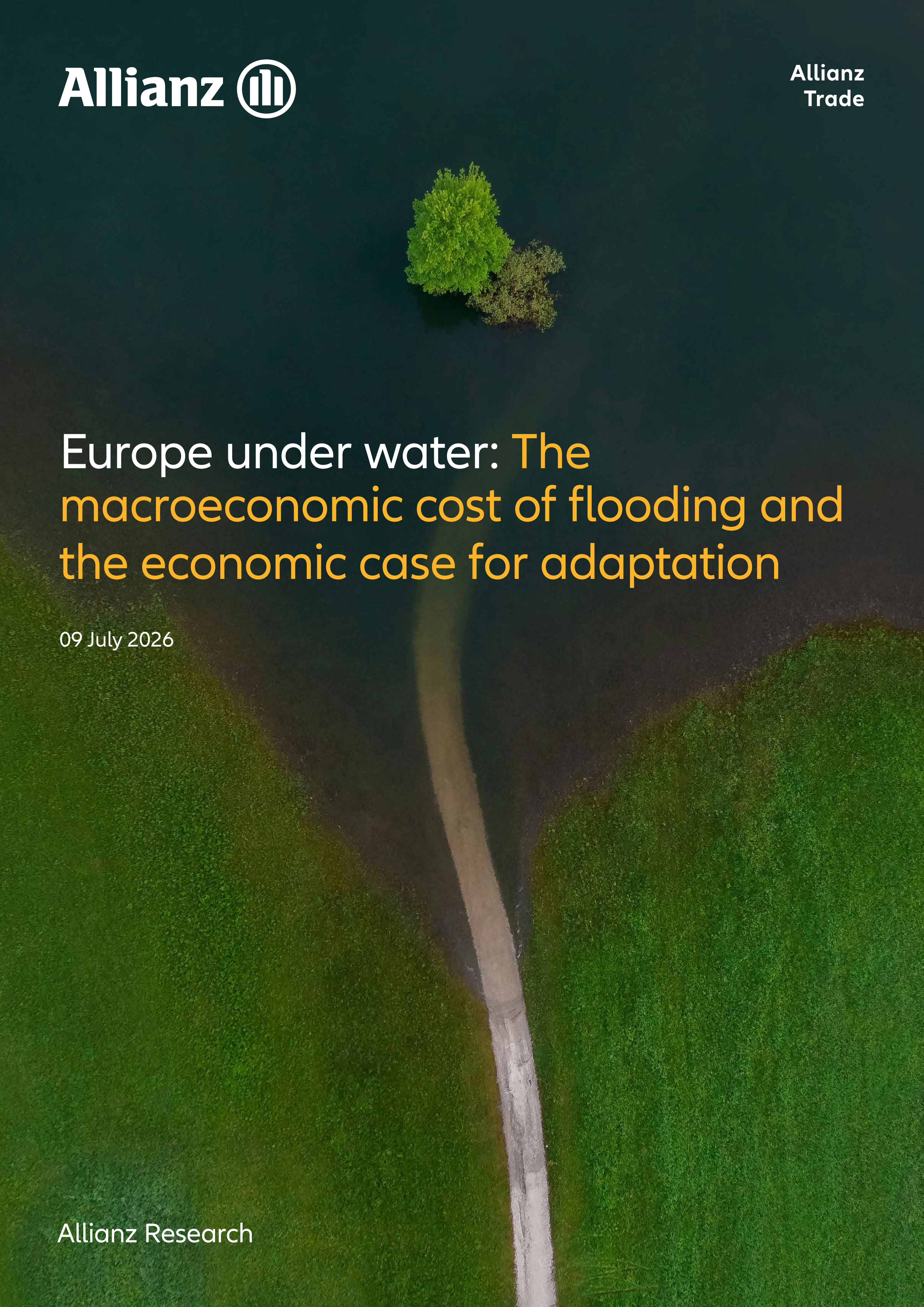

Europe under water: The macroeconomic cost of flooding and the economic case for adaptation

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Executive Summary

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Flood losses are rising rapidly as economic activity continues to concentrate in high-risk areas. Floods are Europe's most frequent and costliest natural hazard, with total economic losses climbing steadily, to EUR226bn in the first quarter of this century. While flood frequency in Europe has remained broadly stable at 46 per year since 2000, their cost has risen sharply. Losses from floods climbed 17.8% from EUR63.1bn between 2000-2009 to EUR 74.3bn from 2010–2019. From 2020-2025 alone, the cost reached EUR88.6bn, a 40% increase from the first decade of the century. Insurance covers only a fraction of the damage: The July 2021 floods alone caused a record EUR38bn in damage, of which only EUR9bn was insured, leaving households, businesses and governments to bear the remainder. Looking ahead, annual river-flood losses across the EU and UK could rise more than six-fold, from EUR7.8bn today to nearly EUR50bn by 2100 in a 3°C warming scenario, driven by more intense rainfall and continued development in exposed areas.

Floods are local events in their physical origin, but their economic consequences ripple through the entire economy. To quantify these economic effects, we simulate a one-off flood in 2027, calibrated to each country's average historical maximum flood depth over 2015–2024, and compare the economic trajectory with a no-flood baseline through 2030. The analysis links observed flood depth to real gross fixed capital formation and real household net disposable income, tracing how flood damage spreads through investment, consumption and public finances. Investment is hit hardest: cumulative gross fixed capital formation losses between 2027 and 2030 range from 10.5% in Norway to 14.6% in the Netherlands, with Germany at 12% recording the largest absolute loss at around EUR84bn. Real household net disposable income meanwhile falls by 3.9–5.4% in 2027-30 as reconstruction costs and labour-market effects accumulate, in turn reducing households' capacity to absorb uninsured losses and rising insurance costs.

Floods create a stagflationary shock, raising prices, slowing growth and eroding fiscal space. Consumer prices rise as damaged infrastructure, disrupted logistics and lower local availability of goods and services create supply bottlenecks. The cumulative price-level impact remains contained, from +0.2% in the United Kingdom to +1.0% in Greece, but it still adds pressure on households already facing an income shock. Private consumption declines in all countries, with cumulative losses ranging from -0.3% in Norway to -0.9% in Czechia; in absolute terms, the United Kingdom records the largest loss at about EUR61bn, ahead of Germany and France. GDP losses then range from around -0.4% in Norway to -1.0% in Spain, with Germany and France losing approximately EUR108bn and EUR79bn respectively. The impact on public finances is also visible, with cumulative 2027-2030 government deficits widening by 1.3pp of GDP on average, from -0.3pp in Norway to -2.4pp in Spain.

The economic case for flood prevention is overwhelming: well-targeted adaptation pays for itself many times over. Adapting to flooding requires more public capital than any other climate hazard, accounting for around 65% of all predominantly public measures in our adaptation taxonomy. Yet target adaptation investments in natural flood retention, resilient infrastructure and risk-sensitive land-use planning can largely offset future losses. Concretely, flood adaptation means keeping people and assets away from high-risk floodplains where possible, restoring natural retention areas, upgrading dikes, drainage, sewers and stormwater systems, and flood-proofing buildings and critical infrastructure. These measures should be combined according to the type of risk: basin-level retention and land-use planning for fluvial floods, local drainage and blue-green urban infrastructure for pluvial floods, supported by early-warning systems, emergency planning and insurance incentives. Flood resilience investments yield roughly four times their cost in avoided damages. Land-use planning offers similarly high returns: prohibiting development in floodplains and integrating green, water-retaining infrastructure into cities offer similarly high returns. This shows that more than climate policy, adaptation is preventive fiscal policy.

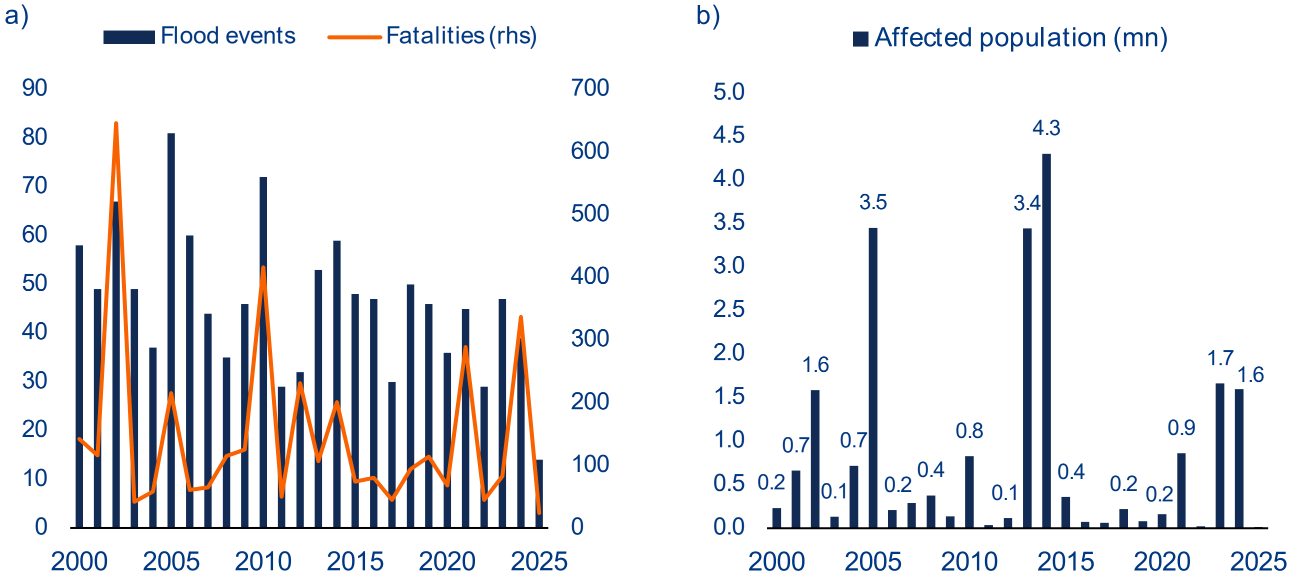
Europe's challenge is to deliver effective flood adaptation solutions at the speed and scale required. The measures with the highest returns, keeping development out of floodplains and restoring natural flood retention, are also the most politically difficult to implement, while major flood protection infrastructure requires lengthy planning and construction. Germany illustrates this implementation gap: despite the EUR38bn flood disaster in 2021, only around EUR500m of the EUR6–7bn planned under the National Flood Protection Programme launched in 2013 has been spent. The main barriers are institutional fragmentation and lengthy approval procedures rather than limited fiscal capacity.

