



Socioeconomic spillovers of the 2016–2017 Italian earthquakes: a bi-regional inoperability model

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Abstract

In August and October 2016, and January 2017, Central Italy was shaken by four strong earthquakes followed by other earthquake swarms. These disruptive phenomena, besides bringing devastation in the territory directly involved, caused economic blackouts to important transactions among activities, with consequent different reactions in the economic performance of the whole country. Therefore, the overall economic impact of a disaster should encompass the complete representation of phenomenon, and requires an analytical framework to depict the circular flow of income in all its phases. In this perspective, the current study presents an evolution of the inoperability input–output model by introducing a new approach of bi-regional inoperability extended multisectoral model. This allows assessing the intra-regional and the inter-regional effects of the earthquakes in the production processes and in the institutional sectors disposable incomes of two Italian macro areas, the North-Centre and the South-Islands.

Keywords Inoperability models · Income distribution · Social accounting matrix · Disaster impact analysis · Socioeconomic spillovers

JEL classification C67 · D31 · D57 · Q54

1 Introduction

The occurrence of disruptive events, natural and man-made hazards, has created in the last two decades a new strand of literature in the topic of the disaster impact analysis. These catastrophic events, besides bringing devastation, cause economic blackouts to important economic activities inside the supply chain. The perturbation produces different magnitude reactions in terms of economic performance, including effects on the social capital,

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the income and the learning (Yamamura, 2010). In the aftermath of these events, the importance of an assessment of the direct and indirect effects and their consequences on the social well-being, is indispensable for identifying and undertaking reconstruction programmes and projects (Mortreux et al., 2018; Bradshaw, 2003).

Different methodologies and approaches have been progressively proposed to assess in the first place the level of the damage occurred in such circumstances. One of the most valuable contributions has been achieved through the use of the input–output (I–O) model. In fact, the I–O approach exploits all the benefits of an accounting scheme that offers a great level of disaggregation in terms of number of industries and commodities involved, and provides direct and indirect connections between the productive processes and the final demand; albeit limits and weaknesses have to be considered and tackled.

Studies using the I–O model and its extensions with respect to the disaster impact analysis, can be found in Okuyama (2007) that presents a literature review of the topic, discussing past and present main issues and proposing future implications. Other contributions have been used to investigate the dynamic nature of impacts over space and time giving different perspectives when characterizing the literature. Examples mentioning the spatial dimension are obtained, for instance, through the use of Multiregional I–O (MRIO) models where recent contributions can be found in Oosterhaven and Tobben (2017), which compared distinct assumptions to estimate economy-wide consequences of a flood disaster.¹ In the case of the time dimension other relevant studies portray the temporal disaggregation as for instance the works of Okuyama (2017), who has revisited the Sequential Interindustry Model (SIM) and raised the point of the stability of the technical coefficients, and Avelino (2017) which developed a consistent methodology to disaggregate the annual I–O table with different technical structures.

One of the most "beaten tracks" in studying and analyzing highly interconnected economic system failures is the inoperability approach. The inoperability I–O Model (IIM) was introduced theoretically for the first time in Haines and Jiang (2001), and from then on, widely tackled and discussed by Santos (2003) and Haines et al. (2005a, b) with several assessments on disruptive events, especially due to terrorism, that cause inoperability across interdependent infrastructures. Further studies that represent an extension of the IIM approach were recently introduced with the purpose of enlarging the spectrum of the results, including not only the direct and indirect effects, but also the induced effects. In fact, the critical aspect of the IIM approach is therefore represented by the overall underestimation of the economic impact of the event due to a partial representation of the economic phenomenon.

Along these lines the effort of this study is to present an evolution of the IIM by introducing the new approach of the inoperability extended multisectoral model (El Meligi et al., 2018) with a bi-regional formulation (hereinafter referred to as B-IEMM) based on a bi-regional SAM (B-SAM) that represents the Italian economy in two macro-areas, North-Centre and South-Islands. The development of the B-IEMM allows quantifying the overall economic impact of a disaster as it is based on a framework (the B-SAM) that offers a complete representation of the circular flow of income in all its phases and between two different areas of the same country. Specifically, it allows assessing the intra-regional and the

¹ The outcomes confirmed the results presented by Koks and Thissen (2016) in the attempt of combining linear programming and I–O modeling to assess indirect impacts with respect to a the natural disaster on a pan-European scale and on Hallegatte (2008) that presents an Adaptive Regional I–O (ARIO) model for assessing the economic cost of Hurricane Katrina.

inter-regional effects of the earthquakes in the production processes and in the incomes of institutional sectors affected by the four strong earthquakes occurred in August and October 2016, and January 2017, in the Central Italy.

The paper is structured as follows. Section 2 briefly describes the bi-regional extended multisectoral model (with further details in “Appendix 2”) while Sect. 3 formalizes the B-IEMM approach. Section 4 introduces the case study with the features of the territories affected by the earthquakes, their particular productive vocation and their relevance in the national economic system. Section 5 highlights the higher order effects results proposing different scenarios for a more accurate disaster impacts analysis, and finally concluding remarks are given in Sect. 6.

2 Modeling and framework for the disaster impact analysis

The literature focusing on the disaster impact analysis is most commonly based on I–O and CGE models depending on the features of the disruptive event and its related consequences. The economic impacts of natural disasters are in general assessed for a short term by I–O models and for the long term with CGE-based models (Koks & Thissen, 2016). The former are commonly considered to overestimate the impacts of a disaster because of the linearity of the model, a lack of resource constraints and of responses to price changes, while the latter can in some cases underestimate the effects due to innumerable substitution possibilities² (Rose, 2004).

