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Assessing direct and indirect economic impacts of a flood event through the integration of spatial and computable general equilibrium modelling

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ABSTRACT

In this paper we developed and tested an integrated methodology for assessing direct and indirect economic impacts of flooding. The methodology combines a spatial analysis of the damage to the physical stock with a general economic equilibrium approach using a regionally-calibrated (to Italy) version of a Computable General Equilibrium (CGE) global model. We applied the model to the 2000 Po river flood in Northern Italy. To account for the uncertainty in the induced effects on regional economies, we explored three disruption and two recovery scenarios. The results highlight that: i) the flood event produces indirect losses in the national economic system, which are a significant share of the direct losses, and ii) the methodology is able to capture both positive and negative economic effects of the disaster in different areas of the same country. The assessment of indirect impacts, in particular, is essential for a full understanding of the economic outcomes of natural disasters.

1. Introduction and background

Water-related extremes, such as floods and storms, account at the global level for the greatest share of natural disasters' inflicted economic damage and death toll (Jonkman and Kelman, 2005; Kunreuther and Michel-kerjan, 2007; United Nations International Strategy for Disaster Reduction Secretariat, 2009). In Europe, according to NatCatService (MunichRE, 2010), 80 percent of the economic losses caused by natural disasters that occurred during the period 1980–2009 were related to hydro-meteorological events (EEA, 2010). Hydrological events only (i.e. flood and wet mass movements) account for 25 percent of the overall losses in the 32 European Environmental Agency (EEA) Member States, estimated as 414 billion Euro over the period 1980–2009 (in 2009 values) (EEA, 2010).

Growing population and capital density, unsustainable development, inappropriate land use and climate change, threaten to intensify natural hazards' risk with even more concerning consequences for the environment and societies (IPCC, 2012). Against this background the EEA warned that flood related losses will rise consistently in Europe (EEA, 2012). According to Feyen et al. (2012), which calculated the expected annual damage (EAD) from river flooding events in Europe, current EAD of 6.4 billion Euro may increase by 2100 to 14–21.5 billion Euro (constant 2006 prices) depending on climate scenarios (Feyen et al., 2012). Under the medium to high emission scenario A1B Rojas et al. (Rojas et al., 2013) calculated that EAD might raise by the end of this century to around 97 billion Euro (constant 2006 prices undiscounted, considering both climate and socio-economic changes).

However, economic impacts of natural hazards are still poorly understood, particularly their indirect, wider and macro-economic effects. Typically estimates from the European Environmental Agency (EEA) (EEA, 2012) and global disaster databases (i.e. the EM-DAT dataset managed by the Centre for Research on the Epidemiology of Disasters, the NatCatSERVICE dataset managed by Munich Reinsurance Company, and the Sigma dataset from Swiss Reinsurance Company) undervalue the full cost of disasters to societies and environment because most of the time they account for direct impacts only, with partial or incomplete consideration given to indirect, wider and macroeconomic effects.

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Several efforts have been made to assess indirect impacts of disasters on national and regional economies (Cochrane, 2004; Green et al., 2011; Messner et al., 2007; Okuyama, 2007; Przyluski and Hallegatte, 2011; Rose, 2004) using different methodologies. These include amongst others: post event economic surveys (Kroll et al., 1991; Molinari et al., 2014; Pfurtscheller, 2014), econometric models (Albala-Bertrand, 1993; Cavallo et al., 2012; Noy and Nualsri, 2007; Strobl, 2010), input–output (I–O) models (Hallegatte, 2008; Hallegatte et al., 2011; Henriet et al., 2012; Okuyama, 2014; Okuyama et al., 2004; Ranger et al., 2011), computable general equilibrium (CGE) models (Berrittella et al., 2007; Bosello et al., 2012, 2006; Haddad and Teixeira, 2013; Jonkhoff, 2009; Pauw, K. et al., 2011; Rose and Liao, 2005; Rose et al., 1997; Tsuchiya et al., 2007). Different methodologies have different advantages and disadvantages. Econometric models and post event surveys, if well specified and based upon data of a reasonable quality, can indeed quantify indirect effects on national/local GDP of extreme events with high levels of accuracy and scarce uncertainty in the assessment procedure (Przyluski and Hallegatte, 2011). However they cannot describe the systemic economic channels through which they propagate within and between the economies affected. I–O and CGE models can do so (Hallegatte, 2008; Moffatt and Hanley, 2001; Okuyama, 2007; Rose, 2004). I–O models can reach a high analytical specificity, they can represent urban contexts as well as even smaller economic entities like natural parks or cities, but then they are usually missing the effect on the overall economy. Moreover I–O models cannot assess the impacts on the supply side, and do not allow for flexibility in the economic system which is indeed a characteristics of CGE models (Hallegatte, 2008). CGE models are able to capture the feedback effects from the macro-economic context on the "markets" initially concerned (Rose, 2004). Furthermore, in general equilibrium approaches the use of consistent accounting methodology for capturing economic flows overcome the problems of 'double-counting', often affecting the evaluation conducted through the application of partial equilibrium (Pauw, et al., 2011). CGE models also offer in principle the possibility to conduct simulated counterfactual analyses, comparison between what happened and what would have happened in the absence of the catastrophic event. Nonetheless, CGE models have several limitations. They assume perfect markets and they are not able to capture non-market values (Pauw, et al., 2011). Another important limitation of CGE models is their "coarse" investigation unit, usually the country. This may allow analysis of aggregated events or trends, but makes local analyses particularly challenging, especially for small to medium disasters.