Long-term flood resilience requires integrating prevention, adaptation and insurance coverage into a single risk-management strategy. Structural flood defences, resilient building standards, property-level adaptation and greater public awareness must be complemented by sustainable public-private insurance partnerships. Experience from Spain's Consorcio, France's CCR and reforms under discussion in Germany and Ireland shows that risk transfer remains sustainable only when accompanied by meaningful risk reduction. Accelerating proven adaptation measures would strengthen public finances, reduce uninsured losses and safeguard the long-term insurability of flood risk.

The scale and cost of flooding in Europe

Europe has recorded an average of 46 flood events per year since 2000 - with close to two events per week in the most active years - but the number of floods has not shown a clear upward trend. Figure 1 plots annual flood events alongside fatalities between 2000 and 2025. Annual flood frequency fluctuates widely, from fewer than 30 events in quieter years to more than 80 in the most active, yet recent years are no more flood-prone than the early 2000s. What has changed is the severity of the worst events. Fatalities and affected populations are concentrated in a handful of catastrophe years, notably the Central European floods of 2002, the devastating floods in western Germany and Belgium in July 2021, and the three major flood events of 2024 - the October storm in eastern Spain and the June and September floods across Central Europe. Between these episodes, flood-related deaths remain comparatively low, giving the series a pattern of intermittent but highly destructive shocks rather than a steady upward trend. The affected population follows a similar pattern, with additional peaks in 2005, 2013, 2014 and 2023, reflecting years in which floods displaced or affected large numbers of people despite relatively low mortality.

Figure 1: Flood events and associated fatalities (a), and affected population in million (b) in Europe, 2000 to 2025



Sources: ClimRad[1], EarthianAI, Allianz Research

Economic losses have risen sharply as more people and assets are exposed to flood risk. The July 2021 floods remain Europe's costliest flood disaster on record, causing around EUR38bn in economic losses, followed by the Europe-wide floods of 2024 (EUR24bn) and the Central European floods of 2002 (EUR22bn; Figure 2a, 2025 prices). As with fatalities, flood losses are concentrated in a handful of catastrophe years rather than accumulating steadily over time. There is also no sign of moderation: the two most expensive years in the record - 2021 and 2024 - occurred within the past five years. The economic cost per event has risen sharply over this period. Between 2000 and 2019, a flood event caused on average around EUR0.1bn in economic losses; between 2020 and 2025 that figure climbed to approximately EUR0.4bn, with the 2021 floods alone averaging EUR0.8bn per recorded event. The rising economic cost of floods is clear when we look at the trend since 2000. Total economic losses grew 17.8% between the 2000–2009 and 2010–2019 decades, rising from EUR 63.1bn to EUR 74.3bn. The 2020–2025 half-decade alone has already reached EUR 88.6bn in losses, driven largely by the disastrous events of 2021, 2023, and 2024 – an increase of 19.1% over 2010–2019 and 40% over the first decade of the century (Figure 2b). This increase reflects not only more damaging weather but, above all, growing exposure. As urbanisation and economic activity continue to concentrate in flood-prone areas, similar flood events destroy substantially more capital than they did two decades ago. Because exposure is shaped by land-use decisions, building standards and flood protection, a large share of these future losses remains within policy control.

Most flood losses remain uninsured, leaving households, businesses and governments to absorb the economic cost. In 2021, insured losses of around EUR9bn covered less than one-quarter of total damage; in 2002 the insured share was around 15%, and in 2010 below 10%. These swings reflect which countries flood in a given year, not a steady trend, because flood cover differs sharply across Europe. It is bundled into standard home insurance in some countries, such as the UK, but remains optional in others, including Germany, so a year dominated by losses in low-coverage markets pulls the European insured share down. Moreover, in several European markets, protection and modelling have historically been stronger for river flooding than for localised heavy-rain and surface-water flooding. Where losses are uninsured, they fall directly on households and businesses or are ultimately borne by the public sector through emergency relief and reconstruction. This protection gap amplifies the macroeconomic consequences of flooding, weakening household balance sheets, constraining investment and increasing pressure on public finances.

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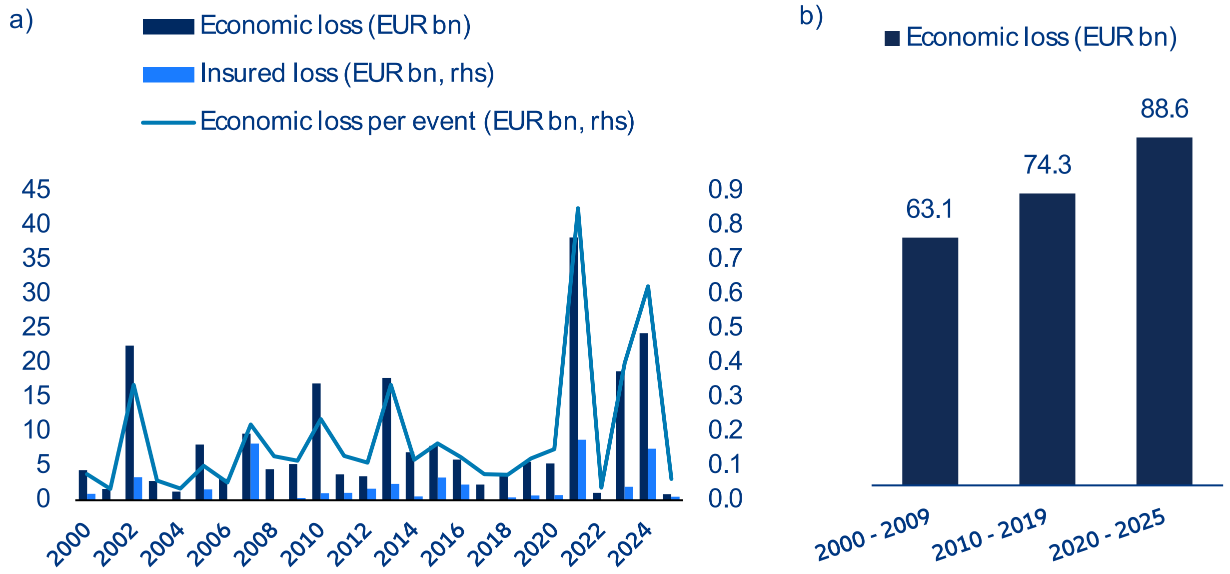
[1] ClimRad is a climate data tool developed by Allianz Research through a collaboration with EarthianAI

Figure 2: (a) Economic and insured flood losses in Europe, 2000 to 2025 (EUR billion); (b) Evolution of economic losses in Europe per decade



Sources: ClimRad, EarthianAI, Allianz Research

Floods impose a disproportionately large economic burden on Europe. Although Europe accounts for around 30% of recorded global flood events, it represents just under one-quarter of global flood losses (Figure 3). By contrast, Asia generates more than half of global flood losses from only around one-quarter of recorded events, reflecting the concentration of people and economic assets in highly exposed flood-prone regions.[2]

Within Europe, floods are by far the most costly natural hazard. Between 2000 and 2025, they accounted for around 55% of all natural-catastrophe losses while representing roughly 45% of recorded events (Figure 4). No other hazard comes close. Storms, both severe convective storms and extratropical cyclones, rank a distant second, while earthquakes account for around one-tenth of losses despite occurring only rarely, illustrating their low-frequency, high-severity nature. Floods combine both high frequency and substantial damage, making them Europe's largest source of cumulative natural-catastrophe losses.

Flood frequency alone is a poor guide to economic risk. Italy, Spain and France recorded the largest number of flood events between 2000 and 2025, but countries with fewer floods often experienced much larger impacts on their populations (Figure 5a-b). Bulgaria, Bosnia and Herzegovina and Czechia stand out as having particularly high numbers of people affected relative to the frequency of flooding, reflecting repeated exposure to major flood events. Ranking countries by economic losses reshuffles the picture again: Germany records by far the largest cumulative losses (around USD78bn), followed by Italy (USD42bn) and Spain (USD25bn) (Figure 5c). The ranking reflects not only flood frequency but also the concentration of economic assets in exposed areas and the occurrence of exceptionally destructive events such as the 2021 floods.