This study represents an intermediate approach, proposing the bi-regional SAM as a suitable framework for studying short-term indirect effects with specific results derived by the primary and secondary income distribution. According to Oosterhaven (2017), this intermediate approach overtakes the limit of the I–O model by also considering the induced effect produced by the income distribution process both in the affected area and in the rest of the country. Furthermore, the regional distinction gives local details for two areas by exploring how ripple effects can be reflected into regions and institutional sectors that are less involved in the disaster.

The increasing interest on the economic analysis related to income distribution and sustainable development requires the implementation and the development of economic tools able to detect transactions among activities and operators of an economic system. The purpose of this process is to verify the effects of internal and external shock, that in this case are represented by the intra-regional and the inter-regional effects (Socci, 2004) among the two macro-areas above mentioned. Contributions presenting bi-regional extended multisectoral models are proposed in Ciaschini and Socci (2007) and Ciaschini et al. (2012). These models, widely studied and discussed, follow the circular flow of income approach that, combined with the SAM scheme, allow to go beyond the interrelation between the final demand and the industries.³ Following the Miyazawa’s approach (Miyazawa, 1976) that interrelated endogenously the consumption with value added divided by households groups, the proposed model further

² In a static model, the results are generally negative while in a dynamic approach the outcome of the assessment can bring to positive benefits in other regions, due to an increase in the demand of the imports or for reconstruction needs from the affected regions (Koks and Thissen, 2016).

³ More recent contributions presenting examples of extended multisectoral models can be found in Socci et al. (2014), Ciaschini et al. (2015), Ahmed et al. (2018a, b) .

contemplates the primary and the secondary distribution of income, combining a set of structural matrices in order to exploit all the accounts presented in the SAM framework.

The Miyazawa's approach (Miyazawa, 1976) paved the way to alternative SAM-based models such as those proposed by Pyatt and Round (1979). Such approach has interrelated output with factor demands and income by decomposing the flows presented in the SAM framework into separate effects, underlining the important role of the income generation and consumption (Ahmed et al., 2020). Considering now an open economic system with b industries, n primary factors and h institutional sectors, the structural form of the bi-regional extended multisectoral model can be obtained.

$$\begin{Bmatrix} x^{SI} \\ x^{NC} \end{Bmatrix} = \begin{Bmatrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{Bmatrix} \begin{Bmatrix} X^{SI} \\ X^{NC} \end{Bmatrix} + \begin{Bmatrix} E^{SI,SI} & E^{SI,NC} \\ E^{NC,SI} & E^{NC,NC} \end{Bmatrix} \begin{Bmatrix} X^{SI} \\ X^{NC} \end{Bmatrix} + \begin{Bmatrix} f^{SI} \\ f^{NC} \end{Bmatrix} \quad (1)$$

Alternatively, Eq. 28, can be defined in its reduced form.

$$\begin{Bmatrix} x^{SI} \\ x^{NC} \end{Bmatrix} = \left[\begin{Bmatrix} I_1 & 0 \\ 0 & I_2 \end{Bmatrix} - \begin{Bmatrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{Bmatrix} - \begin{Bmatrix} E^{SI,SI} & E^{SI,NC} \\ E^{NC,SI} & E^{NC,NC} \end{Bmatrix} \right]^{-1} \begin{Bmatrix} f^{SI} \\ f^{NC} \end{Bmatrix} \quad (2)$$

See “Appendix 2” for a detailed description on how the whole bi-regional extended multi-sectoral model is built.

In order to achieve the task of an economic impact of the four earthquakes it is of primary importance to introduce the starting framework. The use of methodology that takes full advantage of the SAM scheme in the disaster analysis studies has been largely discussed by Cole (1995, 1998, 2004), by Bradshaw (2003) and more recently by Okuyama and Sahin (2009), among others. In fact, this framework is an adaptable tools that presents interdependencies among Activities, Primary factors and institutional sectors at different level, being therefore able to detect interdependent system failures and consequently supporting modeling in the task of measuring the inoperability due to a perturbation. Moreover, this framework points out the disposable income formation process in order to assess not only the impact of intervention policies on the main economic variables (GDP, output, employment) but also to evaluate the income distribution variation among specific groups inside the institutional sectors at different levels. As previously mentioned, this study takes full advantage of a B-SAM where a distinction between two macro-areas, North-Centre and South- Islands, is provided. This scheme includes: 16 industries (see for instance Table 3) per each macro-area, two components of the value added per each macro-area, and the accounts of Capital formation and Rest of the World. Moreover, the framework presents per each macro-area further differentiation in the institutional sectors such as households and financial and non-financial Corporations and offers a detailed scheme that contains different level of Government: Central Government, Regional, Provincial and Municipal. The latter includes five population groups: (i) Municipality 1, lesser than 5000 inhabitants; (ii) Municipality 2, from 5000 to 15,000 inhabitants; (iii) Municipality 3, from 15,000 to 30,000 inhabitants; (iv) Municipality 4, from 30,000 to 60,000 inhabitants; (v) Municipality 5, more than 60,000 inhabitants. The B-SAM for the 2012 exploits data provided by the National Institute of Statistics and can be resumed as shown in Fig. 11 in the “Appendix 1”.

3 The bi-regional inoperability extended multisectoral model approach

An important feature derived from the bi-regional extended multisectoral model approach is the capability of embodying in the higher order effects the intra-regional and inter-regional flows. The outcome of these crossover transactions between the two regions involved are included in the results of the model.

