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AN ECONOMIC PERSPECTIVE AND A REASONING AROUND COST/BENEFIT ANALYSIS FOR ENHANCING FLOODS MITIGATION MEASURES AND REGIONAL RESILIENCE

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SUMMARY

Starting from the early 1990s there has been an increasing attention towards the economic dimensions of natural disasters, mainly referring to the damage accountability, from the one side, and, more recently, to the contribution of the economic thinking and tool boxes in enhancing action and funding for risk and damage mitigation facing natural disasters.

Cost-benefit analysis (CBA) in particular, applied to natural hazards is becoming more and more popular as it makes it more clear and easy to understand the relationship between investments in mitigation measures and the related effects. The essay introduces and discusses these issues, offering methodological elements as the results of the DG ECHO funded European research project "IDEA – Improving damage assessment to enhance cost-benefit analysis".

Two main issues will be discussed. The first refers to the methods and tools to better identify the whole of the costs and benefits to be considered, looking at damage data and mitigation measures able to produce effective images of both values prone to risks and investments needed for mitigation measures. This in the light of the high variety of local conditions influencing the impacts of events, even just floods, on territorial subjects and objects, with reference to exposure and vulnerability. The second refers to the identification of the elements needed to develop an effective cost/benefit analysis, from a methodological and operational perspective, where effective means able to sustain real decision making towards the enhancement of regional resilience.

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1. Introduction

In disaster risk reduction matters, among which we consider the development and implementation of solutions and interventions for floods mitigation and the enhancement of regional resilience, there is an increase in the contribution of economists in multidisciplinary working groups, integrating other study fields with their disciplinary approaches (see among others, the synthesis offered in Rose, 2017).

On the damage accountability side, studies have been actively developed starting from the early 1990s (as an example, see Howe and Cochrane 1993). The economic dimensions and impacts of damage caused by natural disasters definitely became object of specific research activities during these years, as the report from the USA Committee on Assessing the Costs of Natural Disasters (National Research Council, 1999) and the research activities supported by the European Commission (Van der Veen et al. 2003) demonstrate. In these research documents, damage assessment and accountability methods have been developed as an instrument to support public decision-making and action in the aftermath of disasters, in order to understand the related economic and social impacts and the financial needs for recovery and reconstruction. Initially, the economic approaches were meant to enhance the capabilities to recognize all damage typologies – direct, indirect and systemic – involving a specific territorial area. In particular, the possibility and capability to identify satisfactory assessment methodologies, both in physical (number and typologies of territorial subjects and objects exposed to hazards and their vulnerability) and value terms (using money as the measure unit) have been explored. Starting from these, different evaluation methods have been object of discussion and testing activities over time at the international level (see, among other early studies, Hubert and Ledoux 1999). In the last 15 years the interest on damage accountability has considerably grown, both at public and private level (the latter for the insurance market purposes in particular), and different evaluation methods have been object of discussion in an increasing number of studies, as damage assessment revealed over time to be more complex than previewed in the early studies. Damage remains the benchmark for analyzing past predictions and key element to build better correlations between exposition and vulnerability evaluations. It is however clear that, to obtain these goals, damage estimation must exist as a concrete, precise and stable practice and the results be recorded and easily accessible for users. According to this logic, damaged elements recognized and evaluated after a disaster become precious information sources to assess the future potential impacts of hazards and contribute in the design of disaster scenarios, both in the already damaged territories or as a reference in others. This gave floor to new discussions (Cochrane 2004a, Johnson et. al 2007) on assessment methodologies and the tools to overcome uncertainty and the lack for reliable data. All authors anyhow agree that, even when stochastic and uncertain, damage assessment remains one of the mainstays of risk management and risk reduction, the basis for choosing among many possible intervention options. Some literature reviews are now available about such debate (like Meyers et al. 2013, Shreve and Kelman 2014, Mechler 2016).

2. The contribution of the economic approach and CBA in disaster risk reduction and territorial resilience

The assessment methods and tools to quantify some of the damage categories are central elements when referring to the economic approach to disaster risk reduction and resilience matters. The debate developed during the last two decades agrees that damages suffered by populations and built environments have been much more clearly assessed than in the past for quite all events. Less evidence is available, on the contrary, referring to damage to other damage categories like the economic sectors and the whole of the local level territorial resources, such as the cultural heritage, the natural environment and the community's identity and social models (some of these elements are discussed in Mechler 2016). This is mainly due to the incidence of indirect and systemic damage (Cochrane 2004a and 2004b), which is many times underestimated (Shreve and Kelman 2014) but also on the losses

suffered by the territorial systems looking at intangibles, public and common resources and cultural and historical heritage (Pesaro 2005).

In economic sectors, for instance, indirect and systemic damage may be huge and the time needed for restoration or reconstruction may become crucial factors for the capability of a whole territorial system to start again with its “everyday life”. These factors should be better recognized and deepened, the costs being related to the cascade of impacts coming from business interruptions (direct or because of the interruption of lifelines and other territorial infrastructures and services; see Rose and Huyck, 2016), rebuilding and reconstruction investments and time needed, substitution of machineries and production materials, injuries to workers. This may result in a deep loss of competitiveness and reduction of market shares. So high, sometimes, to pull economic subjects to stop their activities. It is therefore easy to understand how indirect and systemic losses might weight in terms of future development and resilience of the territories hit by natural disasters.

Looking at the whole of the resources a territorial area can rely on to sustain its production and consumption models and qualitative and quantitative growth, the economic perspective suggests to account not only direct quantitative damage, using money as its measure unit, but also indirect and systemic damage and losses even if not easily quantifiable and measurable. This, for instance, when the lost resources are public, not renewable or have a very long regeneration time, such as, as already mentioned above, for cultural heritage, natural environment, cultural landscapes, community identity and social models. Monetization models have been developed in the field of environmental economy, first, and in risk and damage matters afterwards, but still, monetary evaluation remains very difficult (see, among others, Meyers et al., 2013). This, as it will be seen in the following paragraphs, can reduce the feasibility of CBA in disaster risk reduction, as it is not possible to take into account the whole of the values prone to risk from a direct quantitative monetary perspective, to be compared with the direct and clear costs of the mitigation measures. When the reference area is rich in cultural heritage, for instance or when the indirect costs cannot be adequately detected, CBA reliability itself weakens as a decision making tool for selecting the most effective mitigation measure among the possible ones. The loss of non-renewable values or potential very high indirect losses might actually suggest implementing expensive solutions even if not directly comparable to the dimensions assessed for the avoided damage. The evidence itself of the existence of such “definitive” potential losses of resources might make the expenditure for the reduction of risk and damage even more desirable and crucial, enhancing the desirability and acceptability of expenditure (investments) in prevention actions and territorial and community resilience projects and solutions. As a matter of fact, from an economic perspective, the costs payed to reduce losses as much as possible mean resilience, because it means to maximize the protection of the whole of territorial resources, engines and basis for future development or precious and irreplaceable heritage from the past. Moreover, avoided damage also means less emergency costs and time to recover from the disaster impacts, values very difficult to forecast in advance, also due to the variability of events themselves. Finally, costs in risk and damage mitigation measures may mean benefits coming from the enhancement of territorial and community resilience itself, seen as a strength of a certain area and making it more attractive for people and economic subjects.

On the other hand, even if the incidence of the non-monetizable values influence the potentials of CBA, it remains an important tool to rely on. In a decision-making framework, the main question is how to choose among different possible action/intervention alternatives using an economy-based toolbox, whose strength also lies in the use of quantitative measure units, able to offer clear-to-read results to support and address a selection process that, many times, takes place at the policy level. Moreover, it enables the possibility to look at the results envisaged for different mitigation measures not only for what concerns the technical/technological and operational performance, linked to the physical capability to face hazards and the related events, but also in terms of investments effectiveness.