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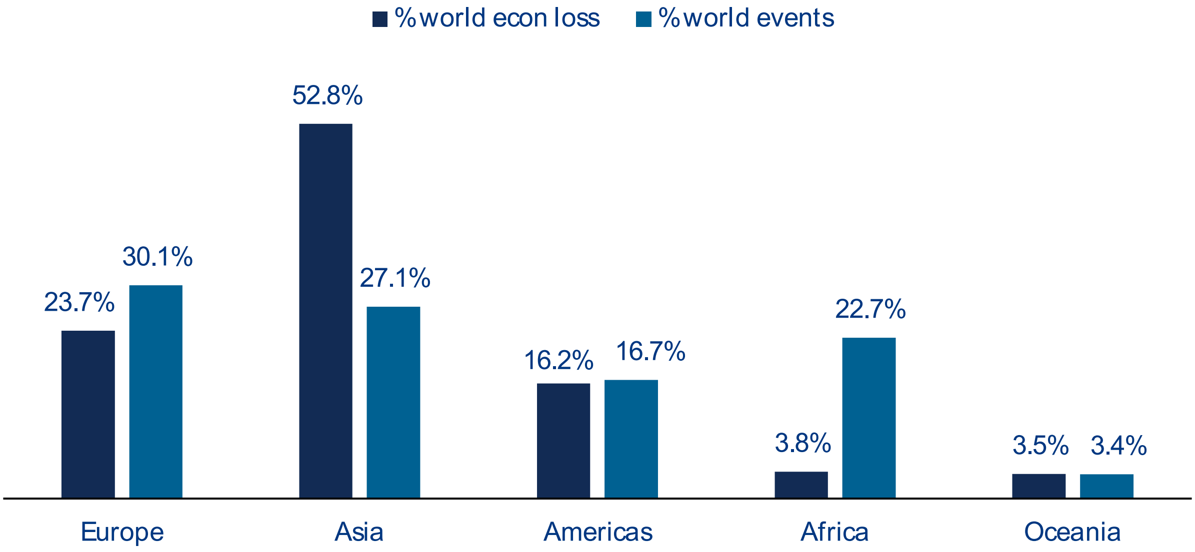
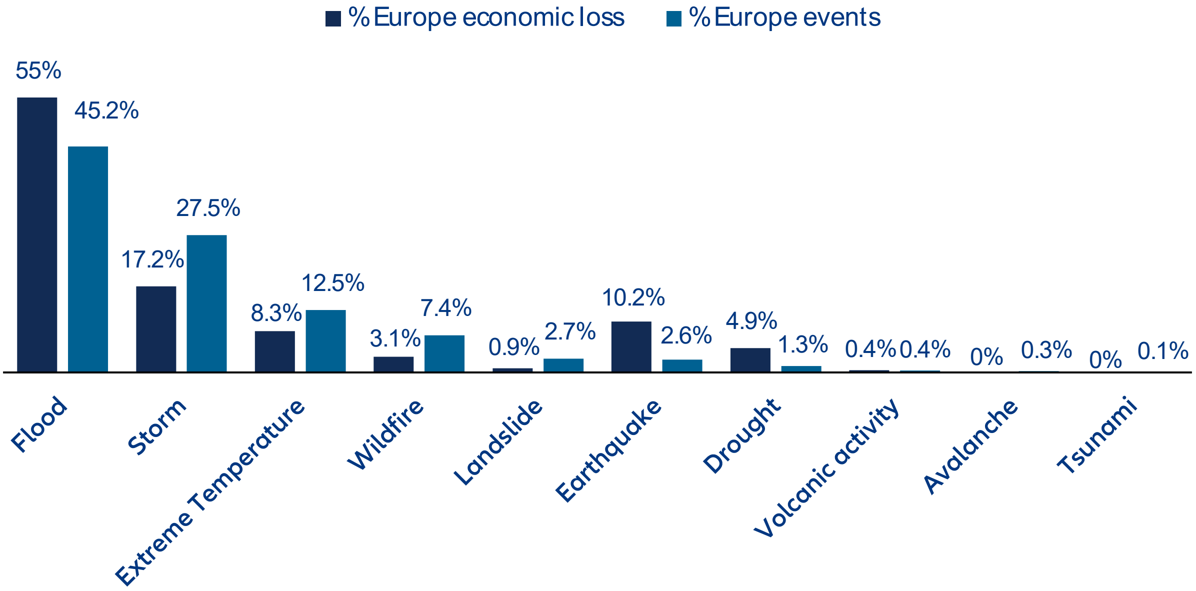
[2] Because flood events are captured through national reporting and emergency-mapping activations, coverage is not fully uniform across countries; this may affect individual figures but not the overall conclusions.

Figure 3: Regional shares of global flood economic losses and of recorded flood events



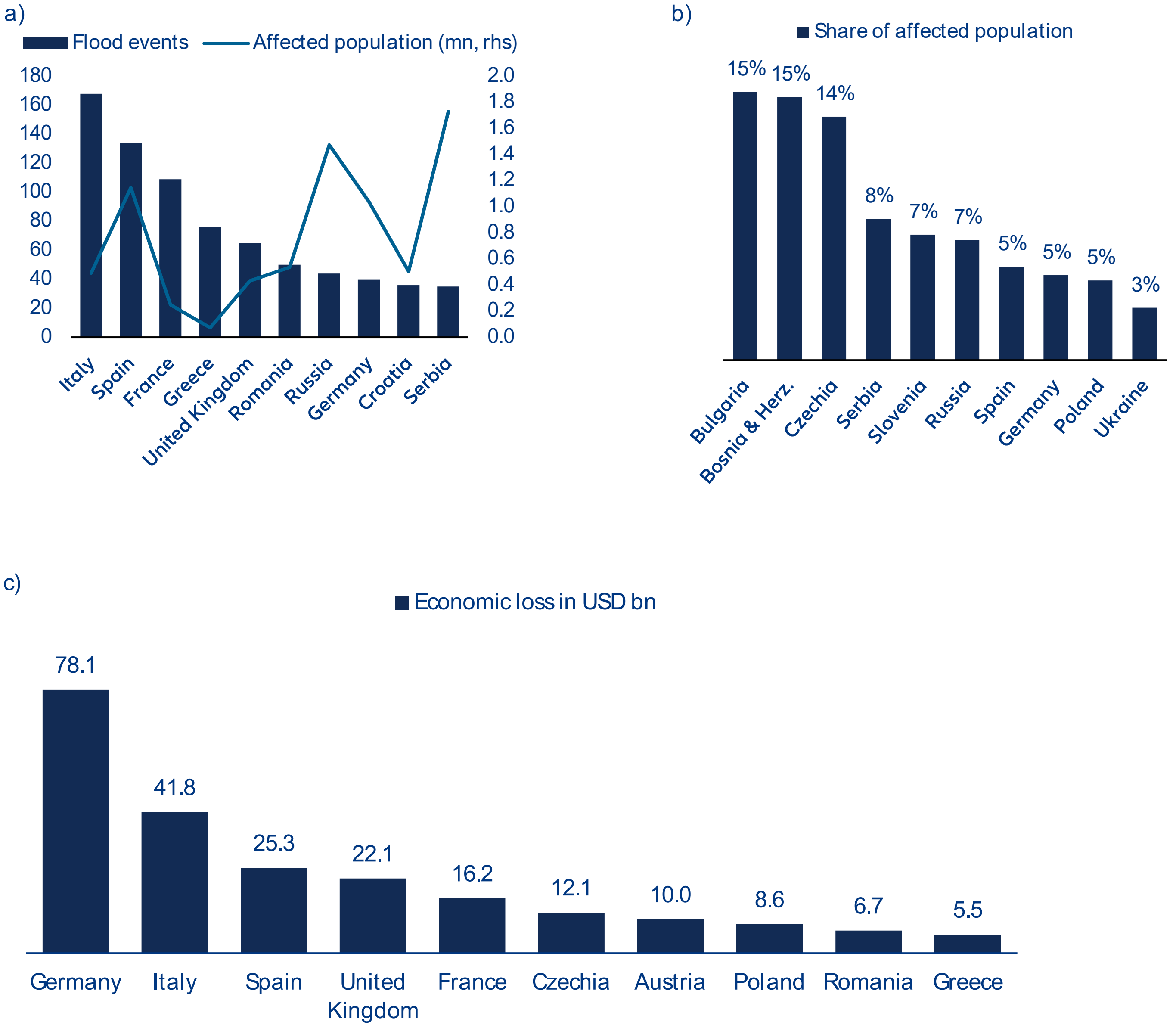
Sources: ClimRad, EarthianAI, Allianz Research

Figure 4: Shares of European natural-catastrophe losses and events, by hazard type