As mentioned before, the B-IEMM approach provides an interdependency analysis tool for assessing the ripple effects triggered by various sources of disruption such as natural disaster or human hazard. This methodology is derived from the Demand-Side (or Demand-Reduction) IIM presented by Santos (2003) that proposed to combine the idea of the inoperability,⁴ suggested by Haines and Jiang (2001),⁵ with the Leontief model.

Important reflections are given by Dietzenbacher and Miller (2015) that substantially criticize the capability of this inoperability approach to add novelty to the related literature. The major claim concerns the fact that this approach is more a revision of the supply-side I–O model, most often associated with the Ghosh name, described and discussed in Miller and Blair (1985) and earlier appeared in Augustinovic (1970). Indeed, the inoperability measure is introduced in the I–O model following the Ghosh (supply-side) model (Ghosh, 1958) through the use of the allocation coefficients matrix (or direct-output coefficients matrix), where the elements "represent the distribution of sector i 's outputs across sectors j that purchase interindustry inputs from i ." This concept, opposed to the technical coefficients matrix one proposed by Leontief (Miller & Blair, 2009), is of key importance for computing the IIM approach. Other critical aspects have been raised more recently by Oosterhaven (2017) on the limited usability of the IIM approach when studying policy interventions due to an underestimation of the negative indirect effects of a disaster. In spite of the critical observations made, the wide use of this methodology when assessing the disruptive phenomena is in part the proof of the success of combining a well-known modeling approach with this topic. The foundations of the Demand-Side B-IEMM (as well as for IIM approach) are presented in Eq. 3.

The degraded normalized output per industry is expressed in vector z_i , while the other elements \bar{x}_i and \tilde{x}_i of the equation are: (i) the intended output vector representing the economy before the disaster occurs and (ii) the damaged output vector registered after the perturbation, respectively.

$$z_i = \frac{\bar{x}_i - \tilde{x}_i}{\bar{x}_i} \quad (3)$$

After this consideration, the structural form of the B-IEMM can be written as

$$\begin{Bmatrix} x^{SI} \\ x^{NC} \end{Bmatrix} = \begin{Bmatrix} A^{*SI,SI} & A^{*SI,NC} \\ A^{*NC,SI} & A^{*NC,NC} \end{Bmatrix} \begin{Bmatrix} X^{SI} \\ X^{NC} \end{Bmatrix} + \begin{Bmatrix} E^{*SI,SI} & E^{*SI,NC} \\ E^{*NC,SI} & E^{*NC,NC} \end{Bmatrix} \begin{Bmatrix} z^{SI} \\ z^{NC} \end{Bmatrix} + \begin{Bmatrix} f^{*SI} \\ f^{*NC} \end{Bmatrix} \quad (4)$$

or in its reduced form as

⁴ The definition of inoperability has been introduced by Jiang (2003) as the inability of the system to perform its intended function.

⁵ See also Santos and Haines (2004) and Leung et al. (2007).

$$\left\{ \begin{matrix} \bar{x}^{SI} \\ \bar{x}^{NC} \end{matrix} \right\} = \left[\left\{ \begin{matrix} I_1 & 0 \\ 0 & I_2 \end{matrix} \right\} - \left\{ \begin{matrix} A^{*SI,SI} & A^{*SI,NC} \\ A^{*NC,SI} & A^{*NC,NC} \end{matrix} \right\} - \left\{ \begin{matrix} E^{*SI,SI} & E^{*SI,NC} \\ E^{*NC,SI} & E^{*NC,NC} \end{matrix} \right\} \right]^{-1} \left\{ \begin{matrix} f^{*SI} \\ f^{*NC} \end{matrix} \right\} \tag{5}$$

Equation 5 describes the bi-regional inoperability vector \mathbf{z} , brought about by the final demand perturbation \mathbf{f}^* that spreads the damage effect in the interdependency matrix \mathbf{A}^* and the matrix \mathbf{E}^* .

Expressing Eq. 3 in its structural form,

$$\left\{ \begin{matrix} \bar{z}^{SI} \\ \bar{z}^{NC} \end{matrix} \right\} = \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \bar{x}^{SI} \\ \bar{x}^{NC} \end{matrix} \right] - \left[\begin{matrix} \tilde{x}^{SI} \\ \tilde{x}^{NC} \end{matrix} \right] \right\} \tag{6}$$

and following the considerations of Eq. 5, each matrix and vector can also be redefined as

$$\left\{ \begin{matrix} A^{*SI,SI} & A^{*SI,NC} \\ A^{*NC,SI} & A^{*NC,NC} \end{matrix} \right\} = \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \begin{matrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\} \tag{7}$$

$$\left\{ \begin{matrix} E^{*SI,SI} & E^{*SI,NC} \\ E^{*NC,SI} & E^{*NC,NC} \end{matrix} \right\} = \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \begin{matrix} E^{SI,SI} & E^{SI,NC} \\ E^{NC,SI} & E^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\} \tag{8}$$

$$f^* = \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \tilde{f}^{SI} \\ \tilde{f}^{NC} \end{matrix} \right] - \left[\begin{matrix} \bar{f}^{SI} \\ \bar{f}^{NC} \end{matrix} \right] \right\} \tag{9}$$

Therefore, in Eq. 9, the nominal value of the final demand (without the occurrence of the perturbation) is identified in the vector $\bar{\mathbf{f}}$ while the degraded final demand after the events is represented by the vector $\tilde{\mathbf{f}}$.