Against this background, in this paper we propose the combination of a spatially based analysis with a CGE model, regionally calibrated to the Italian macro-regions North, Centre and South (Standardi et al., 2014). Our sub-national version of the global CGE model allows to assess the regional impacts (at sub-national level), whilst maintaining the global scale of the economic system (e.g. global trading, international exports and imports, etc.).

Our aim is to couple the high resolution of spatial analysis (Zerger, 2002) with the CGE models' systemic ability to capture economic interaction (Bosello et al., 2012, 2006; Liang et al., 2014), without pushing the CGE aggregation need too far to loose completely local specificities. We then apply our methodology to estimate the economic impacts at the sub-national and national level of a flood event that occurred in Northern Italy in October 2000. At country level the outputs of the model provide an indirect-direct losses ratio of 0.19–0.22. The model is also able to unravel the wider impact of the flood into differentiated effects in sub-national economies. Thus the indirect losses in the North are partially compensated by (small) economic gains in non-affected areas (Centre and South) because of the interconnectivity of the economic system, the mobility of productivity factors and substitution of goods. The propagation of impacts beyond national border is negligible and the EU level GDP is in practice unaffected.

The paper unfolds as follows: Section 2 briefly reviews the case study area and the flood event; Section 3 provides a comprehensive discussion on the conceptual framework and methodology, a description of the sample data and the integrated model; Section 4 presents and discusses the results; Section 5 concludes the document providing a critical review of the outcomes, in the broader context of flood impact assessment and disaster risk management.

2. Background information on the Po river October 2000 flood event

The Po river is located in Northern Italy, which includes eight Italian regions: Piedmont, Aosta Valley, Liguria, Lombardy, Trentino Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia-Romagna. The area produces around 77 percent of the national Gross Domestic Product (GDP), with Lombardy having by far the largest economy (21 percent of national GDP), followed by Emilia-Romagna with 9 percent, Piedmont with 8 percent and Aosta Valley with 0.3 percent. Because of the strategic importance of the area, this paper analyses the economic impacts of the Po river flood that occurred in October 2000 in Piedmont, Aosta Valley and other downstream regions in the Northern Italy. Between 13th and 16th October 2000, a series of extreme precipitation events, up to 600 mm in 48 h hit the Northwest of Italy leading to numerous inundations and landslides (Ratto et al., 2003; Regione Piemonte, 2000a, 2000b). The event is amongst the most significant that have occurred in Italy over the past decades. It caused 37 casualties and missing persons (27 in Italy and 10 in Switzerland) and economic damages of over 2.5 billion Euro, as reported by the Information System on Hydrogeological Disasters (IRPI), 5.2 billion Euro as reported by Guzzetti and Tonelli (2004) or 8.6 billion Euro as reported by the EM-DAT International Disasters Database (Centre for Research on the Epidemiology of Disasters – CRED). More than 40,000 people were evacuated and at least 3000 lost their houses (Guzzetti and Tonelli, 2004). The flood hit more than 700 municipalities and almost all main cities of Piedmont and Aosta Valley. All economic sectors were severely impacted, either directly through structural damage or indirectly through business interruptions. The flood caused significant damages to industries, transport infrastructures and urbanized areas. It led to lifelines interruptions, cutting-off major highways, regional and provincial roads. Milan-Turin and Turin-Aosta highways were severely damaged. Bridges were destroyed resulting in temporal isolation of small and medium sized towns (Tropeano and Turconi, 2001). In several areas electricity, telecommunication, and drinking water supply services were interrupted for days – up to a week in Turin and other towns in the area (Tropeano and Turconi, 2001). In addition to hitting the constructed areas, the flood caused serious damages to agriculture affecting livestock, crop production, farm structures, and farming facilities (Farinosi et al., 2012).

3. Methodology

3.1. Conceptual framework

Our work aims to estimate the economic impacts of the Po river 2000 flood event. Because of the knowledge gap in indirect impact assessment, this paper focus on developing and testing an integrated methodology specifically aiming at their quantification. Therefore the direct impact assessment shall be considered