This takes also to another crucial element, that is the suffering of finance which characterizes many territorial areas and countries, mainly affecting the public subjects but having effects also on private

spending options. Such sufferance creates the conditions for the development of tools to support decision making processes among investments, comparing different mitigation measures models, different expected effectiveness results due to local specificities, different impacts of the undertaken measures and possible negative externalities (see for instance mitigation measures producing important interferences with natural environment and cultural landscape).

The results of a CBA might be effective also in the light of a common problem decision-makers have to face very often, that is the perception of direct and quantifiable costs related to mitigation measures implementation. Quantified costs, even when related to damage prevention, are much more clear and easy to perceive than the possibility of a reduction of potential damages and losses in an uncertain and not visible or known future. As much uncertain an event is, which many times also means the much devastating it might be (referring to the relationship between return time and severity of natural disasters), as much low the perception of the value of the avoided future damages is. The more today's mitigation costs are clear but not directly comparable to future damage decrease, the more difficult is to obtain consensus on expenditure (both public and private) in time of peace. This is a core matter, as the predisposition to investments in mitigation measures is a milestone in enhancing the implementation of disaster risk reduction policies and in the involvement of territorial subjects. In places where floods are more likely to happen and in which there is a kind of "tradition" in facing floods, the perception about the advantages of prevention is, for instance, higher. If looking at the "extreme" case of Venice, it is clear how preparedness is central to maintain the city alive. Something perceived as normal because floods, the so-called *acqua alta* phenomena, are expected and previewed on a daily base. Looking at the behaviors of public authorities, residents, shopkeepers and businesses (especially those linked to tourism), expenditure in defense measures and preparedness has become "ordinary". Some of these have even become a local trademark, like the bulkheads and shutters for the front doors, moving up from the floor to close the shops and houses entrances or the gangways to walk over the water in open spaces. Venice prevention measures also mean other less visible actions. In restaurants, there are places where to put tables and chairs in case of water coming inside, electrical devices and plugs are positioned above the floor level, walls are protected with water-resistant coverings, etc. Advices are also normally given to tourists, like to take cash with them as the flood might stop cash machines and the shops devices for credit cards (AdnKronos, 2009).

In such a conceptual framework, CBA should be regarded as an effective tool even when "only able" to identify the whole of the knowledge elements needed for addressing policy makers in choosing among many different possible measures and interventions for reducing damage and risk. This even when some of the "matters in the list" cannot be directly assessed in money terms. As a matter of fact, quantitative measure units, even when not expressed in money terms (even if monetization is preferable), are needed to enlighten positive and negative evidence and impacts of different mitigation measures options and therefore address decision makers in the selection process.

3. The contribution of CBA in flood risk and damage management and reduction

The use of CBA analysis in order to enhance the implementation of a disaster mitigation measure relay on the concept of intervention profitability, which, at its turn, refers to the capability of investments in mitigation measures to obtain the expected outcomes in terms of risk prevention and/or damage mitigation. It is a method to compare the whole of the direct costs associated with each typology of mitigation measure and the whole of the results of it, measured as the total value of the avoided damage and losses plus the benefits coming from the increase in safety and territorial quality. Such method can therefore sustain the decision makers by making available knowledge about the positive results attainable by way of the expenditure referring to a certain mitigation measure to be implemented.

In this conceptual framework, CBA is seen as an ex-ante decision-making tool, which calls for the capability to develop the assessment process in an ex-ante perspective. This is important to underline

because the prevention concept is involved. Mitigation measures in flood risk allow the system to act both in risk and damage mitigation and reduction. The action on risk mitigation appears more effective because the investments work on the reduction itself of the flood risk reduced exposition, no matter how vulnerable the exposed subjects and objects are. Working on the damage reduction site means, on the contrary, the capability to recognize and intervene on exposure and vulnerability of a great variety of individual situations, and identify the potential loss of territorial resources/values which could be not replaceable with others or be easily restored/rebuilt. Finally, it is important to consider the economic subjects' viewpoint if a flood occurs. According to forecast capabilities but also to climate change, floods appear to be more and more disruptive and the damage might be so high, compared to the territorial and social specificities and working framework, that there might be not anymore the conditions to continue producing goods and services to sustain the life of the concerned area. Mountain and internal areas are, for instance, very prone to such additional risk (Botzen et. al 2017). Mitigation measures have therefore to be identified and mitigation costs have to be evaluated also according to such potential dynamics.

Once stated the importance to make it more visible and understandable the ratio between mitigation effectiveness and implementation costs, the next step is related to how to concretely recognize the "list" of costs and benefits suitable for describing the risk of a certain territorial area and how to evaluate and monetize them. This because there is a high variety of local conditions influencing the impacts of events, even just floods, on territorial subjects and objects, with reference to exposure and vulnerability. Moreover, the accounting of potential damage has to be related to a realistic dimension and severity of the potential risk affecting the area, which means related to the probability of an event with different possible destructive consequences. The experts in the economic appraisal should therefore work nearer to risk and damage scientists, engineers, architects and other experts able to recognize the exposed elements and to identify and understand their vulnerabilities according to the severity of events, thus producing an image of the components of the potential damage to be finally evaluated in CBA.

The evidence of the economic and territorial effectiveness of measures to mitigate risk and damage is increasingly important as floods destroying power is growing at the world level. This both if assessed in terms of lost people and territorial objects or in terms of economic losses (at the EU level see European Environment Agency 2010 and 2016). Such dynamics are related to two main issues. The first is the growth, in number and values, of territorial objects (buildings, infrastructures and other physical elements), subjects and activities exposed to floods. The second is an increase in the frequency and severity of floods due to climate change (at the EU level see European Environment Agency 2010). Why is it therefore so difficult to share consensus on mitigation measures (apart from the difficulties in modelling the potential damage to be compared to)? The dialogue with territorial active subjects and stakeholders reveals to be very important, as their viewpoints and demands are central components in the CBA design. Costs and benefits to be compared are, as a matter of fact, related to the related system of stakeholders, their activities, resources and expectations in terms of development and quality of life and work. Linked to this, another question arises: who is paying for what and for whose advantage? This particularly referring to public/private expenditure and public/private impacts of such expenditure which, in presence of suffering finance, should better consider emerging trade-offs between mitigation and compensation. Over time, apart from the evidence that the "pure" compensation for the entire suffered damage is not any more sustainable for public systems alone, the importance of mitigation and prevention measures is increasing. This also because of the value of human lives and in presence of non-renewable and highly valuable territorial resources and heritage, which are more and more considered and perceived as fundamental resources and values. Mitigation measures become therefore also means of territorial resilience enhancement.

It is important to underline that the approach proposed in the IDEA project for the development of CBA is the economic one, as in Brouwer and van Ek (2004) (Pesaro et al. 2016). The distinction is between the economic approach, when the costs and benefits associated with a policy or project ensure

a broader sense including effects on third parties, and the financial approach, mainly based (when not only based) on a cash flow analysis. Economic CBA aims at highlighting the whole of the values – externalities - incorporated and produced by a certain mitigation measure, even when it is not possible, or very hard, to measure it by way of money as the quantitative measure unit. This is particularly important in flood risk as all hazard cycle phases are concerned. As said above, it is possible to intervene to mitigate the risk itself of a flood or the exposure or its vulnerability. Hazard refers to the probability a flood occurs and with which physical characteristics, such as duration (time needed for the reduction of the water level) and severity (inundation maximum depth) of the event. Exposure assembles the exposed elements (territorial subjects, objects and activities) to the hazard in terms of quantity and values in danger of inundation compared to the flood event characteristics. Vulnerability addresses the factors, characteristics and other conditions that can make the exposed elements more fragile and prone to potential damage. The effectiveness of mitigation measures, might they be structural/physical or non-structural, is therefore assessed in terms of capability to reduce the – economic – impact of floods working on the reduction/mitigation of risk, exposure and vulnerability.