Finally, the B-IEMM can be introduced in its extended version.

$$\begin{aligned} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \tilde{x}^{SI} \\ \tilde{x}^{NC} \end{matrix} \right] - \left[\begin{matrix} \bar{x}^{SI} \\ \bar{x}^{NC} \end{matrix} \right] \right\} &= \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \begin{matrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \tilde{x}^{SI} \\ \tilde{x}^{NC} \end{matrix} \right] - \left[\begin{matrix} \bar{x}^{SI} \\ \bar{x}^{NC} \end{matrix} \right] \right\} \\ &+ \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \begin{matrix} E^{SI,SI} & E^{SI,NC} \\ E^{NC,SI} & E^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \tilde{x}^{SI} \\ \tilde{x}^{NC} \end{matrix} \right] - \left[\begin{matrix} \bar{x}^{SI} \\ \bar{x}^{NC} \end{matrix} \right] \right\} \\ &+ \left\{ \begin{matrix} \bar{x}^{SI} & 0 \\ 0 & \bar{x}^{NC} \end{matrix} \right\}^{-1} \left\{ \left[\begin{matrix} \tilde{f}^{SI} \\ \tilde{f}^{NC} \end{matrix} \right] - \left[\begin{matrix} \bar{f}^{SI} \\ \bar{f}^{NC} \end{matrix} \right] \right\} \end{aligned} \tag{10}$$

Furthermore, similar to Eq. 30, the B-IEMM disposable income can be obtained.

$$\begin{aligned} \left\{ \begin{matrix} D^{SI,SI} & D^{SI,NC} \\ D^{NC,SI} & D^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} \bar{z}^{SI} \\ \bar{z}^{NC} \end{matrix} \right\} &= \left\{ \begin{matrix} D^{SI,SI} & D^{SI,NC} \\ D^{NC,SI} & D^{NC,NC} \end{matrix} \right\} \left[\left\{ \begin{matrix} I_1 & 0 \\ 0 & I_2 \end{matrix} \right\} - \left\{ \begin{matrix} A^{*SI,SI} & A^{*SI,NC} \\ A^{*NC,SI} & A^{*NC,NC} \end{matrix} \right\} \right. \\ &\quad \left. - \left\{ \begin{matrix} E^{*SI,SI} & E^{*SI,NC} \\ E^{*NC,SI} & E^{*NC,NC} \end{matrix} \right\} \right]^{-1} \left\{ \begin{matrix} f^{*SI} \\ f^{*NC} \end{matrix} \right\} \end{aligned} \tag{11}$$

4 Earthquake economic outlook: the case study

The earthquake subject in the literature review played a decisive role for the development of the disaster analysis. In fact, due to a series of earthquake disasters in the mid 1990's,⁶ the research community started to pay more and more attention to these phenomena, understanding how urgent is the task for a first assessment of the damages for such natural hazards (Okuyama, 2007).

In that sense, the effort of this section is to describe the four Central Italy earthquakes, in order to build a full picture of the productive vocation of the affected territories and their relevance in the national economy, and to provide a first evaluation of the phenomena for preparing an intervention plan with suitable economic measures aim to a quick recovery programme of the productive processes. The Central Italy was faced with four strong earthquakes in August 24th, October 26th and 30th 2016, and January 18th 2017, followed by other earthquake swarms events of different magnitudes.

The first event involved four Regions of the Apennines territory (Umbria, Marche, Lazio and Abruzzo), eight Provinces and sixty-two Municipalities. The second event involved four Regions, seven Provinces and sixty-nine Municipalities together with several areas already implicated in the first event and the third event involved other nine Municipalities in three Provinces of Abruzzo.⁷ It must be observed that by following the partition of the Italian territory used by the National Institute of Statistics (ISTAT), three Regions are considered in the Central Italy area (Lazio, Umbria and Marche), while Abruzzo has been included in the southern part of the national territory.

Figure 1 shows a filled map of the total area involved in the four events, with a colored differentiation by Region, for the hundred-forty municipalities involved. Marche region is the most involved with eighty-seven municipalities included in the list presented in the Law n. 229, followed by twenty-three municipalities for Abruzzo and fifteen for Lazio and Umbria. The next Fig. 2 displays the location of the municipalities, with a colored differentiation by Region. The dimension of the circles indicates its relevance among the others in terms of number of employees.

Afterward, the importance of those industries (as percentage share per industry on national scale) in the four mostly harmed areas, given by the number of the employees⁸ is illustrated in Fig. 3.

The next Fig. 4 shows which are the leading activities of the affected municipalities and their relative weight per Region.

The relevance of the industries mostly involved in the events and then in the disaster assessment (see Sect. 5) is given by the number of the employees that provides a ranking among all the activities. This allows identifying some of the most important industries in order to, at a later step, focus the study on those productive processes that can be mainly implicated in the disaster. From Fig. 4, it can be easily recognized the prevalence of the activities I_15.Private Services by a 22.0%, I_01.Agriculture, Forestry and Fishing by a 16.8% and I_12.Wholesale and Retail Trade by a 16.0% of the overall harmed areas. Comparing the statistics with Fig. 3, it can be observed how the same activities are entangled

⁶ The Northridge Earthquake in 1994 and the Kobe Earthquake in 1995. Since then relevant progress has been made in the impact assessment of earthquakes, see for instance Okuyama et al. (1999), Okuyama (2014), Kajitani et al. (2013), Kajitani and Tatano (2014).