Sources: ClimRad, EarthianAI, Allianz Research

Figure 5: (a) Top 10 European countries ranked by number of flood events and by affected population from 2000 to 2025 (b) Top 10 European countries ranked by affected population from 2000 to 2025 (c) Top 10 countries ranked by total economic losses from 2000 to 2025



Sources: ClimRad, EarthianAI, Allianz Research

The macroeconomic impact of flood events in Europe

Floods become macroeconomic shocks that spread through the whole economy reducing investment, household incomes and fiscal space. Floods affect the macroeconomy through three channels. For households, the shock reduces real disposable income through repair costs, temporary displacement, lost working time and higher prices for essential goods and services. For firms, it reduces productive capacity through damage to buildings, machinery and inventories, while also raising short-term costs through emergency repairs, business interruption and supply-chain disruptions. These effects weaken investment. For the public sector, floods increase emergency and reconstruction spending while reducing tax intake as activity slows. We capture these channels in two steps. First, we estimate how observed flood depth[3] affects real gross capital formation and real net disposable household income. Second, we feed these estimated shocks into a macro-econometric model to assess the wider macroeconomic effects. The exercise is calibrated as a one-off flood shock in 2027, based on the recent historical average of maximum flood depth over 2015 to 2024, and all results are measured relative to a no-flood baseline. This analysis is based on recently observed flood events; however, more extreme floods could have even greater economic impacts across European countries than indicated here. For example, more than 18% of the populations of Austria, Hungary, Netherlands; Liechtenstein and Slovakia live in floodplains.[4] The numbers should therefore be read as a standardized stress test rather than a macroeconomic forecast under a tail risk event.

Investment is hit the hardest. A flood destroys part of the existing capital stock, but it also changes the conditions under which firms decide whether to commit to new capital. Since the dependent variable is real gross fixed capital formation for the total economy, the estimate already includes any reconstruction investment recorded as fixed capital formation. The reported loss is therefore a net shortfall relative to the no-flood baseline, after rebuilding spending has partly offset the initial capital damage. (See Appendix A1 for details on our empirical methodology). Estimation results show that the cumulative loss in capital formation — over the period 2027 – 2030 — is large across all countries, ranging from around -10.5% in Norway to -14.6% in the Netherlands from 2027 to 2029 (Figure 6). The Netherlands records the largest relative loss, followed by Croatia, France and Greece at about -14%, while Spain and Ireland are close to -13.4%. Germany is less affected in percentage terms, at 11.9%, but records the largest absolute loss at about EUR83.6bn. France follows with EUR78.4bn, the United Kingdom with EUR66.5bn, Italy with EUR51.3bn and Spain with EUR36.6bn.

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[3] See Appendix A3 on how we calculate flood depth in Europe from 2015 to 2024

[4] Population characteristics in potential flood-prone areas | Maps and charts | European Climate and Health Observatory Climate-ADAPT

Figure 6: Cumulative capital formation loss (2027–2029) from a one-off 2027 flood shock, calibrated to the 2015–2024 average maximum depth, relative to a no-flood baseline

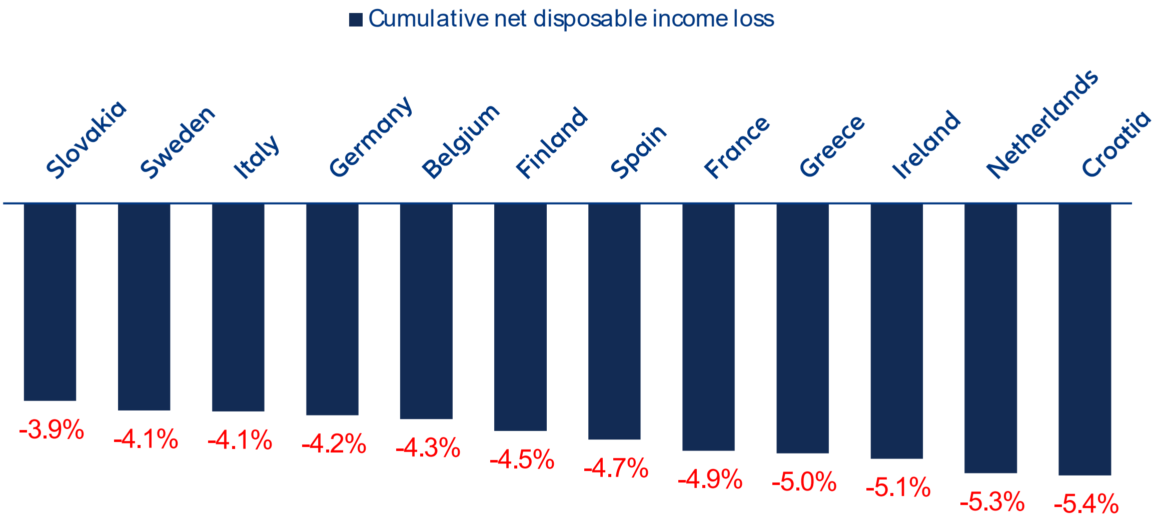
Source: Allianz Research

Floods leave a lasting mark on household incomes. Cumulative real net disposable income losses for the period 2027 – 2030 range from -3.9% in Slovakia to -5.4% in Croatia is (Figure 7). Sweden, Italy and Germany sit just above -4%, while Belgium is at -4.3% and Finland at -4.5%. The largest losses are recorded in Spain (-4.7%), France (-4.9%), Greece (-5.0%), Ireland (-5.1%), the Netherlands (-5.3%) and Croatia (-5.4%). Household income however does not collapse in the year of the flood rather the impact is lagged, which is consistent with the way disaster losses are absorbed in annual data, as reconstruction costs, business interruption and labor-market effects accumulate over the following years. Here the macro analysis begins to connect with insurance affordability. Under risk-based pricing, the same homeowners in floodplains often face higher than average flood premiums and more frequent losses. A flood therefore creates a double pressure: it weakens the income base from which protection is paid, while insurers might re-assess the risk, which could lead to higher prices.

Flood shocks lead to significant GDP losses, with the strongest relative impacts in Spain, Croatia, Greece and the United Kingdom. The largest cumulative GDP loss over 2027 to 2030 are in Spain (-1.0%), Croatia (-0.8%), Greece (-0.8%), the United Kingdom (-0.8%), France (-0.7%) and Germany (-0.7%), mainly reflecting the severity of flood events observed over the last decade. In monetary terms, Germany loses around EUR108bn relative to the baseline, followed by the United Kingdom (EUR106.3bn), France (EUR79.2bn), Spain (EUR59.2bn) and Italy (EUR56.5bn).

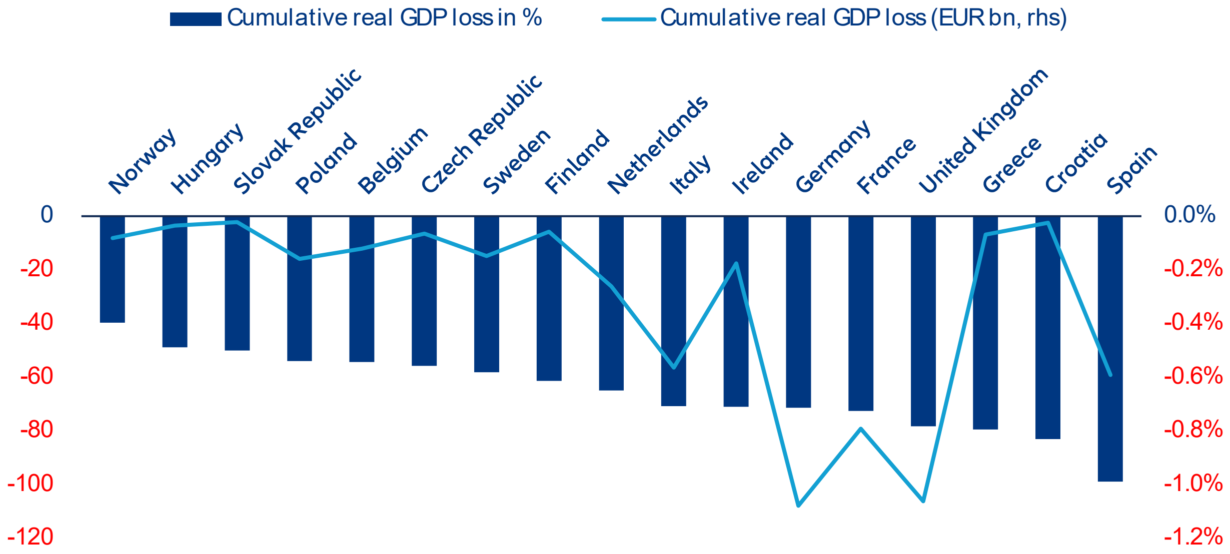
The key insight is that a flood is a local physical shock, but its macroeconomic effects spread beyond the flooded area. A flood lowers GDP not only through the immediate destruction of assets, but also through delayed investment, weaker household income, lower consumption and higher reconstruction needs. Reconstruction spending offsets part of the loss, but it does not erase it. The model result is consistent with the broader disaster literature: the immediate destruction is only the first-round effect; the more persistent cost comes from disrupted accumulation and weaker income and demand over the following years.