Several studies are available introducing the cost-benefit analysis in order to assess the economic feasibility of implementing flood risk management strategies (Botzen et al. 2017). Brouwer and van Ek (2004), for instance, justify changes in land use and floodplain restoration in the Netherlands based on both cost-benefit and multi-criteria analysis when ecological, social and economic benefits in the long term are included. Jonkman et al. (2004) investigate the application of the CBA in decision-making on flood protection measures in the Netherlands as well. Policy and decision makers should use the information provided by the CBA as an advice about the economic feasibility of the flood prevention measure, but combined with other relevant types of information that may exist, such as the technical feasibility of the measure. Joseph et al. (2014) apply conceptually the cost-benefit analysis framework to property level flood risk adaptation measures in the United Kingdom and show what are the costs and benefits involved with the actions of homeowners in the attempt of adapting their property and behavior to flood risk. It has anyhow to be said that, according to the EU Flood Directive of 2007, CBA is mandatory in supporting public decision making to face flood risk in all member countries of the European Union.

In IDEA Project, the proposed challenge is to try CBA exercises from data available from real events: the floods which hit Umbria Region (Italy), in 2012 and 2013 (Pesaro et al. 2016 is the general reference for the presentation of such work). From the benefit side, avoided costs are assessed starting from the forensic analysis of post flood damage. From the costs side, different damage mitigation measures have been considered to be implemented in buildings, starting from the knowledge of the typologies of the real damages and, therefore, making realistic hypothesis about the possible concrete structural interventions which could have reduced the impacts of the real flood events if implemented before. Moreover, a non-structural measure has been considered, related to the management of a dam made for the production of hydroelectric power. Here the mitigation cost is represented by the economic loss suffered by the economic subject producing the electric services. To develop the case studies, costs and benefits had to be better recognized and understood.

3.1 Identifying the Costs side: the mitigation measures

The most traditional structural flood risk mitigation measures are the construction or the enhancement of barriers, levees, dams and dikes, in order to prevent water from entering the land. Other non-structural approaches also consider river widening, land use functions changes and building codes, aiming at mitigating the damage and not necessarily prevent floods from happening. An effective synthesis focused on the comparison among the costs of different available mitigation measures assessed by way of different assessment methodologies is offered in Hawley et al (2012), based on a previous study developed in Australia in 2002. The authors classify flood risk reduction strategies under three primary headings: (i) flood modification activities; (ii) property modification activities; (iii) response

modification activities. They assume structural and non-structural flood control strategies are typically structural in nature and modify or adjust the flow of flood water. Exposure and vulnerability reduction and property modification strategies attempt to avoid or reduce loss by ensuring that flood water is kept away from areas of habitation or other activities or structures are designed in ways that are flood-adaptive. For example, zoning of development areas to ensure that building does not occur in a flood prone area or if it is constructed in a flood prone area that it is raised so that habitable spaces are above likely flood levels. Behavioral response modification strategies attempt to adjust human behavior to respond adequately to floods. For example, the implementation of a flood warning system or introduction of flood-resistant crops can be considered a response mechanism.

It is here important to underline that in this classification there is not a direct reference to the distinction between risk and damage mitigation which has, on the contrary, been underlined above. It is anyhow easy to identify these elements. In figure 1 the Hawley et al (2012) taxonomy is introduced and red and blue lines have been added to distinguish risk mitigation (red lines) and damage mitigation (blue lines). Worthwhile to say that in this taxonomy the dam is listed as a structural measure as only construction is considered. In IDEA Project the dam exercise is considered as a non-structural measure as the dam exists and the measure refers to dam management.

Figure 1 – A taxonomy of flood mitigation measures after Hawley et al (2012)

Sample Measures	Structural or Non-Structural
STRUCTURAL AND NON-STRUCTURAL FLOOD CONTROL	
Levees	Structural
Dams	Structural
Diversions and channel improvements	Structural
Flood gates	Structural
Restoration of Flood Plain	Non
Detention basins	Structural
EXPOSURE & PROPERTY MODIFICATION /VULNERABILITY	
Zoning and land use planning	Non
Voluntary purchase or acquisition	Non
Building regulations	Non
House raising	Non
Other flood-proofing (not necessarily residential)	Non
BEHAVIORAL RESPONSE MODIFICATION	
Information and education programmes	Non
Preparedness	Non
Forecasts and warning systems	Non
State and national emergency services response	Non

Red line = risk reduction measure
Blue line = damage reduction measure
Source: elaboration based on Hawley et al (2012)

After the taxonomy, in Hawley et al (2012) a first classification in terms of effectiveness of a benefit-cost ratio can be found, defined as "*an overall economic evaluation that incorporates all societal costs and values, not just the financial returns to a project. A benefit-cost ratio of greater than one, as a result, suggests the investment has returns that are at minimum competitive with other readily available forms*

of investment (such as leaving the funds in a bank at current interest rates). The benefit-cost ratio takes the discounted benefits divided by the discounted costs. The higher the benefit-cost ratio, the better the investment". The authors, by the way, again claim for caution because direct comparisons cannot be made between the results obtained "*due to the nuances and assumptions made during each study*". The result seem also influenced by the fact that non-structural and structural flood modification strategies are the most evaluated of the types of strategies considered in the study, followed by behavioral response modification strategies. Exposure reduction and property modification is much less widely evaluated. Information on the returns to investment in both property and response modification appear to be more rare than for structural measures. Other options, like zoning, building regulations, etc. only report avoided costs. Overall, economic evaluations focus heavily on the large structural investments where cost data are readily available.

Here is important to add that, without a distinction between risk and damage reduction, another important evaluation element has not been considered, that is the value of the avoided damages possible in risk mitigation because of the protection of commons, cultural heritage, social models and other non-renewable, non-reproducible or non-restorable territorial resources. The reasoning around CBA and the exercises developed in the IDEA Project try to overcome such limitations by way of the use of real and reliable damage data. The discussions and thinking developed during the IDEA Project work have also led to carefully consider the influence of some other factors on the economic values and assessments.

- It is important to take into account that the different mitigation measures involve, in different ways, public and private actions, decision making and investments. It may therefore be possible to address attention not only to risk or damage mitigation measures or to structural and non-structural interventions but also to "public-based" and "private-based" mitigation measures.
- It is important to more clearly distinguish mitigation measures addressed to risk, exposition and vulnerability, as they offer different cost and benefit profiles. In the same logic, it seems interesting to deepen research about the cost-benefit profiles of hard and soft measures.
- Try to better identify and assess the real costs of the different possible mitigation measures and their effectiveness (benefits), trying to obtain better evidence of "which costs to obtain what kind of effects" to better compare the economic impacts of different solutions (a levee along the river or a lamination basin?).
- In ex-ante measuring of the costs of mitigation measures the following should be taken into account:
    - The private interventions on properties for households in order to mitigate damage.
    - The private intervention on properties and activities for economic subjects in order to mitigate the damage. For buildings it is the same as for households but a variety of different elements have to be recognized and taken into account looking at the production activities.
    - The public material/structural interventions needed to mitigate risk and damage. Here there is a great variety of different mitigation measures. Moreover, it is important to remember that also non-structural measures might be very effective, as the so-called economic-based solutions. Very recently (February 2017) the UNISDR released the following definition for non-structural mitigation measures in Preventionweb terminology section: "*Non-structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education. […] Common non-structural measures include building codes, land-use planning laws and their enforcement, research and assessment, information resources and public awareness programmes*". Economic based solutions to be better prepared if an event occurs are not explicitly considered. Insurances, for instance, needed to enhance the reimbursements systems, or stable financial reserve programs. The public material/structural interventions to be "better prepared" and better intervene should therefore not only be assessed in

technical and operational terms but also financial, like, for instance, the creation of financial funds.