⁷ The list of the areas subject to restoration, reconstruction, assistance to the population and economic recovery was presented.

in the Law n. 229 of December 15th 2016 and updated with the Law n. 45 of April 7th 2017.

⁸ The referring dataset *Local units and local unit persons employed* provided data until municipal level and by 2011 Local labor market area (ISTAT).

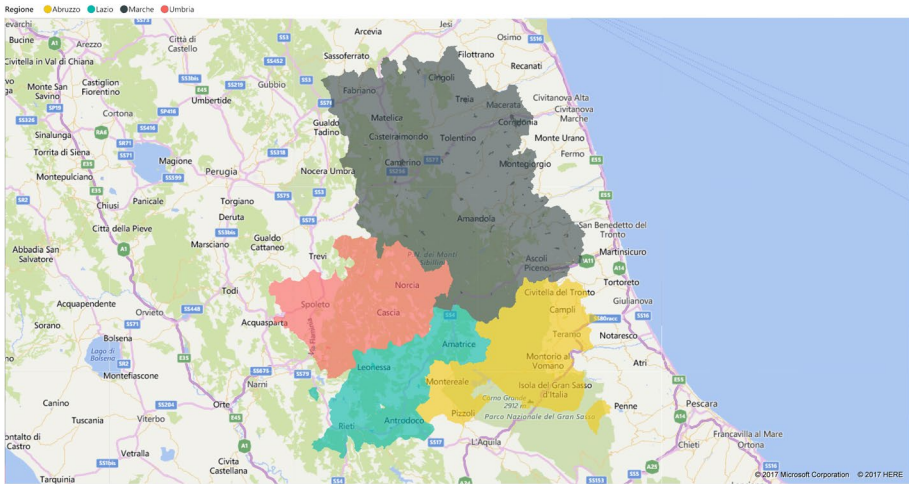


Fig. 1 Map of the affected areas per Region. Source: own graphic elaboration on the dataset provided by ISTAT

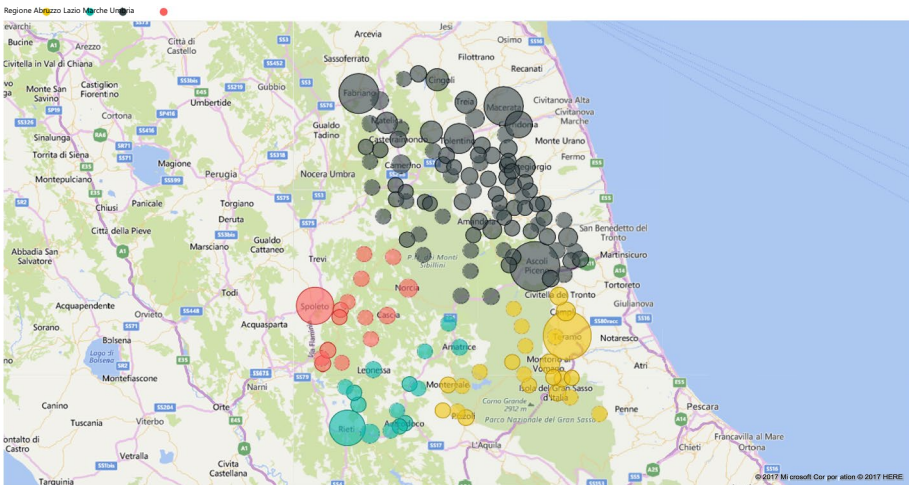


Fig. 2 Map of the affected areas per municipality and region. Source: own graphic elaboration on the dataset provided by ISTAT

on the national economy. In this case, after cross-checking the data, some of the industries that seem to be less implicated in the productive process (Fig. 4) are instead of national relevance, as for instance *I_09.Textiles and Wearing apparel*, mainly in the Marche Region, and *I_06.Machinery and Equipment* and *I_08.Food and Beverages*, that represent, respectively, 1.96%, 1.44% and 1.42% of the whole national economy. The overall percentage of employees for the affected areas on the Italian territory is of 0.95%.

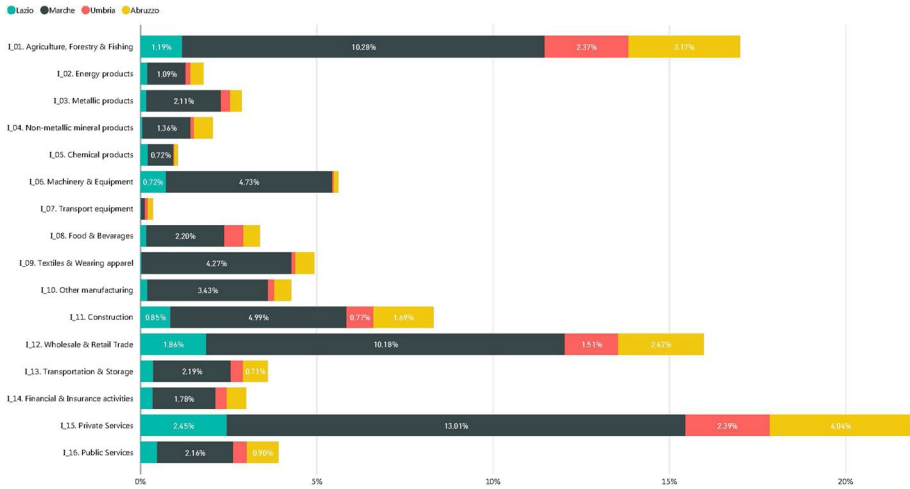


Fig. 3 Employees at national scale by industry and regions. Source: own graphic elaboration on the dataset provided by ISTAT