Figure 7: Cumulative net disposable income loss, constant 2013 price, (2027–2029) from a one-off 2027 flood shock, calibrated to the 2015–2024 average maximum depth, relative to a no-flood baseline



Sources: Allianz Research

Figure 8: Cumulative GDP loss (2027–2030) from a one-off 2027 flood shock, calibrated to the 2015–2024 average maximum depth, relative to a no-flood baseline

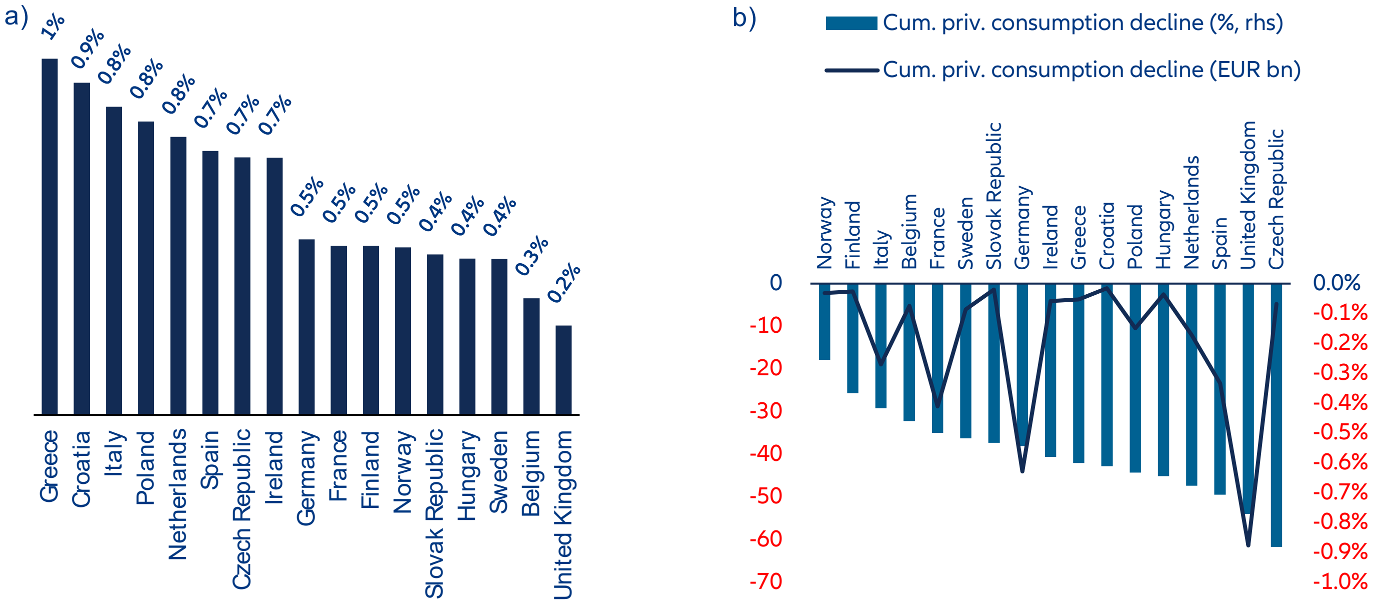


Sources: Allianz Research

Floods create a stagflationary shock by raising prices even as economic activity weakens. Damaged infrastructure, disrupted logistics and lower local supply temporarily increase prices across countries (Figure 9a). The cumulative (2027 – 2030) price-level impact is highest in Greece, at around +1.0%, followed by Croatia (+0.9%), Italy (+0.8%), Poland (+0.8%), the Netherlands (+0.8%) and Spain (+0.7%). At the lower end, the impact is more contained in Belgium (+0.3%) and the United Kingdom (+0.2%). While the inflation effect is moderate, it compounds the loss of household purchasing power.

Floods reduce household consumption by eroding real incomes and purchasing power (Figure 9b). Private consumption falls in every country, with cumulative losses ranging from around -0.3% in Norway to -0.9% in Czechia. The largest relative declines are recorded in Czechia (-0.9%), the United Kingdom (-0.8%), Spain (-0.7%), the Netherlands (-0.7%), Hungary (-0.6%) and Poland (-0.6%). In absolute terms, the largest losses are in the United Kingdom with about EUR61.3bn in private consumption relative to baseline, Germany EUR44bn, France EUR28.8bn, Spain EUR23.3bn and Italy EUR18.9bn.

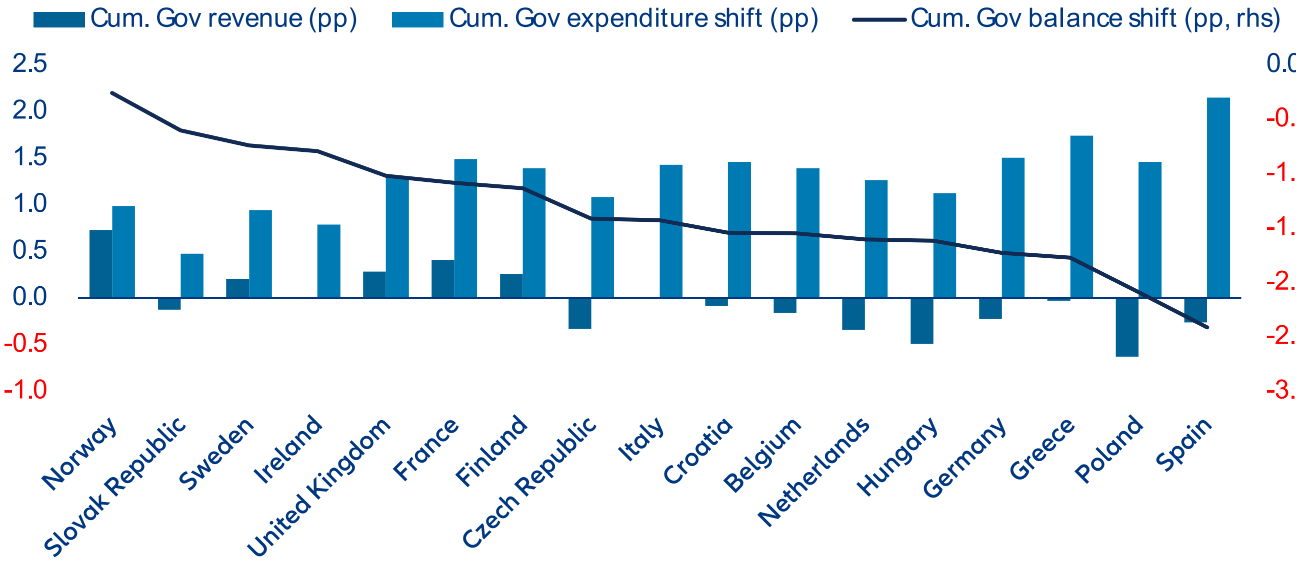
Figure 9: Cumulative inflation rise (a) and private consumption decline (b) (2027–2030) from a one-off 2027 flood shock, calibrated to the 2015–2024 average maximum depth, relative to a no-flood baseline



Sources: Allianz Research

Floods place sustained pressure on public finances, leaving governments with less fiscal space (Figure 10). The government balance deteriorates in every country in the stress test, from a relatively contained -0.3 percentage points in Norway to -2.4pp at the upper end. The largest balance shifts are recorded in Spain (-2.4pp), Poland (-2.1pp), Greece (-1.8pp), Germany (-1.7pp), Hungary (-1.6pp) and the Netherlands (-1.6pp). The deterioration is mostly expenditure-driven, reflecting emergency response, reconstruction support and the public share of recovery costs. Spain records the largest expenditure shift, at about +2.2pp, followed by Greece (+1.7pp), Germany (+1.5pp), France (+1.5pp), Poland (+1.5pp) and Croatia (+1.5pp). The revenue channel is more mixed. It is positive in some countries, including Norway, France, the United Kingdom, Finland and Sweden, but negative in others, especially Poland (-0.6pp), Hungary (-0.5pp), the Netherlands (-0.3pp), Czechia (-0.3pp), Spain (-0.3pp) and Germany (-0.2pp). This mixed pattern is plausible: reconstruction and price effects can support some nominal tax bases, while weaker real activity and consumption reduce others. What is common across all countries is the pressure on the fiscal balance. Flood risk therefore creates a public finance problem in addition to a household income and capital accumulation problem.

Figure 10: Cumulative government balance (2027–2030) from a one-off 2027 flood shock, calibrated to the 2015–2024 average maximum depth, relative to a no-flood baseline



Sources: Allianz Research

Adaptation to flood-proof our economies

Floods are already Europe's costliest natural hazard, relying most heavily on public capital. Flood adaptation requires the most public capital of all climate hazards: of the 61 adaptation measures in our taxonomy, flood protection accounts for 65% of all primarily public measures, reflecting the dominance of large-scale infrastructure, retention and spatial planning in managing flood risk.[5] The largest losses, the widest protection gap and the heaviest reliance on public investment together make closing the flood-adaptation gap not only an insurance, but a fiscal priority.