3.2 Identifying the Benefits side: the avoided or reduced damage and the related positive effects

As previously stated, flood events present major damages to the economic, environmental and social aspects of a community. The losses include physical damage to buildings, infrastructures, lifelines, environmental assets, cultural heritage and social models. Frequently other damages can be identified in population distress, business interruption, health problems and, of course, loss of lives.

Such assessment, as well as the costs side mentioned in the above paragraph, can be developed both ex-ante and ex-post the flood occurs. In the IDEA Project, major attention has been devoted to ex-post assessment, as clearly visible in the forensic analysis work. In CBA, benefits are evaluated as the "positive consequences from damage reduction" possible from the different mitigation measures to be implemented. Here territorial specificities and production-consumption models are very important. "Where do territorial values concentrate in a territorial area"? This is one of the main questions to give an answer to, in order to address decision making on mitigation solutions and investments able to maximize the expected benefits.

Among others, the discussions developed during the IDEA Project activities also made emerge some interesting points from the stakeholders. Civil protection representatives, for instance, carefully consider as positive externalities the possible image effects coming from the enhancement of the prevention and mitigation measures. Moreover, important synergies have been observed coming from a more homogeneous, stable and strategic action against floods at the system level, with cross effect results obtained by mitigation solution useful for avoiding or reducing other risks.

Looking at avoided damages, economic subjects and businesses are still less considered than households or public infrastructures, even if the economic activities are one of the core elements for the functioning and development of a territory. The problem is the great variety characterizing the economic subjects, their sectors and production activities and the related potential damages they are prone to. Moreover, for businesses the systemic impacts of damage might be very strong and persist in the long term. This particularly in presence of geographic concentration of production activities, like in industrial districts, or of end markets (the study of the US Congress about the effects of the Japanese tsunami 2011 on the US economy is very clear about these, see Nanto et al. 2011). Again looking at systemic damage, it is really difficult to detect the ex-ante connections in the production/consumption of services, as the location of services production might be very far away from the supply location (supply chain characteristics). For instance, how to produce a complete framework of the cascade of economic effects produced to businesses by a cut in energy or water supply or other lifelines and infrastructural services like transportation?

It is finally important to at least try to identify the "system benefits" arising from the perception itself of safety by stakeholders and which have to be better integrated in the "benefit scenarios". If safety is well perceived as a strength/a value of a place where to live or to locate economic activities, a "safer" place might become more attractive. This of course producing an increase in the demand for spaces and properties which, at its turn, not only generates an increase in the real estate values but also a more dynamic environment for households and businesses. Over time, anyhow, also exposure to the residual flood risk increases. Other system benefits could be recognized in preparedness at the systems level, obtained, for instance, by way of an increase in knowledge and information diffusion, able to produce changes in households and economic subjects' behaviors towards flood risk. In case a flood occurs, the exposed community components become much more capable to rapidly respond to the event, reducing damages, losses and also psychologic distress.

4. Damage assessment and CBA for flood risk reduction measures: a case study in the Umbria Region

The Italian Umbria Region is prone to a variety of flood hazards, such as flash floods, debris flow and riverine floods. Peak river discharges are usually observed in November and February. Severe flood events occur regularly. For instance, severe floods were experienced in November 2005, December 2008 (Berni et al. 2009), November 2012 and November 2013. The Tiber River in Umbria caused itself several of these floods, but its tributaries and smaller channels also significantly contributed to these flooding problems. The flood in 2012 was characterized by different types of hazards occurring in different towns and towns localities. Depending on the morphology of locations, observed hazards ranged from flash floods to riverine floods due to levees failure. The flood event in 2013 was more complex including landslides and debris flows (Menoni et al., 2016). The return period of the floods varies between 1 in 100 years to 1 in 200 years for the flood in 2012 and from 1 in 10 years to 1 in 75 years for the flood in 2013, depending on the area in Umbria. A forensic approach (Menoni et al. 2016) was used to assess flood impacts on the basis of surveys, interviews, consultation with the civil protection and local authorities, internal reports and requests for compensations. Table 1 shows this collected flood damage information for different categories for the 2012 and 2013 floods. The collected flood impact information shows that, although total damages were about €72 million in both flood events, the damages per category can differ substantially. For instance, the impacts to the commercial sector are about €22 million in 2012 and €1.5 million in 2013. After the 2013 flood, more cities were sampled for the flood damage data collection than after the 2012 floods. The observation that commercial flood damages were higher in 2012 than in 2013 suggests that the inundated areas in 2012 contained more commercial buildings than in 2013.

Table 1. Different categories of flood damages during the 2012 and 2013 flood events in Umbria (in €1,000)

Category	Damage 2012 (in €1,000)	Damage 2013 (in €1,000)
Commercial activity	22,123	1,479
Industry	603	299
Residential buildings	2,900	17,560
Agriculture	12,239	3,800
Emergency response; Assistance to population	150	30
Emergency response; Flood defenses	20,815	29,044
Transportation	11,807	17,541
Infrastructure; Electricity system	514	230
Infrastructure; Sewage system	461	250
Infrastructure; Water system	179	1,577
Total	71,791	71,810

Source: Menoni et al. 2016

Insights into potential flood water heights are useful for determining to which height flood-proofing measures in buildings have to be installed. In order to get an impression of the potential flood water heights in Umbria, we obtained flood inundation maps for the Umbria region created by the hydrodynamic flood model GLOFRIS described in Winsemius et al. (2013). These maps were used to show the occurrence of potential water heights in cells for the 1 in 10 year flood and the 1 in 100 year flood. These simulations indicate that water levels during flood events in areas in Umbria, can reach up to 140 cm or 280 cm for floods with return periods of 1 in 10 year and 1 in 100 year, respectively. In an

unlikely extreme event of a 1 in 1.000 year return period flood, the water level can reach a maximum of 400 cm in a few areas, but in most areas water levels remain well below 180 cm. The most frequent water levels are lower than 50 cm for the 1 in 10 year flood event and lower than 100 cm for the 1 in 100 year flood.

The damage data have been obtained directly on the field, by reading the "damage declarations" filled in by households and economic subjects. The declarations have been used as questionnaires where to find the damage description and the related monetary values. Those used by the Umbria Region Civil Protection have been developed with the support of a group of researchers of Politecnico di Milano (Menoni et al. 2016) and can be considered advanced in terms of effectiveness in reporting the damage characteristics and dimension. Even if characterized by representative and realistic damage values, the use in a CBA simulation revealed to be quite difficult for the economic sectors and subjects, while the households results have been considered good. In the light of the following elaborations for damage assessment and CBA analysis, the lack for some information or just the need for different ways to sum together different damage voices in the questionnaires, created some difficulties in producing a realistic image of the damage characteristics, which are important to better understand the whole of the floods impacts. Actually, is has to be said that an element related to this problem may be recognized in the insufficient contribution of economic approaches and professional support. As an example, a brief discussion about the 2012 damage assessment voices for economic subjects follows.

The communities and enterprises exposed to the 2012 Umbria flood incurred in significant economic damage to hydraulic infrastructures, agriculture productions, commercial and productive activities, private properties and other goods, especially near the towns of Orvieto Scalo, Marsciano and through all the Tiber Valley. Even though there were no casualties amongst the population, many first aid and assistance were needed (Menoni et al. 2016). The damage questionnaires which have been used were integrating, thanks to the work of the Politecnico researchers team, three additional questions compared to the previous ones, about the different direct damage typologies affecting buildings, equipments and other elements able to negative impact the capability of the economic subjects to continue their production and distribution activities. The added damage categories were (i) real estate and fixed installations; (ii) machinery, equipment, facilities, vehicles and furniture; (iii) raw materials, finished products, half processed items and commercial goods.