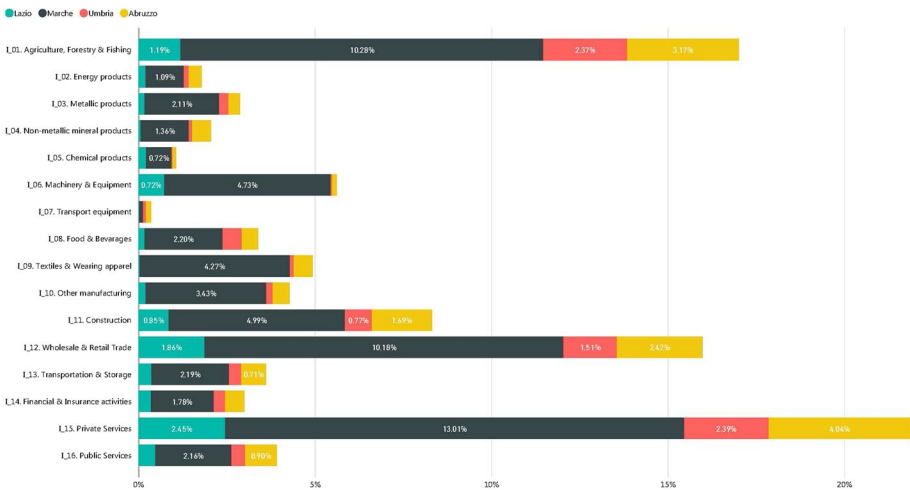


Fig. 4 Employees of affected areas by industry and regions. Source: own graphic elaboration on the dataset provided by ISTAT

5 A disaster impact analysis for the affected areas

According to the handbook presented by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) "This assessment need not entail the utmost quantitative precision, but it must be comprehensive in that it covers the complete range of effects and their cross-implications for economic and social sectors, physical infrastructure and environmental assets" (Bradshaw, 2003). In that sense, the most relevant task when studying these events after a disaster occurs is to provide an evaluation as quick as possible for starting a prompt recovery and reconstruction plan. By doing so, the main issue that

has to be considered is the data reliability. In fact, the lack of information on the spreading damage, especially in the aftermath of a disruptive event, is the first obstacle to provide an initial disaster assessment.

It is important to say that a disaster is often translated into an exogenous shock affecting the economic system (Koks & Thissen, 2016). The consequences of these shocks can be studied from different perspectives and can conduct to different conclusions. A disaster analysis can be addressed considering two types of losses, direct (affecting the stocks) and indirect (affecting the flows). The physical damage occurs on the stocks concerning: (i) Dwellings; (ii) Industries; and (iii) Infrastructures and communication networks. Each stock category creates distinct flows losses: (i) those provoked on the dwellings (collapsed or declared unusable) resulting in displaced residents that move from the affected areas to other accommodations that consequently creates a final demand reduction; (ii) economic activities that suffered structural damages which interfere with the production and cause supply side issues; and (iii) the temporary interruption of roads infrastructures and communication channels that can affect both, the demand and supply side.

In the attempt of proposing an urgent assessment of the damages and in order to have results not only on the production sphere but also from the income distribution perspective, the study investigates the ability of the Italian territory of maintaining functionality after a demand-side decrease brought by the households displacement, in accordance with the concept of static resilience (Rose & Wei, 2013).

Given the lack of official data on the overall monetary loss and the heterogeneity of the impacts that this type of natural disasters can have (Mohan et al., 2018), the study estimates the final demand reduction on the basis of the total number of the displaced residents, the disposable income by Institutional Sector and its propensity to expenditure, divided proportionally by macro-area, for the main activities of the affected territories (Figs. 3 and 4). This 10% reduction already offers an insight on the structure of the impacts among the most relevant industries. An eventual increasing or decreasing of the final demand percentage loss proposed will not change the structure of the impacts in absolute terms.

In the effort of determining the most accurate impact assessment of a catastrophic event, a series of scenarios that can help describing the size of the interindustrial damages are now proposed. Each of the scenarios examined, that individually underlines all the possible impacts in terms of output that the territory may have suffered, are leaded mainly by six activities, three of which identified among the most relevant at national scale (Fig. 3) and other three being relevant among the hundred thirty-one Municipalities (Fig. 4):

I_01. Agriculture, Forestry and Fishing, I_06. Machinery and Equipment, I_08. Food and Beverages, I_09. Textiles and Wearing apparel, I_12. Wholesale and Retail Trade and I_15. Private Services.⁹ The higher order effects are expressed in output percentage share on the total economy¹⁰ and in a second step the results in terms of disposable income percentage variation from the benchmark per Institutional Sector, are shown.

⁹ It must be noted that the aggregation level for this industry includes several activities involved: *I: Accommodation and food service activities, J: Information and communication, L: Real estate activities, M: Professional, scientific and technical activities, N: Administrative and support service activities, H: Arts, entertainment and recreation and S: Other service activities.*

¹⁰ Please note that the results in terms of output percentage variation are presented in Table 3 in the Appendix A, where a comparison between the outcome of the B-IEMM and the bi-regional formulation of the IIM (B-IIM) approach is provided.