Concretely, flood adaptation is a layered risk-reduction strategy rather than a single type of investment. It starts with spatial planning: avoiding new development in floodplains, restoring natural retention areas and giving rivers more room to absorb peak flows. It then requires blue-green and grey infrastructure, including retention basins, dikes, levees, flood walls, sustainable drainage systems, porous pavements, green roofs, stormwater management, wastewater and sewage upgrades and pumping equipment. In already exposed areas, adaptation must move down to the asset level through flood-adapted construction, elevated foundations, protected utilities, backflow prevention, water-resistant materials and the relocation of vulnerable equipment above expected flood levels. Finally, these physical measures need to be complemented by risk mapping, early-warning systems, evacuation planning and insurance incentives that reward actual risk reduction. The point is not to choose between nature-based solutions, infrastructure and property-level protection, but to combine them according to the type of flood risk: fluvial flooding requires river-basin management and retention, while pluvial flooding depends more on local drainage, urban design and building-level resilience.

One of the most positive developments since 2021 is the rapid improvement in flood risk information. Traditionally, flood management focused on river floodplains, mapping areas at risk from overflowing rivers and identifying exposed assets. While these remain important, the 2021 European flood event demonstrated that destructive floods are often compound events, combining fluvial flooding, when a river bursts its banks, with pluvial flooding, flash floods caused by intense rainfall and surface water floods from overwhelmed drainage systems. These flood types differ fundamentally. Fluvial flooding typically allows somewhat longer warning times and can often

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[5] From invisible to investible: An investment taxonomy for climate adaptation | Allianz

be managed through dikes, retention areas, and coordinated water management. The German Insurance Association (GDV) reports that less than 8% of addresses in Germany lie in the river floodplains[6]. Pluvial flooding, by contrast, can occur outside mapped floodplains, develops rapidly, and depends heavily on local factors such as urban drainage, topography, and land use.

Fragmented flood management leads to structural challenges for governance, but high-resolution flood mapping can help. In Germany, for example, river flood management is largely organized at the state and basin level, while pluvial flooding is primarily a municipal responsibility. This creates a structural challenge: municipalities play a critical role in managing risk but often lack the resources, data, or capacity to evaluate and implement effective measures at scale. Tools such as the surface water flood maps in North Rhine-Westphalia highlight areas at risk from pluvial flooding, including estimates of potential water depth and velocity[7]. These maps provide an essential bridge between regional-level hazard assessment and local decision-making. In practice, this makes flood risk operational rather than abstract: municipalities can use these maps to prioritise sewer and drainage upgrades, identify locations where temporary pumping may be needed and prepare emergency access routes. They also improve public risk communication by showing which homes, schools, care facilities and critical services are most exposed, allowing evacuation planning and adaptation spending to be targeted more precisely.

Artificial intelligence is accelerating the ability to evaluate adaptation options. AI-supported approaches allow rapid scenario testing, enabling stakeholders to simulate the impact of measures such as retention basins, drainage upgrades, or structural protections before committing to costly engineering studies. While they do not replace detailed local studies, they enable municipalities, planners, and citizens to better understand and discuss risk. The value of maps and models extends beyond identifying risk, to shaping behavior, such as guiding land use, informing building standards and supporting emergency planning.

Germany after the 2021 floods as a case study for European analysis: stronger frameworks, but persistent implementation challenges. The 2021 floods made the implementation gap especially visible, and the five years since then provide a useful test of how far policy frameworks, risk mapping and local adaptation planning have actually moved from recognition to execution.

Germany has taken some important steps since the 2021 floods. One immediate response was the strengthening of early warning systems, including the introduction of alerts via Cell Broadcast (DE-Alert) to rapidly reach citizens in a potentially affected area via mobile phone during emergencies. Germany also adopted the Federal Climate Adaptation Act[8], which entered into force in 2024. This creates a binding framework for adaptation policy across federal, state, and municipal levels. It requires systematic risk analysis, coordinated planning, and measurable targets for adaptation progress. Concrete implementation is still at an early stage, as the federal framework only entered into force in mid-2024. But some measures are already visible at local level, such as improved flood risk communication, even if large-scale infrastructure projects remain slow to deliver. The updated German Climate Adaptation Strategy[9] complements this by establishing measurable targets for climate adaptation, including goals for infrastructure, land use, water management, spatial planning, business and civil protection.

There have also been improvements in flood mapping and risk communication, but delivery at scale remains slow. In response to the 2021 flood along the Ahr River, the German state of Rhineland-Palatinate revised the flood hazard maps a few months after the event. which incorporated improved hydrological understanding to better represent extreme runoff dynamics and flood extents[10]. A full revision of all floodplains in Rhineland-Palatinate was completed in February 2026[11].

Despite progress, delivery at scale remains slow. Germany's federal system spreads planning and disaster-response responsibilities across multiple levels of government and aid organisations, creating coordination challenges, and large-scale projects such as retention basins face long planning and approval timelines. The National Flood Protection Programme

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[6] „ZÜRS Geo" - Zonierungssystem für Überschwemmungsrisiko und Einschätzung von Umweltrisiken

[7] LANUK Klima

[8] BMUKN: The Federal Climate Adaptation Act

[9] BMUKN: German Strategy for Adaptation to Climate Change

[10] Überschwemmungsgebiet . Struktur- und Genehmigungsdirektion Nord

[11] Hochwassergefahren- und -risikokarten . Hochwasserrisikomanagement in Rheinland-Pfalz

(NHWSP) captures both the ambition and the lag: it bundles around 109 priority, supra-regional measures worth an estimated EUR6–7bn - co-financed 60% by the federal government and 40% by the Länder - targeting close to 1 billion m^3 of new retention and roughly 40,000 ha of reconnected floodplain,[12] and federal modelling confirms these measures would lower the peak levels of future major floods by 10–50 cm over long river stretches[13]. Yet more than a decade after the 2013 floods, only a little over EUR500m had actually flowed through the dedicated „Preventive Flood Protection" framework, with many NHWSP measures still in planning or early construction. The same lag appears locally: in the Ahr valley, communities and the district of Ahrweiler published their technical study of catchment-wide flood protection only in 2025 - four years after the disaster - with concrete measures still to be designed and built. This highlights a broader European challenge: adaptation frameworks have improved markedly, but delivery on the ground lags well behind.

The most effective flood adaptation measure — floodplain protection — is also the most politically challenging. Floodplains are natural water storage zones. When they are developed, flood risk intensifies. Giving rivers more room to flood and avoiding new development in floodplains are therefore key to risk reduction. However, this principle often conflicts with local economic and political realities. Municipalities depend on population and economic growth, which lead to development pressures—particularly in urban and waterfront areas. Additionally, floodplains are attractive to development because they are flat and require minimal grading. Another challenge is posed by rebuilding in affected locations after a major flood, either because it is permitted or required by authorities, or because homeowners seek to restore the communities they lost and remain emotionally attached to. Yet unless new construction incorporates resilience measures, these properties remain vulnerable to future floods.

Development in flood-prone areas requires strict building and planning requirements. Examples such as Hamburg's HafenCity demonstrate that building in exposed areas can be compatible with risk management, if designed appropriately. This includes elevated structures, floodable public spaces, protected utilities, and clear evacuation and emergency strategies. The key is not simply whether to build, but how—and under what conditions. If exposure cannot be avoided, it must at least be made resilient. In this way, development and nature-based flood solutions can be combined rather than treated as mutually exclusive.

Large-scale structural measures remain an important component of flood risk management, but should be used selectively. Levees, flood walls, and retention basins can significantly reduce the frequency and severity of moderate flood events. However, they also have limitations. Extreme floods can exceed design levels and overtop defenses. When this occurs, the impact can be even more severe, particularly if communities behind defenses have become less aware of the underlying risk or have accumulated additional values due to new construction. Structural protection is most appropriate where high exposures already exist, and relocation and individual property level retrofitting is not feasible or economically viable. In particular, it should not be used to justify new development as this would lead to increasing loss potential in catastrophic flood events. Importantly, it must be complemented by residual risk awareness, emergency planning, and building-level resilience.

While infrastructure plays a crucial role, properties need to be adapted at an individual building level. Especially in areas facing pluvial flooding and residual risk, flood-adapted building should become standard for all new construction. Already in 1995 the LAWA (Bund/Länder-Arbeitsgemeinschaft Wasser, Germany Working Group on Water Issues) concluded that adapted construction and individual prevention at the property level is the most cost effective and sustainable risk reduction method. Resilient renovation includes:

- Raising critical systems (electricity, heating)
- Choosing more resilient heating systems (e.g. replacing oil systems that cause contamination and avoiding wood pellets that expand when wet and can damage structures)
- Sealing entry points
- Installing backflow prevention
- Using water-resistant materials for walls, insulation and floors.
- Designing spaces for easier recovery

Tools such as the Hochwasserpass, a building specific flood risk certificate, help translate technical risk information into actionable guidance for property owners. They increase awareness, support

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[12] 10 Jahre Nationales Hochwasserschutzprogramm (NHWSP)

[13] Untersuchungen zur Ermittlung der Wirkungen von präventiven Hochwasserschutzmaßnahmen im Rahmen des Nationalen Hochwasserschutzprogramms

preparedness, and empower homeowners to take preventive action. Adapted construction also includes:

- Avoiding living spaces in basements
- Elevated foundations that allow for waterflow below or at the design flood level
- Waterproof material for walls, insulation and floors (at least up to the design flood level)
- Low value occupancies in ground floor below the design flood level.