Table 2 – Sectors affected by direct damage and weight of different damage categories on total damage – 2012 flood data

Sector	Real estate and fixed installations	Machinery, equipment, facilities, vehicles and furniture	Raw materials, finished products, half processed items and commercial goods	Total direct damage
Industry	€ 78.229,24	€ 102.000,00	€ 219.500,00	**€ 399.729,24**
	20%	**26%**	**55%**	**31,08%**
Handicraft	€ 22.880,00	€ 65.610,00	€ 17.900,00	**€ 106.390,00**
	22%	**62%**	**17%**	**8,27%**
Service	€ 107.000,00	€ 16.150,00	€ 0,00	**€ 123.150,00**
	87%	**13%**	**0%**	**9,58%**
Commerce	€ 248.823,34	€ 126.642,85	€ 281.277,34	**€ 656.743,53**
	38%	**19%**	**43%**	**51,07%**
				€ 1.286.012,77

Source: IDEA Project, Pesaro et al. 2016

Damaged subjects have been distinguished in five macro-categories of economic agents: industry, commerce, tourism, handicraft and service providers. The tourism sector does not appear in the analysis because only one subject proved to belong to such category and was therefore integrated in the commerce category. The results of the data analysis and organization is presented in table 2, which summarizes the main findings of the damage data analysis for the economic sectors. As displayed, the service sector experienced the highest damage in terms of real estate and fixed technological systems affected by flooding, with slightly higher values than the average for commercial activities. The peak in damage to machinery and equipment occurred, unexpectedly, in the commerce sector, followed by industries. The highest direct damage to finished products, semi-finished components and raw materials occurred to industries and commercial activities in quite similar proportions, even though it can be assumed that the commerce sector registered higher losses in terms of finished products in shops and retails, while industries experienced losses in terms of both finished products and raw materials. It is possible, in any case, to notice how, within this pool of economic agents, the commercial activities are the ones which suffered the highest total damage.

From and economic perspective, anyhow, the distinction in three damage categories does not allow for a complete understanding of the damage profile to the economic subjects and reduces the evidence of the typologies of potential impacts of damages affecting the production activities. A proposal has then been developed (of course to be used in next events), introducing a really small change in the questionnaires and, therefore, in the information content obtainable from the collection forms. This consists in a further division of the damage categories used when surveys are submitted to economic agents, in order to better identify elements which might affect the economic activities in different ways and with different impacts, to be compared with the economic subjects main activity category. The proposed improvements are shown in table 3.

Table 3 – Proposal of new damage categories for the damage assessment and categories used during the post-event survey in the aftermath of the Umbria flood

Categories of damage used for the survey after the flood event (2012)	Proposal of damage categories for a further study
Real estate and fixed installations	Properties (non-compromising)
	Structures (needing restoration)
	External elements or secondary structures (e.g. shacks, boxes…)
	Installations and technological systems
Machinery, equipment, facilities, vehicles and furniture	Equipment, vehicles and machinery
	Furniture
Raw materials, finished products, half processed items and commercial goods	Finished products and stocks
	Productive factors (e.g. semi-finished products, raw materials…)

Source: IDEA Project, Pesaro et al. 2016

The new subcategories reflect different elements and phases of the production processes, which, crossed with the activity sector, may represent minor or major damages and direct or indirect damage. For instance, the distinction between finished products and productive factors and raw materials influence the (expected) value flows in different ways. The first one means loss of incomes due to the failure to sell to the final market; the second means the loss of production resources and factors, which might imply a longer period of business disruption, different if the warehouse is empty or damaged and

therefore, in the second case, producing a higher damage. The same looking at the real estate and the fixed installations. In some cases in the Umbria flood, for instance, mainly the external walls or the perimeter fences have been damaged by the event, without any real direct damage to the economic activity, even if the restoration works might require large financial amounts.

5. CBA exercises using flood damage data in Umbria Region: the "dam exercise"

As already mentioned above, in IDEA Project, based on the damage assessment developed as the first working phase, three CBA exercises have been developed using the real information and data available after the flood events in Umbria Region in 2012 and 2013 at the microscale. This to produce a methodological evidence of the capability of certain mitigation measures to reduce/avoid a part of the real damage because of the possible protection effects obtained if they would have been implemented. Two exercises are related to damage mitigation for the built environment, looking at a variety of possible structural mitigation measures for construction and maintenance, one for residential buildings and one for commercial buildings. The third relates to risk mitigation and involves a non-structural mitigation measure, that is the use of a dam built for the production of electric hydropower for an ex ante action of lamination of the potential overflow due to the heavy rains.

1. CBA for residential buildings. Here damage data collected by civil protection has been used for the assessment of the potential benefits obtainable if some damage mitigation measures would have been implemented before the floods occur. From the costs of mitigation measures side, assumptions have been made about the costs of works at the building level, which have been identified as useful to avoid, at least partially, the damages observed in realty because of the flood events. The assessment of such costs has been based on available official price lists, where the selected works and interventions are associated to prices per measure unit. The cost-benefit ratio has been interpreted as the difference between the two analysis dimensions.
2. CBA for commercial buildings. The exercise has been developed using the same approach as in the exercise 1 for recognizing the costs and benefits. Here commercial buildings have been considered and the cost-benefit analysis approach relates to the CB ratio. The analysis is completed by a sensitivity analysis for examining how the outcome of the cost-benefit analysis may change with variations in inputs, assumptions, or the manner in which the analysis itself is set up.
3. CBA for the use of a privately owned dam to laminate the expected overflow. Dams had already been used to laminate the river flow during flood events in Umbria in 2005, 2008 and 2010. Three dams have therefore been identified in order to try to assess the cost and benefits profiles of this risk mitigation measure. Here the costs are represented by the losses suffered by the private owner because of the interruption in the electricity production. The benefits have been accounted in terms of avoided damages, detected by way of a simulation of the inundated area and of the water depth with and without this measure.

In this essay, the third case study will be introduced, as an example of ex-ante flood risk mitigation measure, aiming at reducing the potential dangerousness of a flood caused by very heavy rains (data collection, maps design and calculations developed by Tamara Mendoza and Guido Minnucci).

5.1 The "dam exercise": introduction

A national directive on operational guidelines for the organizational and functional management of the national and regional warning system for hydro-geologic risk for civil protection purposes was issued in Italy in 2004. Within this context, the National Department of Civil Protection established a technical panel concerning the Tiber river basin for the definition of proper regulatory activities of the outflows in order to manage floods. As a first result of this activity, an "informal agreement" on flood management *(Ipotesi di Regolazione dei deflussi ai fini del governo delle piene nel bacino del Tevere)* was signed among different