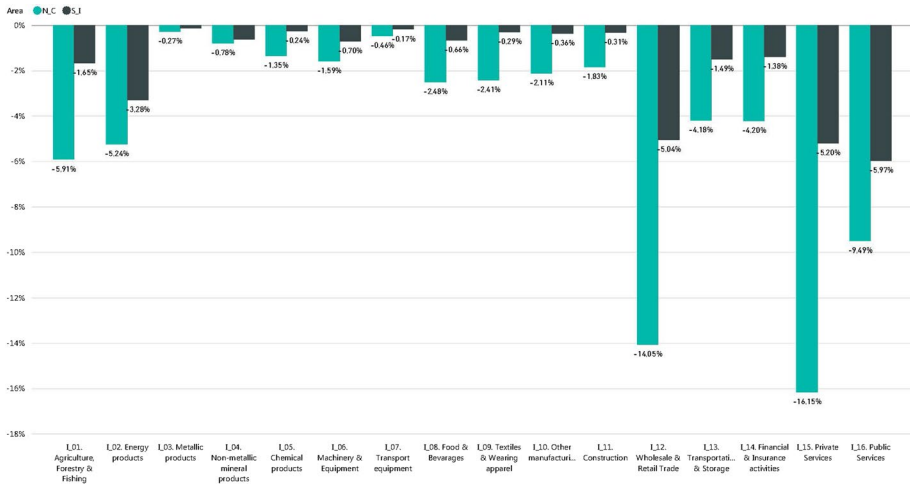


Fig. 5 Degraded normalized output per scenario (in percentage share)—Agriculture, Forestry and Fishing. Source: own elaboration

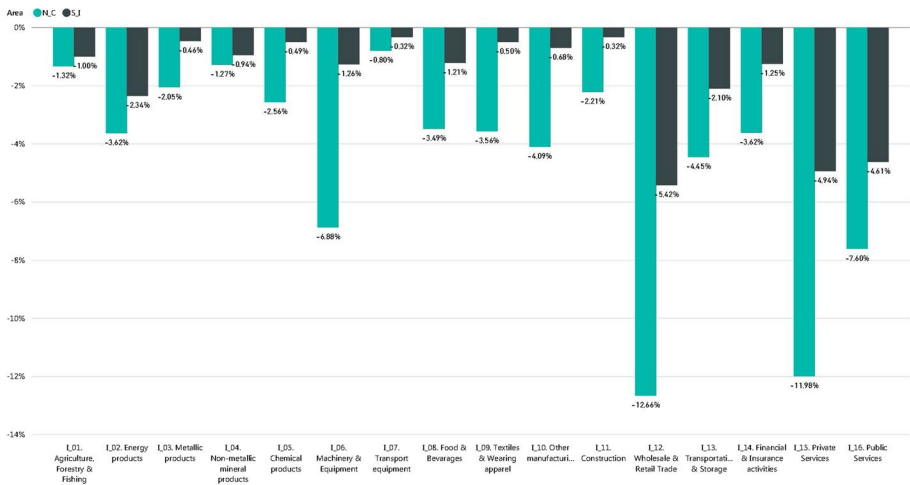


Fig. 6 Degraded normalized output per scenario (in percentage share)—Machinery and Equipment. Source: own elaboration

The impact of a 10% final demand reduction in the I_01.Agriculture, Forestry and Fishing industry, which affects proportionally all the industries per area, is shown in Fig. 5. The results must be read as the percentage shares on the overall scenario. The highest damage can be observed in the I_15. Private Services industry in the NC area, although the reduction is attributed only in the I_01 industry. Once again the effects in the SI area are similarly concentrated in the service activities as I_15.Private Services, I_16.Public Services¹¹ and I_12.Wholesale and Retail Trade.

¹¹ This industry includes the activities: *P: Education and Q: Human health and social work activities.*

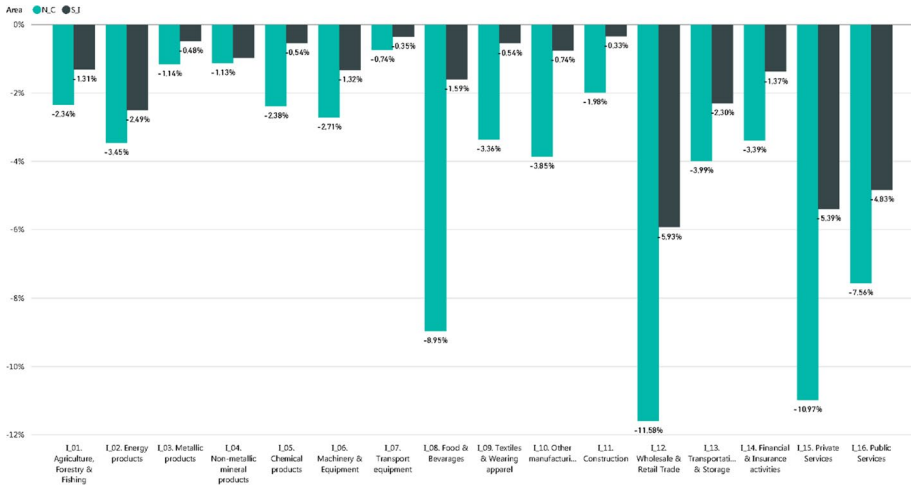


Fig. 7 Degraded normalized output per scenario (in percentage share)—Food and Beverages. Source: own elaboration