These measures do not fully eliminate risk, but they significantly reduce the damage and recovery time. This is particularly important given the long disruption associated with flood events.

The economic case for targeted flood adaptation is strong and could significantly reduce economic damage. Without action, river-flood losses in the EU and UK are projected to rise more than six-fold to nearly EUR48–50bn a year under 3°C of warming by 2100, with close to 500,000 people exposed each year.[14] Coastal flooding compounds the picture: absent adaptation, EU+UK annual coastal-flood damage could climb from about EUR 1.4bn today to nearly EUR240bn by 2100, of which roughly 95% could be avoided by pairing moderate mitigation with raised defenses.[15] Using flood-risk modelling and cost–benefit analysis, the European Commission Joint Research Council (JRC) finds that reducing flood peaks with retention (detention) areas is the most economically attractive strategy: it can cut projected 2100 river-flood losses from about EUR50bn to EUR 8bn a year – an ~84% fall in expected losses, roughly back to today's risk level – while returning about EUR4 for every EUR1 invested over 2020–2100.[16] Strengthening dykes delivers a somewhat lower risk reduction (~70%) for comparable annual outlay, and building-level "damage-reduction" measures (the property-level retrofits discussed above) are found to be cost-efficient in most EU countries. These returns sit well within the wider evidence base: across all hazards, the Global Commission on Adaptation puts benefit–cost ratios for resilience investment at 2:1 to 10:1, and estimates that USD1.8trn invested globally across five adaptation priorities in 2020–2030 could generate USD7.1trn in net benefits.[17]

Adaptation is therefore preventive fiscal and insurance policy. As insurance premiums reflect expected losses, public investment in flood defences and resilient construction is also an investment in insurance affordability and macro-financial stability. Despite these climate-induced trends, insurers have expanded flood coverage in many countries over the past 25 years. The protection gap for residential buildings in Germany shrank from 80% in 2003 to 43% in 2024, even as the building stock grew by three million structures. While the gap remains significant, it is not caused by a lack of insurance availability. Instead, in reflects limited awareness of flood risk among property owners and affordability challenges for those exposed to higher levels of risk.

A balanced approach to flood insurance: risk-based pricing and risk reduction. Coverage absorbs losses for individual homeowners after floods, but it also signals the presence of risk. Pricing insurance based on risk is therefore essential, as it provides incentives for adaptation and discourages development in areas highly prone to flood events. Risk-based pricing is an important element of fairness within the insurance pool, as it helps ensure that premiums more closely reflect the level of risk each policyholder contributes, thereby limiting cross-subsidization between lower- and higher-risk properties. However, without complementary measures, it can create affordability challenges for vulnerable households. Effective approaches combine:

- Risk-based pricing
- Ability for customers to choose limits and deductibles
- Support for risk reduction
- Incentives for resilient behavior
- Public-private partnerships with a focus on risk reduction

Public–private partnerships (PPPs) have long been used in Europe to address flood risk where private insurance markets alone cannot provide affordable and comprehensive coverage. Established systems such as Spain's Consorcio de Compensación de Seguros and France's Caisse Centrale de Réassurance (CCR) represent two mature models. Both operate on a risk-transfer mechanism in which risk is pooled nationally and backed by the state, ensuring broad coverage also in high-risk areas. In Spain, the Consorcio provides compensation for extraordinary risks—including floods—through a mandatory surcharge on insurance policies. France's

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[14] JRC Publications - Adapting to rising river flood risk in the EU under climate change

[15] JRC Publications - Adapting to rising coastal flood risk in the EU under climate change

[16] Cost-effective adaptation strategies to rising river flood risk in Europe | Nature Climate Change.

[17] Adapt now: a global call for leadership on climate resilience - Global Center on Adaptation

CCR works through a Nat Cat scheme, which combines private insurers with a state backed reinsurer. The premiums increased significantly in 2025, after years of increasing risks and little focus on mitigation. Encouragingly, the Barnier Fund, which had been introduced dedicated to funding prevention, has recently returned to the political agenda. In the past it was chronically underfinanced and underused.

Ireland and Germany are exploring PPP approaches to resolve existing protection gaps and growing affordability pressure. In Ireland, a government-led working group is developing a long-term strategy to address access to flood insurance. The group has acknowledged that the problem "cannot be solved by insurance alone" and requires a public–private partnership approach. In Germany, the GDV is calling for a comprehensive natural hazard strategy that would cover extreme risks by combining universal insurance coverage (with an opt-out solution), binding adaptation measures and state participation. For both countries, these exploratory frameworks highlight an important implication for resilience investment: PPPs are most effective when paired with risk reduction. If insurance pricing reflects underlying risk, then public funding and policy should prioritize measures such as floodplain restoration, resilient construction, and infrastructure upgrades that reduce expected losses over time. In this way, PPPs can move beyond simply redistributing risk toward actively lowering it, thereby supporting long-term affordability and reducing future economic losses.

Appendix

A1 – The impact of floods on capital formation

Floods bear on capital through two channels that pull a measured investment series in opposite directions. They destroy or damage part of the existing physical stock (buildings, factories and equipment, transport and utility infrastructure, agricultural land and crops) and they raise the uncertainty under which firms commit to new projects. Both of these depress investment in the immediate aftermath. Post-flood reconstruction is recorded as gross investment, so a flood can leave a positive imprint on the same aggregate once rebuilding gets under way. The net effect on a flow measure of investment is therefore an empirical question, and the sign and timing are what the regressions below are designed to recover.

The wider literature frames why the answer matters. Hsiang and Jina (2014)[18] find that the national-income losses from tropical cyclones are persistent and do not recover within two decades, pointing to a capital channel that compounds rather than heals. At the city scale, Kocornik-Mina et al. (2020)[19] reach a more sanguine conclusion for floods specifically, documenting rapid recovery of local economic activity and little permanent relocation. The companion analysis in this paper places investment at the center of the heat transmission, in line with Casey et al. (2024)[20], who argue that standard climate-economy models understate damages to capital-intensive activity. The exercise here asks the parallel question for floods: whether European gross fixed capital formation carries a detectable, datable response to flood events.

The analysis uses a balanced country-year panel of 36 European countries[21] over 2010–2024 (540 observations), with no missing values in the outcome. The dependent variable is the log of gross fixed capital formation for the total economy (the AMECO series labelled OIGT), measured in volume terms at 2020 constant prices. Because the series is real and expressed on a national-currency base, country fixed effects absorb level differences in currency base and price level without contaminating the estimates with inflation.

Flood exposure is constructed from Copernicus Emergency Management Service (CEMS) activations aggregated to the country-year level[22]. Two treatment forms are used. The first is a binary indicator equal to one when a country records any flood activation in a given year; this is the case in 47 of the 540 country-years, spread across 17 countries. The second, which is the severity measure carried into the headline specification, is the average across affected NUTS-2 regions of each region's maximum inundation depth in centimeters, entered as log(1 + depth). This measure is a regional average of regional maxima rather than the single deepest point recorded nationally; among treated country-years it averages roughly 125 cm.

Specification

The baseline is a two-way fixed effects (TWFE) model with country and year fixed effects, estimated in levels of log OIGT (Eq. 1). Identification rests on the meteorological exogeneity of flood timing conditional on the fixed effects: year effects absorb common shocks (the pandemic, euro-area financial conditions), country effects absorb time-invariant exposure and structure, and the flood term picks up within-country, within-year deviations.

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[18] The Causal Effect of Environmental Catastrophe on Long-Run Economic Growth: Evidence From 6,700 Cyclones | NBER

[19] Flooded Cities - American Economic Association

[20] Understanding climate damages: Consumption versus investment - ScienceDirect

[21] Main results consider only 17 European countries, where flood events were recorded for the period 2015 – 2024.

[22] We use flood depth data from ClimRad, a tool developed by Allianz Research and EarthianAI. CEMS Rapid Mapping is activated on request by authorised users (national civil protection authorities, the ERCC and others), so activations reflect both the severity of an event and the decision to request mapping. This means that coverage is not fully uniform across countries or constant over time, as activation practice and user uptake have evolved since the service became operational in 2012. We therefore treat the activation count as an indicator of significant, officially recognised flood events rather than a complete census of all flooding. We rely on the severity measure (inundation depth) rather than activation frequency alone for the headline specification.

$$\ln\left(\mathrm{OIGT}_{\mathrm{it}}\right) = \beta.\,\mathrm{Flood}_{\mathrm{it}} + \alpha_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}}\ (\mathrm{Eq.}\ 1)$$

Because flood damage propagates into investment with a delay the preferred specification is a distributed-lag extension that enters the flood term contemporaneously and at four annual lags (Eq. 2). A Wald test on the sum of the lag coefficients summarizing the cumulative multi-year response. Standard errors are clustered at the country level throughout (36 clusters in the full panel).

$$\ln\left(\mathrm{OIGT}_{\mathrm{it}}\right) = \sum_{\mathrm{k}=0}^{4} \beta_{\mathrm{k}}.\,\mathrm{Flood}_{\mathrm{i,t-k}} + \alpha_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}}\left(\mathrm{Eq.}\ 2\right)$$

Here Flood denotes the log average maximum depth, log(1 + depth). The contemporaneous-only model (Eq. 1) is reported for reference; the distributed-lag model (Eq. 2) is the one from which the headline estimate is drawn. Because the number of clusters is modest, the inference on the headline coefficient is cross-checked with a restricted wild cluster bootstrap (Rademacher weights, B = 1999).