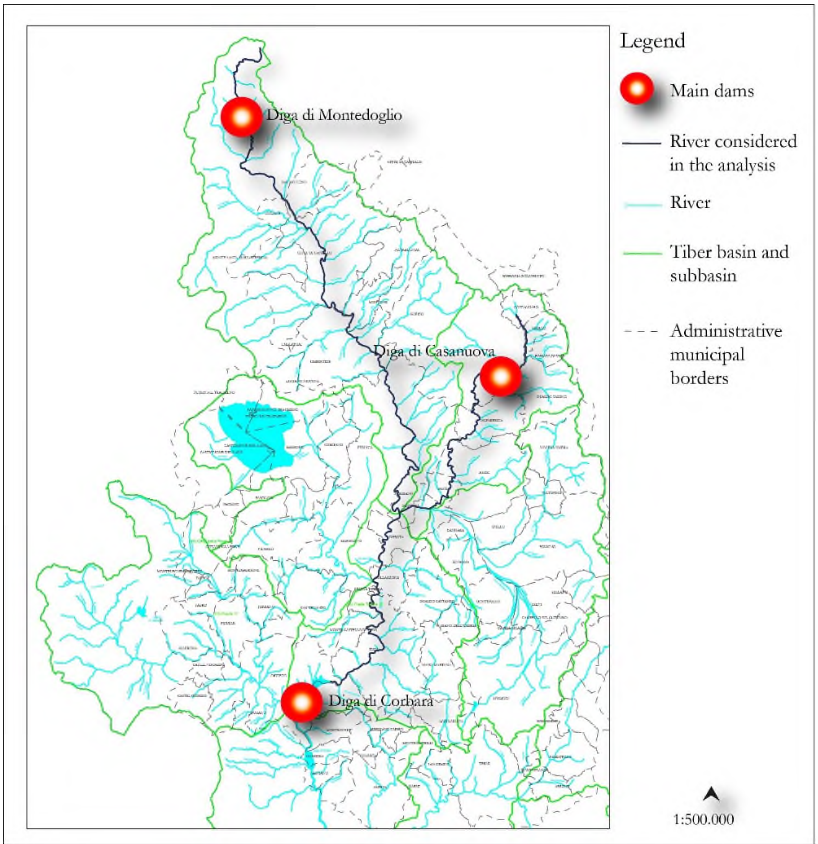
authorities (Tiber river Authority, National Civil Protection, Ministry of Infrastructure and Transport, Regions, Dam Operators) in 2005. This gave space to the possible use of dams to reduce the amount of water falling down in valleys in case of heavy rains. As further result of this technical panel, a framework agreement and a flood management plan was adopted by the Umbria and Lazio Regions in June 2016. On the base of the 2005 agreement, dams were used to laminate the river flow during flood events in Umbria in 2005, 2008, 2010, 2012 and 2013.

Here, the use of dams to laminate the flow during both the 2012 and 2013 flood events is described and the costs and benefits related with the application of this non-structural measures are identified. The aim of the study was to understand the net benefits thanks to the use of the dams. To do this, four main steps were followed: (i) identification of the "avoided event" and its associated damages; (ii) identification of damages of the "occurred event"; (iii) identification of costs; (iv) identification of the net benefits**.** Such activities have been developed by an interdisciplinary group, able to deal with hydraulic matters, flood risk analysis, data collection and mapping and the economic analysis.

5.2 The "dam exercise": data collection, maps design, data processing and CBA assessment

Three dams (Montedoglio, Valfabbrica/Casanuova and Corbara) were used to laminate the river flow during both the 2012 and 2013 events (Figure 2). In order to estimate the damages that were avoided thanks to the use of the dams it was necessary to model the "avoided event", that is the flooding which did not happen because of the intervention on the dam activities and its associated damages. The avoided damages due to the operation of the dams during the event result from the difference between the estimated damages of the "avoided event" and the "real damages" (those that effectively occurred and were collected, as seen above).

Figure 2 – Montedoglio, Valfabbrica/Casanuova and Corbara dams



Source: IDEA Project, Pesaro et al. 2016

The first step was to identify the "avoided event", which can be done by analysing the rainfall data and/or the water depth measured upstream of the dams. From the reports done by the Civil Protection of Umbria Region, it was possible to identify the "avoided events" as:

- 2012. Tiber and Chiascio rivers 100 years of return period; Nestore River 200 years of return period and Paglia river 100 years of return period, both not regulated by the dams.
- 2013. Tiber River 50 years of return period; Chiascio River 75 years of return period.

The estimation of the damages due to the "avoided damage", as assessed by using the true flood damage values collected through the questionnaires (table 1 in the chapter above), has been compared to the cost of the mitigation measure considering the ex-ante intervention upstream the potential flood. The simulation has been developed with the Flood-IMPAT procedure (see Molinari et al. 2016), which performs a damage estimation at the meso-scale level by depth-damage curves in a GIS environment. One of the main inputs required by Flood-IMPAT is a flood hazard map, displaying the spatial distribution of the water depth into the flooded area. This is a typical result from a 2-dimensional hydraulic model but, at present, it is not available in Umbria nor, in general terms, in the Italian territory. To overcome this limitation, another procedure was used that considers the water levels from a 1-dimensional hydraulic model and a Digital Terrain Model of the area. For Umbria Region, water levels available from hydraulic analysis correspond to 50, 100, 200 and 500 years of return period. The procedure was followed for 50, 100 and 200 years of return period.

Table 4 – Estimate of the avoided damage for the 2012 and 2013 events in Umbria Region

Event	**Avoided damage event – no dams (FloodIMPAT) [€]**			
	Total	**Residential**	**Agriculture**	**Industry/ Commercial**
2012	55.310.495	5.401.440	19.232.591	30.676.465
2013	12.747.998	1.034.653	6.487.247	5.226.098

Source: IDEA Project, Pesaro et al. 2016

The flooded areas that were obtained were confronted with the hazardous areas A and B of the Tiber river PAI ("Piani di Assetto Idrogeologico") that show the area that is likely to be flooded due to an event of return period of 50 and 200 years respectively. Water depths were established considering the distance from the river (water depth reduces when moving farther). The development of Flood-IMPAT allowed estimating direct damages to the residential, industrial/commercial and agricultural sectors, consequently, only these typologies were considered for the analysis of avoided damages (Table 4). The flood lamination by the dams involved different rivers and, thus, areas, but not the whole Region. It would be desirable to differentiate between involved municipalities ("Comuni") to take only these into account to prevent including more errors in the calculation of avoided damages. Nevertheless, due to the level of aggregation of the damage data available for the 2012 event, this was not possible. The Paglia River and corresponding municipalities (Allerona, Castel Viscardo and Orvieto) were removed from the calculations because of several reasons. First, this river is not regulated by the considered dams. which means that no avoided damages in the area could be considered. Second, because of an incongruity between water levels and DTM that made the water depths

questionable. Finally, because more detailed damage data was available in the case of industries in Orvieto, where the damages were very important. For the 2013 event it was possible to differentiate between damages at the municipal level and, thus, the considered area for the simulation exercise on the lamination of the flood was the one of both the Montedoglio and Casanuova dams. This area was identified using the Flood Plan for the Tiber river ("Piano di Laminazione", preliminary version not published) and includes the municipalities of San Giustino, Città di Castello, Montone, Umbertide, Perugia, Torgiano, Assisi, Bastia, Bettona e Deruta.

Table 5 –Real damage per sector for the 2012 and 2013 events in Umbria Region

Event	Direct Damages of the real event [€]			
	Total	Residential	Agriculture	Industry/ Commercial
2012	35.908.081	2.500.000	12.238.966	21.169.115
2013	2.035.890	1.538.790	0	497.100

Source: IDEA Project, Pesaro et al. 2016

Concerning the benefits produced by the use of dams to laminate the flood events, those were calculated as the difference between the total avoided damage and the direct damages of the real event (table 6).

Table 6 – Benefits due to the use of the dams in the 2012 and 2013 events in Umbria Region

Event	Avoided damages with the use of dams [€]			
	Total	Residential	Agriculture	Industry/Commercial
2012	19.402.414	2.901.440	6.993.625	9.507.350
2013	10.712.108	-504.137	6.487.247	4.728.998

Source: IDEA Project, Pesaro et al. 2016

Table 7 – Costs beard by the energy operator (operators' calculations)

Event	Dam	Laminated volume [m3]	Loss of revenue [€]
2012	Corbara	70 M	2.000.000
	Montedoglio	25 M	714.286
	Casanuova	20 M	571.429
2013	Montedoglio	25 M	714.286
	Casanuova	21 M	600.000

Source: IDEA Project, Pesaro et al. 2016

Last, the assessment of the costs associated to the use of the dams for flood lamination was based on the hypothesis that the dams of Montedoglio and Casanuova were used exclusively for energy generation, instead of irrigation and water provision. These costs (table 7) were

estimated based on the loss of revenue due to the unsold energy as a consequence of the lack of whirl of the dams during the whole operation (considering also the days before the flood when the dams were emptied).

