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Socio-economic exposure to natural disasters

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ABSTRACT

Even though the correct assessment of risks is a key aspect of the risk management analysis, we argue that limited effort has been devoted in the assessment of comprehensive measures of economic exposure at very low scale. For this reason, we aim at providing a series of suitable methodologies to provide a complete and detailed list of the exposure of economic activities to natural disasters. We use Input-Output models to provide information about several socio-economic variables, such as population density, employment density, firms' turnover and capital stock, that can be seen as direct and indirect socio-economic exposure to natural disasters. We then provide an application to the Italian context. These measures can be easily incorporated into risk assessment models to provide a clear picture of the disaster risk for local areas.

1. Introduction

The perception about the relevance of economic and social damages generated by natural disasters has grown substantially in recent decades (Blaikie et al., 2014). This greater awareness about natural disasters triggered the demand, from both the public and the private sectors, of actions aimed at preventing the occurrence of natural disasters (when possible), at mitigating the damages and at adapting to increasing risks (Zeleňáková and Zvijáková, 2017). Information about risk and exposure to damages is fundamental both in an *ex-ante* perspective (e.g. risk reduction, risk assessment) and in an *ex-post* perspective (e.g. risk management, assessment of damage, reconstruction).

Even though the correct assessment of risks is a key aspect of the risk management analysis (and for this reason, the academic literature contains a large variety of sophisticated models for risk assessment), we argue that less effort has been devoted in the definition of comprehensive measures of socio-economic exposure at very low scale. For this reason, we aim at discussing a selection of methodologies suitable to provide a complete and detailed assessment of the exposure of economic activities to natural disasters. We are then able to provide detailed information on several socio-economic variables that can be easily incorporated into risk assessment models to provide a clear picture of the disaster risk. These variables are population density, employment density, firms' turnover and capital stock (divided also in its main components: buildings and machineries). Even though these measures appear to be highly correlated, it is important to consider at the same time all the various aspects of socio-economic exposure.

In this respect, given the difficulties to address all the exposed values and the absence of clear methodologies able to define proper socio-economic exposure values, the existing literature employs different proxies of socio-economic exposure (Chen et al., 1997) that depend on the features of the disaster that is analyzed. In fact, the choice of the proxy used in the evaluation of the economic losses due to natural disasters mostly depends on the sequence of effects which are expected to occur when different natural disasters affect a given area (Modica and Zoboli, 2016; Pelling, 2003). For instance, the density of the built environment is a common proxy used in the case of flood risk assessment (e.g. Jongman et al., 2012; Koks et al., 2014, 2015: Sterlacchini et al., 2016). Gross Domestic Product, (GDP) or population density is commonly used in earthquake risk assessment (Chen et al., 1997), as well as the value of real estate assets (Field et al., 2005; Meroni et al., 2016). A similar proxy can be used in the case of drought (land value, Simelton et al., 2009) while for landslides an interesting measure is the mix between social (population), physical (buildings and infrastructures), economic (land value) and environmental (site of community importance) indicators (Bloechl and Braun, 2005; Pellicani et al., 2014).

On these regards, there is extensive literature focusing on the definition of losses caused by extreme events (see ECLAC, 2003; FEMA, 1992; and Pelling et al., 2002, for more details). Even though definitions are not always coherent among each other, for simplicity we discriminate between direct and indirect losses.

Direct losses refer to direct damages to people (injuries and fatalities) and objects (e.g. goods, buildings, infrastructures; see ECLAC, 2003). For instance, earthquakes destroy buildings and infrastructures, which in turn, generate damages to other goods and people. Floods

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may generate minor damages to buildings if compared to damages to other goods (e.g. vehicles) and people (FEMA, 1992; Luino et al., 2009). Damages arising from the interruption of economic activities due to the natural disaster are also considered to be direct losses (see Rose and Lim, 2002; Rose et al., 2007). Interruptions may occur for several reasons: damages to critical infrastructures such as energy and water supply and transport network; damages to people involved in production processes, destruction of production capital, etc. The interruption of economic activities in a region reduces the firms' turnover for a certain amount of time, which in turn reduces region's GDP.

The category of indirect losses is, instead, broad and borderless. Limiting the discussion to business interruption, foregone production and turnover influence the whole (local and global) supply chain of the production activities that experience the interruption (e.g. Van Der Veen and Logtmeijer, 2005). Suppliers of intermediate goods will experience a reduction in the demand for their products and consequently a reduction in turnover. On the other hand, customers will experience potential shortages of inputs needed for their production process and may be forced to find alternative suppliers, thus increasing production costs and potentially reducing production. Foregone wages will also influence region's GDP as consumption will be reduced. Finally, if the interruption lasts for a long period, producers may lose their customers permanently, limiting the possibility of economic recovery even once the cause of interruption is removed. For all these reasons indirect losses need to be evaluated looking at general equilibrium effects by means of specific economic models (see Okuyama, 2007).