Results

Table A1 reports the distributed-lag estimates for the depth specification, where the effect of a single flood is allowed to play out over the event year and the four subsequent years. The contemporaneous coefficient is small but significant at the 10% level. The estimated effect grows over the following two years and is largest at the second lag, where a one-log-point increase in average maximum inundation depth is associated with a reduction in capital formation of about 1.1% (–0.0108, $p < 0.05$). This is the only lag individually significant at the 5% level and the coefficient the paper carries forward. By the fourth year after the event the sign turns positive, though far from significant, which is what one would expect if reconstruction investment re-enters the capital formation measure and partially offsets the earlier shortfall. The depth regressor is zero in non-flood years, so moving from no flood to an average-severity event (log(1 + 125) ≈ 4.8) implies a cumulative shortfall on the order of 5% of capital formation two years out.

Table A1. Distributed-lag TWFE estimates: log gross fixed capital formation (OIGT) regressed on flood-depth severity in the event year and the following four years (lags 0–4).

Log avg-max depth	
Flood depth (t)	-0.0077* *(0.0042)*
Flood depth (t-1)	-0.0088* *(0.0047)*
Flood depth (t-2)	-0.0108** *(0.0045)*
Flood depth (t-3)	-0.0067 *(0.0050)*
Flood depth (t-4)	+0.0042 *(0.0095)*
Sum of coefficients	-0.0298
Fixed effects	Country + Year
SE cluster (clusters)	Country (36)
Observations	396

Notes: Dependent variable is log OIGT (AMECO gross fixed capital formation, total economy, 2020 constant prices). The treatment is the log average maximum depth, log(1 + depth), entered at t to t-4. The common-sample size (N = 396) reflects the loss of early years to the lag window. Standard errors clustered by country in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Allianz Research

A2 –The impact of floods on household disposable income

Floods reach household income through three channels that operate at different speeds. The most immediate is direct asset destruction and damage which erodes both wealth and the income those assets generate. The second is labor-market disruption, as flooded workplaces cost days of work and, in the worst-hit areas, push some workers out of employment entirely. The third is business interruption, as damaged premises, markets and transport links suppress local activity and the wages and profits that flow from it. None of these is instantaneous in annual data: most damage is incurred and absorbed over the months following an event, so the income response is expected to build over one to two years rather than only in the year of the flood itself.

The analysis uses a balanced panel of 72 NUTS-1 regions across 15 European countries over 2013–2023 (792 region-year observations). The dependent variable is net disposable household income per inhabitant (ESA 2010, item B6N), drawn from the Eurostat regional accounts (nama_10r_2hhinc). Because B6N is published in current euros, the series is deflated to real 2013 euros using a cumulative price index built by chaining annual HICP headline inflation to a 2013 = 100 base.

Specification

The baseline model is a two-way fixed effects (TWFE) model with NUTS-1 region and year fixed effects (Eq. 1). Region effects absorb time-invariant structure (geography, industrial mix); year effects absorb common shocks, such as ECB policy and pandemic transfers. Conditional on these, flood timing is treated as quasi-random, since extreme-precipitation events are driven by meteorology rather than by income trajectories.

$$\ln\left(\mathrm{Y_{it}}\right) = \beta.\,\mathrm{Flood_{it}} + \alpha_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}}\ (\mathrm{Eq.}\ 3)$$

Because damage is absorbed over the months after an event, the retained specification is a distributed-lag version of Eq. 3 that enters log maximum depth at t, t – 1 and t – 2, tracing the dynamic profile rather than compressing it into a single contemporaneous coefficient. This is the same depth-in-lags form carried forward in the capital analysis, which keeps the severity measure and the dynamic structure consistent across outcomes. The identifying assumption is that, conditional on the fixed effects, the timing of floods is unrelated to prior income trajectories; a pre-trends check in growth rates supports this, with pre-flood coefficients indistinguishable from zero (Wald p = 0.285).

Results

The retained estimates are the distributed-lag depth specification, reported in Table A2. The contemporaneous effect is small and insignificant (–0.33% per log-point of maximum depth, p = 0.111), in line with the annual-data timing, then becomes significant at the first and second lags (–0.30%, p = 0.031; –0.37%, p = 0.027), summing to a three-year cumulative effect of about –1.0% per log-point of maximum depth. Because both sides of the regression are in logs, the coefficients are elasticities of real income with respect to flood depth: a flood twice as deep is associated with a cumulative real-income loss roughly 0.7% larger over three years (–0.0100 × ln 2).

Table A2. Retained specification : distributed-lag log maximum depth, real household income per inhabitant

Log max depth	Coefficient	p-value
Flood depth (t)	-0.0033	0.111
Flood depth (t-1)	-0.0030**	0.031
Flood depth (t-2)	-0.0037**	0.027

Notes: NUTS-1 + year TWFE; log maximum depth entered at t, t–1, t–2. Coefficients are elasticities of real income with respect to maximum depth. SE clustered at country (15 clusters). N = 648. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Allianz Research

A3 – The construction and interpretation of flood-depth data

Flood depth gives the macro shock its physical scale. The variable is not a count of flood events and it is not a regional-average water level. It is constructed from satellite-mapped inundation footprints, linked to official event records, and then aggregated to the country-year or regional panel used in the regressions. This matters because a depth of 125 cm should be read as the characteristic depth of flooded footprints within an event-region, not as the depth of water across the whole country or region.

The underlying event dataset combines several layers of information (Table A3). The primary source is the JRC satellite-derived flood-depth map catalogue for Europe, which provides 20 m raster maps for 2015-2024 with pixel values expressed in centimetres. These maps are derived from systematic flood detection in the Sentinel-1 radar archive, with water depth reconstructed from the mapped flood extent and terrain elevation. Permanent and seasonal water bodies are flagged separately and excluded from the depth statistics. Copernicus EMS Rapid Mapping products are used to attach named event information, area of interest, flood extent and sensing-date metadata. EU-Hydro, geoBoundaries and Natural Earth are then used to attribute the footprint to the nearest river, the relevant administrative unit and the country.

The JRC maps are spatio-temporal clusters rather than named disaster events. Each relevant map was therefore matched to a Copernicus EMS Rapid Mapping activation by comparing the map date and the first-level administrative units intersected by the flood raster with activation records. Candidate matches were then checked visually in QGIS by overlaying the satellite flood footprint with the CEMS delineation products. This step avoids treating anonymous raster clusters as events before they are anchored to a documented flood episode.

For each matched map, the raster is processed into contiguous flooded footprints. Each footprint receives GIS attributes: planimetric area, country, administrative unit, nearest EU-Hydro river reach and zonal water-depth statistics. The matched CEMS vector product is then joined to the footprint, adding event-level information such as activation code, area of interest, flood type when available, sensing source and acquisition date. The final record therefore corresponds to a flood footprint within one event-region, rather than to an entire national event.

Table A3. Flood-depth dataset: source inputs and role in the construction

Input	Role in the construction
JRC satellite-derived flood-depth maps for Europe	Primary source of flood extents and water depths; 20 m rasters, with depth values expressed in centimetres.
Copernicus EMS Rapid Mapping vector prodcuts	Event delineations, areas of interest, maximum flood extent where available, sensing source and event metadata.
EU-Hydro river network database	Attribution of flooded footprints to the nearest river reach.
geoBoundaries and Natural Earth administrative boundaries	Country and first-level administrative-unit attribution, plus screening of flood locations.
QGIS manual verification	Visual overlay of satellite footprints and CEMS delineation products before the consolidated event table is retained.

Source: Allianz Research based on JRC, Copernicus EMS Rapid Mapping, EU-Hydro, geoBoundaries and Natural Earth

The depth statistics are deliberately conservative. First, each contiguous flood footprint is summarized by the median of its 20 m pixels. This reduces sensitivity to isolated extreme pixels near channels, in topographic lows or in areas affected by elevation-model artefacts. Second, the event-region median, mean and maximum are calculated across these footprint medians. The reported maximum is therefore the characteristic depth of the most severely inundated footprint, not the single deepest pixel in the event. This distinction is important because the deepest pixel can be much larger than the economically relevant flooded-area statistic.

The statistics describe flooded land only. A mean or maximum depth of 125 cm does not mean that the wider NUTS region, or the country, was under 1.25 metres of water. It means that, within the inundated footprints identified for that event-region, the representative footprint depth was around 1.25 metres. Areas outside the mapped footprint are dry by construction and do not enter the depth statistic.

The statistics are also not exposure-weighted. A footprint in a sparsely populated field and a footprint in a dense urban area receive the same weight when the event-region depth distribution is formed. Exposure is captured separately through the affected-population attribute and through the macroeconomic panel structure. The depth variable should therefore be interpreted as hazard intensity, not as damage, exposed capital or population-weighted risk.

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