Finally, the net benefits associated to the flood lamination (table 8) for each event were calculated with the difference between avoided damages (benefits) and the loss of revenue (costs). As further step, it has been calculated the absolute net benefits in order to understand the relevance of the net benefits in relation to the damages of the avoided event. The absolute net benefit for the 2012 and 2013 flood events is respectively 32% and 73%, which means that the use of the dams in both cases clearly allowed reducing damages, up to a so high performance as in the second case.

Table 8 – Net benefit from the CBA assessment (simple subtraction)

Event	Benefits [€]	Costs [€]	Net benefits [€]
2012	19.402.414	1.285.714	18.116.700
2013	10.712.108	1.314.286	9.397.822

Source: IDEA Project, Pesaro et al. 2016

5.3 The "dam exercise": limits and open problems

Limits and open problems manly refer to a variety of factors related to the uncertainties linked to the collection and processing of technical and scientific elements and to the difficulties arising in the use of the CBA methodology in the understanding and interpretation of the cause-effect chains and the system of externalities.

From the technical scientific perspectives, a first issue concerns the spatial scale of the assessment. Most of existing flood databases supply only aggregated damages at the meso-scale or macro-scale (i.e. at the level of a municipality, a province or a region) whereas information at the micro-local scale is also required for damage modelling, depending on the asset under consideration. Moreover, damage modelling requires sector based information (damage to buildings, roads, industrial activities, etc.), while most of times only the total damage is reported. The same for the data needed to build 2-dimensional hydraulic models to be used in Flood IMPAT modelling simulations.

Table 8 – Summary table of the expected damages according to CLC before and after the modification intervention. Results for the Deruta dam

	Total damage	Residential	Agriculture	Industry
Before	9.147.776	0	444.620	8.703.155
After	2.058.978	5.534	444.620	1.608.822

Source: IDEA Project, Pesaro et al. 2016

A second issue is related to accuracy of the available geographical information and map sources. This particularly refers to the accuracy of the Corine Land Cover (CLC) in defining, and therefore detecting, the different land use categories. For instance, the land use for economic purposes was classified only as "industria". According to this land use, the expected damages are in total € 9.147.776 and respectively: € 444.620 for agriculture and 8.703.155 for industries. However, by better analysing this area and increasing the detail level of observations, the result is that it is object of a mix of uses. Based on these corrections, the new amount for

the expected damages is in total €2.058.978 and respectively 5.534 for residential buildings, 444.620 for agriculture and 1.608.822 for industries. In Table 8 a summary of the two experiments carried out using Flood-IMPAT is offered.

From the economic approach perspective, some problems arise because of the difficulties in the identification and assessment of the whole potential total damage and the related difference between the cases "with or without" the intervention on the dam. This is mainly due to the presence of indirect and systemic damage, suffered by the territorial elements and subjects, from the one side, and by the private owners of the dam on the other side. This means a potential lack for damage information from both the benefits side, in terms of avoided damage, and in terms of costs, due to the losses produced because of the implementation of the measure. In this particular case, the production of electrical hydropower is concerned, which means that the accounting for costs depends on the energy costs, the tariffs profiles, the customers typology, the variable demand for power during different periods of the day and the related energy production functions. From the other hand, negative externalities could occur because of the interruption of energy production, depending on the overall power production sources, and the amount of the power demand covered by the dam production.

It is of course difficult to express such elements in direct monetary dimensions and the interdisciplinary approach should be enhanced during the data collection and processing to better integrate the economic thinking dimensions and apply the more appropriate economic and monetary measure units. To make the interdisciplinary approach operational, moreover, the sharing of terminology is important, for instance when describing the impacts of a flood or designing risk, damage and benefit scenarios.

Also local specificities are very important, as the differences in the inundated area resulting from the simulations with and without the dam measure cannot be easily described in terms of the economic values involved. This, again, partially deals with the local production and consumption model and the natural environment characteristics. It is also connected to a problem of spatial and time scales, which may vary a lot and produce different damage scenarios in the simulations as the avoided damage is related to the not or less inundated surface and territorial objects and subjects. Severity, from the one side, and the time extent of the measure influence the results.

Finally, also negotiation costs should be better taken into consideration, to obtain not only the collaboration from the private subjects but also the economic value of "being prepared" thanks to the active involvement (and potential economic loss) of private stakeholders. Of course the latter have been obliged to accept the demand for intervention under the specific regulation mentioned above, the Umbria Region's *Piani di laminazione* (laminations plans), but can negotiate the economic amount for the compensation demanded for the implementing the mitigation measure. Which means that private subjects should be compensated for the costs undertaken for public interest purposes as they contribute in producing the safety as a public good (Pesaro, 2007). In the same perspective, another element should be underlined, that is the value of coordination of the public decision makers at different territorial level, which created the conditions and rules to both develop and implement such a measure.

Even if in presence of such limits and working conditions, the results of this exercise are very interesting, especially because the economic advantages obtainable by mean of a non-structural risk mitigation measure proved to produce high savings in terms of avoided damage.

6. Conclusions

The exercises let the researchers to experiment the CBA as a tool for supporting the decision-making for the mitigation of risk and damage based on the availability of real data. Strengths and weaknesses have therefore been highlighted, looking at the building of the list of elements representing the cost and benefit elements to be measured and assessed and to the related needs for data collection.

The exercises also demonstrated that CBA development is still a too complex and scientific based issue to become, at least at present, a "normal" and extensively used assessment tools to support decision-making in public administrations and the State. This also because the analysis is meant to be used in ex-ante situations, where real damage data could not be available and where, therefore, other data sources should be made available. Such datasets, often developed for other territorial assessments purposes could not be directly or easily used in ex-ante simulation for expected damage modeling. The predictive capabilities of CBA in assessing mitigation measures without the evidence from previous events and when trying to shift attention from the micro to the mesoscales could therefore be weakened. Still, the increase in the availability of case studies and operational methodologies suggests that relevant improvement could be done in order to better learn how to asses and interpret such evaluation methods, what kind of professional profile are needed from an interdisciplinary perspective and, finally, how to make them become more diffused.

From the benefit side perspective, when referring to the accounting for damage as the avoided costs, problems have been observed in data collection activities. This particularly looking at economic subjects. For households present data collection methods and tools seem able to catch the high majority of the damages really suffered while for the economic subjects improvements are still needed. This is manly related to the high variability and differences of this kind of subjects and of their activities and built environments, at least at present. The dam exercise also demonstrated that there are problems in providing base mapping and a reliable image of land uses needed to develop territorial assessments at the over-local level, especially when trying to obtain models of ex-ante damage assessment for a certain area. This because existing data sets for land use analysis have not been conceived in order to provide such information. It is anyhow important to underline that a more detailed and precise image of land uses is more and more needed for many other territorial policy activities, which calls for a better integration and collaboration in data production and processing among different categories of potential final users.

From the costs side, in an economic perspective, the main goal of a decision making process is to be able to identify the best possible mitigation measures able, at its turn, to maximize the reduction in damage amounts and the flood risk if an event occurs. In the Umbria exercises, only one non-structural measure has been considered, using ex-post damage data for the design of the related cost and benefit scenarios. Still, many of the difficulties and distortions enlightened in the methodological survey and discussion have been confirmed by the exercises. Moreover, some other crucial elements have revealed to be able to affect the analysis results.