Given these premises it turns out that policy makers and private actors have the vital need to have knowledge about both the direct and indirect components of economic exposure. Indeed, policy makers need to know clearly what is the socio-economic value of the area under analysis, as well as the possible interconnections with neighbouring areas. In this way it is possible to define optimal disaster mitigation policies, estimate the likely (or potential) maximum cost suffered by a region and elaborate effective risk management strategies. Private actors, such as insurance companies, can instead use this information to define more accurate risk analysis (i.e. to provide better insurance plans).

Direct components of exposure refer to those that might produce direct losses because of a disaster ('direct socio-economic exposure'). Indirect components refer to losses due to disruption of local and global supply chains of the production activities ('indirect socio-economic exposure'). However, measuring the socio-economic impacts of extreme events is a difficult task due to the unpredictability of the different types of natural events (Hallegatte and Przylusky, 2010), and to the scarcity of information about economic activities for small geographical units, both in an *ex-ante* and in an *ex-post* perspective. We propose simple methodologies to define several socio-economic exposure measures that can be used in different contexts and in relation to several natural disasters at a very detailed scale, providing in this way a full map of the potential exposure of socio-economic activities to natural disasters. We then test these methodologies in the Italian context.

According to the literature (see Cardona et al., 2012), elements that are exposed to natural disasters are the human beings and all the other related basics constituting their livelihoods and assets. For this reason, and according to previous works that have reviewed the literature of the economic assessment of natural disasters (Modica and Reggiani, 2015; Modica et al., 2017), we mainly focus on a set of recurrent measures that consider the three aspects mentioned above (e.g. human beings, livelihoods and assets): population density, employee density, turnover) and capital stock. These measures provide interesting information on the direct exposure since they are all proxy for the 'local' loss due to natural disasters. In order to consider the indirect socio-economic exposure, we provide evidence about local linkages and possible diffusion of economic damages by means of input-output inter-sectoral linkages across neighbouring municipalities. Moreover, we also provide descriptive evidence on the spatial clustering of the socio-economic activities as measured by our set of indicators by means of the Local Indicator of Spatial Autocorrelation (LISA, see Anselin, 1995 and Cutter and Finch, 2008) in order to identify areas where high values are spatially concentrated.

The paper then aims at providing information on the direct and indirect socio-economic exposure of territories to natural disasters by means of selected variables that can be used by policy makers and private actors for the elaboration and implementation of correct and effective risk management strategies. For these reasons, we define a series of suitable methodologies that are able to provide at a very low scale a comprehensive assessment of the exposure of economic activities to natural disasters. These methodologies offer robust and replicable tools for the risk management at different administrative levels (municipalities, regions, national government) and provide important information on local exposure per se. We then expect to identify areas with high concentration of economic activities, indicating in this way a greater economic exposure to risk and potentially higher indirect losses.

2. Material and method

This section describes different methodologies that are useful to define adequate socio-economic measures of exposure. While some of these measures are readily available from statistical or administrative sources, other measures need to be treated with appropriate methodologies. We deal in this section only with those measures that need to be estimated and leave any further discussion to the Results section for those that do not need any preliminary operations. We mainly differentiate methodologies able to define direct components of exposure (Section 2.1) and indirect components (Section 2.2).

2.1. Direct components of exposure: estimating turnover and capital stock at municipal level

According to the existing literature (Cardona et al., 2012; Modica and Reggiani, 2015) suitable proxies able to provide useful information for the potential direct 'local' losses suffered by selected areas due to natural disasters are: population density (proxy for potential life loss), employee density (proxy for exposure during 'working hours'), turnover (direct costs due to business interruption) and capital stock (direct costs due to the destruction of capital goods). While population and employee density can be timely retrieved from official statistics and censuses, turnover and capital stock need to be estimated in order to provide appropriate information of direct socio-economic exposure of territories. The reason is the following: actual turnover and capital stock data are not available for most of the firms as a public and official data (e.g. firms' turnover is available for turnover bands) and no direct information is available for local units. Then, these facts do not allow obtaining detailed information at low scale (e.g. municipal level) of both the measures of capital and turnover and they need to be estimated. These estimates are based on the combination of statistical and administrative data sources and rely on the validity of a set of clearly defined assumptions.

The estimate of turnover is necessary because actual turnover is typically available only for a small number of large firms. For smaller firms, it is possible to gain access to information on turnover bands rather than to exact information on turnover. On the other hand, information on employment for the universe of firms and local units is easily available and it is usually collected in business registries, censuses or social security registries. This claims for the possibility of estimating the value of economic production (i.e. turnover) that is generated within a municipality by exploiting information on employment of the local units. On this regard, we adopt the following two-step procedure to estimate firm-level turnover at the municipality level. First we estimate firm-level turnover by means of an interval regression model (a generalisation of the Tobit model, in which both interval data and point data are allowed). Second, we attribute the total turnover of the firm to its local units by assuming that the ratio between turnover and number