A better knowledge of the variety of structural and non-structural risk and damage mitigation measures seems more and more important looking at the variety of potential stakeholders and interventions. Multidisciplinary research groups could ameliorate the knowledge system starting from data collection activities and processing to the use of data in CBA models. It is also important to enhance the capabilities of all public and private involved subjects to distinguish the better options compared to a variety of different starting environments for the design of more effective risk and damage mitigation measures. Moreover, the multidisciplinary perspective in teams working on data collection and the implementation of CBA in flood risk management has proved to be very important. The scientific and technical capabilities needed to design risk and damage scenarios must better interact (and vice versa) with those needed to recognize and deal with the whole of the socioeconomic elements and values involved, their specificities and measure units. This particularly refers to the need for a better integration

of the economic thinking when assessing the economic impacts of mitigation, also in the light of other, economic-based, solutions to tailor on the economic subjects' needs, such as "better fitting" insurance options or incentives programs to develop mitigation measures at the firm level.

Finally, the importance of a better understanding of the role of the non-structural measures as a mean of flood management emerged, aimed at prevention and reduction of damage in the case of flood events. This also considering the related systems of costs, which are for sure really lower compared to those of structural measures (even if these latter may obtain stable risk reduction effects, contributing to the safeguard from losses) and produce, quite every time, a highly positive CB profile in the medium and long term. In such a perspective, it is important to say that non-structural mitigation measures might also produce important effects looking at the activities of the Civil Protection offices and to their visibility in peace time. The "dam exercise", for instance, demonstrated the importance of the negotiation activity to enhance the preparation of the system facing new floods after the ones of 2005 and 2008. The same for the information campaigns and the activities devoted to enhance the territorial systems capabilities to face floods from all points of view, producing a community more aware of the risk and ready to respond in terms of prevention culture and better reaction to the events.

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References

AdnKronos (2009), Maltempo: Venezia, così la città si difende dall'acqua alta, in *AdnKronos Archives*, December 23rd

Berni, N., Brocca, L., Giustarini, L., Pandolfo, C., Stelluti, M. Melone, F., Moramarco, T. (2009), Coupling hydrologic and hydraulic modelling for reliable flood risk, in *Geophysical Research Abstracts*, 11, EGU2009-9498-3

Botzen W.W.J., Monteiro E., Estrada F., Pesaro G., Menoni S. (2017), Economic Assessment of Mitigating Damage of Flood Events: Cost–Benefit Analysis of Flood-Proofing Commercial Buildings in Umbria, Italy, in *The Geneva Papers on Risk and Insurance - Issues and Practice*, forthcoming, accepted for publication on June 21, 2017

Brouwer, R., van Ek, R. (2004), Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands, in *Ecological Economics*, 50(1-2): 1-21

Cochrane H. C. (2004a), Economic loss: myth and measurement, in *Disaster Prevention and Management*, 13, 4:290-296

Cochrane, H.C., (2004b). Indirect Losses from Natural Disasters: Measurement and Myth, in Okuyama Y. Chang S.E. (eds) (2004), *Modeling the Spatial and Economic Effects of Disasters,* New York, Springer

European Environment Agency (2010), *Mapping the impacts of natural hazards and technological accidents in Europe. An overview of the last decade*, EEA Technical report. No 13/2010, Copenhagen

European Environment Agency (2016) *Floodplain management: reducing flood risks and restoring healthy ecosystems*, EEA Report, Copenhagen

Hawley K., Moench M., Sabbag L. (2012), *Understanding the economics of flood risk reduction: a preliminary analysis*, Institute for Social and Environmental Transition-International, Boulder

Howe C.W., Cochrane H. C. (1993), *Guidelines for the uniform definition, identification, and measurement of economic damages from natural hazard events: With comments on historical assets, human capital, and natural capital, Program on Environment and Behavior*, Special Publication No. 28, Institute of Behavioral Science University of Colorado

Hubert G., Ledoux B. (1999), *Le coût du risque. L'évaluation des impacts socio-économiques des inondations*, Paris : Presses de l'école nationale Ponts et chaussées

Johnson C., Penning-Rowsell E., Tapsell S. (2007), Aspiration and reality: flood policy, economic damages and the appraisal process, in *Area*, 39, 2:214-223

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2014), Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures, in *Structural Survey*, 32(2): 102-122.

Mechler R. (2016), Reviewing estimates of the economic efficiency of disaster risk management: opportunities and limitations of using risk-based cost–benefit analysis, in *Nat Hazards*, 81(2016): 2121–2147

Meyers V. Becker, N., Markantonis, V., Schwarze, R., van den Bergh, J. C. J. M., Bouwer, L. M., Bubeck, P., Ciavola, P., Genovese, E., Green, C., Hallegatte, S., Kreibich, H., Lequeux, Q., Logar, I., Papyrakis, E., Pfurtscheller, C., Poussin, J., Przyluski, V., Thieken, A. H., Viavattene, C. (2013), Review article: Assessing the costs of natural hazards – state of the art and knowledge gaps, in *Natural Hazards and Earth System Sciences*, 13: 1351-1373

Menoni S., Molinari, D., Ballio, F., Minucci, G., Mejri, O., Atun1, F., Berni, N., Pandolfo, C. (2016), Reporting flood damages: A model for consistent, complete and multi-purpose scenarios, in *Natural Hazards and Earth Systems Sciences*, 16: 2783-2797

Molinari D., Menoni S., Aronica G. T., Ballio F., Berni N., C. Pandolfo C., Stelluti M., Minucci G. (2014), Ex post damage assessment: an Italian experience, in *Natural Hazards and Earth System Sciences*, 14: 901–916

Nanto D.K, Cooper W.H., Donnelly J.M., Johnson R. (2011), *Japan's 2011 Earthquake and Tsunami: Economic Effects and Implications for the United States*, Congressional Research Service Report for Congress

National Research Council, Committee on Assessing the Costs of Natural Disasters (1999), *The Impacts of Natural Disasters: A Framework for Loss Estimation*, Washington DC, The National Academies Press

Pesaro G. (2005), La conservazione dei centri storici in zona sismica: un approccio economico, in S. Lagomarsino S., Ugolini P. (eds), *Rischio sismico, territorio e centri storici*, Milano, FrancoAngeli

Pesaro G. (2007), Prevention and mitigation of the territorial impacts of natural hazards: the contribution of economic and public-private cooperation instruments, in Aven T., Vinnem J.E. (eds.) *Risk, Reliability and Societal Safety – Vol.1 Specialisation Topics*, London, Taylor&Francis

Pesaro G., Bezzam V., Botzen W.W.J., Hudson P., Mendoza M., Menoni S., Minnucci G., Erika Monteiro E., Russo F. (2016), *Cost-benefit analysis of mitigation measures to pilot firms/infrastructures in Italy*, IDEA Project, Deliverable D.4, http://www.ideaproject.polimi.it

Rose A. (2017) *Defining and Measuring Economic Resilience from a Societal, Environmental and Security Perspective*, Singapore, Springer Science+Business Media

Rose A., Huyck C.K. (2016) Improving Catastrophe Modelling for Business Interruption Insurance Needs, in *Risk Analysis,* DOI: 10.1111/risa.12550

Shreve C.M., I.Kelman I. (2014), Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction, in *International Journal of Disaster Risk Reduction*, 10(2014): 213–235

Van der Veen A., Vetere Arellano A.L., Nordvik J-P., (eds) (2003), *In search of a common methodology on damage estimation*, Workshop Proceedings, European Commission - DG JRC, EUR 20997 EN European Communities

Winsemius, G.C., van Beek, L.P.H., Jongman, B., Ward, P.J., Bouwman, A., (2013), A framework for global river flood risk assessments, in *Hydrological Earth System Science*, 17: 1871-1892