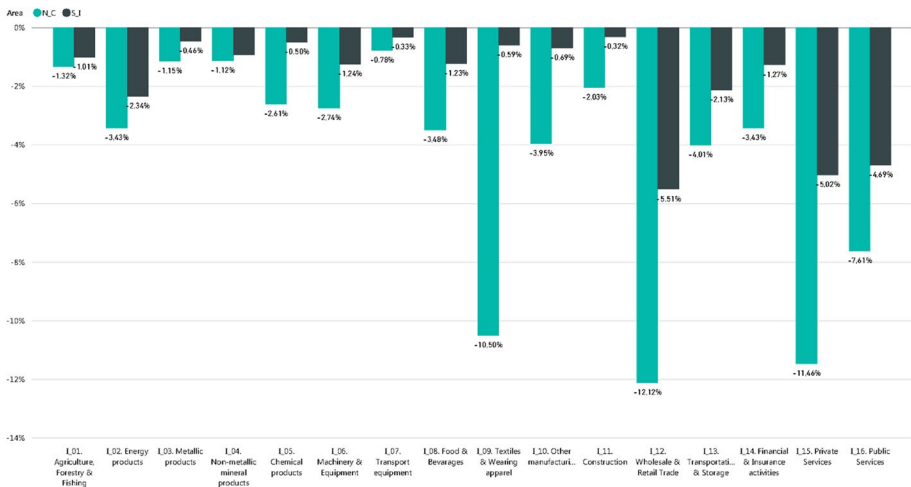


Fig. 8 Degraded normalized output per scenario (in percentage share)—Textiles and Wearing Apparel. Source: own elaboration

Same considerations can be made with respect to a 10% final demand loss in the I_06.Machinery and Equipment industry (Fig. 6). All the impacts are mainly localized in the same service activities but with more weight observed in the I_12.Wholesale and Retail Trade industry.

From Fig. 7 it can be observed that even though the impacts of the service activities remain higher in both of the areas, the overall effects on the I_08.Food and Beverages manufacturing industry and on the I_01.Agriculture, Forestry and Fishing industry are more relevant with respect to the previous figures.

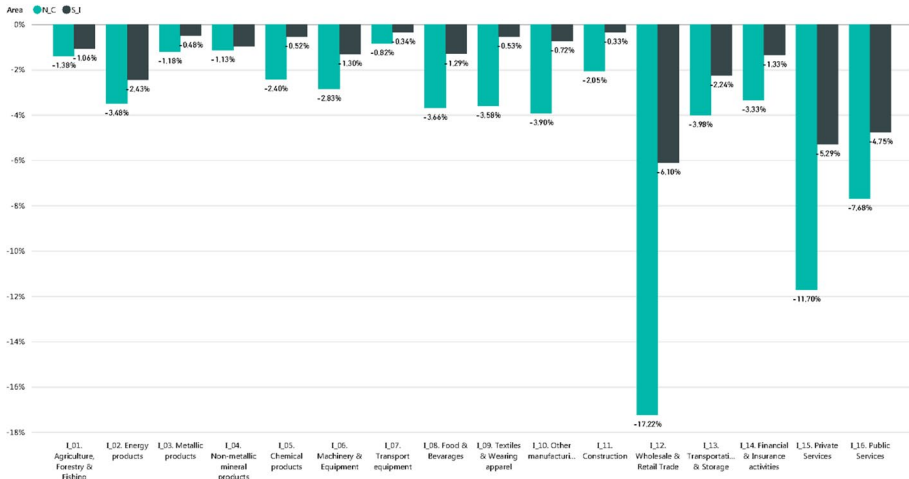


Fig. 9 Degraded normalized output per scenario (in percentage share)—Wholesale and Retail Trade. Source: own elaboration

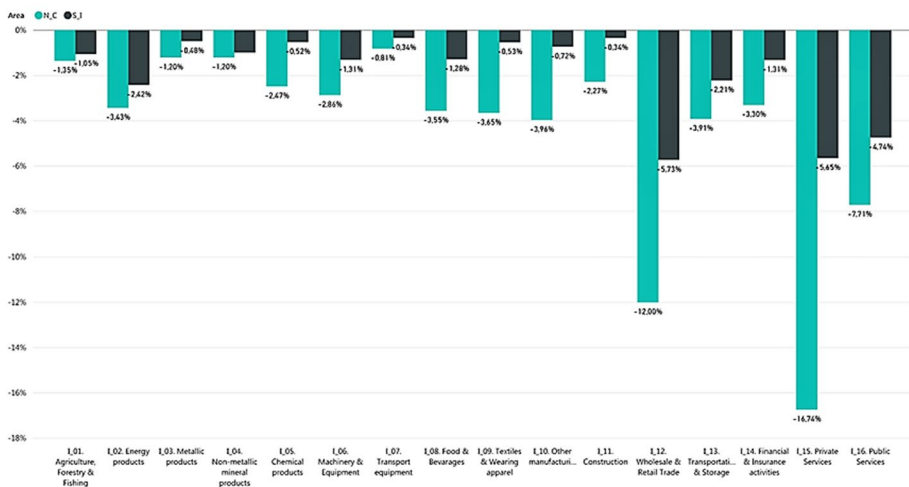


Fig. 10 Degraded normalized output per scenario (in percentage share)—Private Services. Source: own elaboration

The I_09.Textiles and Wearing apparel industry (Fig. 8), as previously mentioned, is the most important activity among the affected territories for the national economy (see Fig. 3). The reduction results follow the same consideration of the Machinery and Equipment scenario. The higher order effects in this case are stronger in the same industry and underline important interconnections with activities such as I_12 and I_15.

Figure 9 displays the impacts when the Wholesale and Retail Trade industry carries the final demand reduction. The scenario shows the prevalence of the three main service

activities, underlying the highest impacts in the same affected industry mainly as a result of direct effects.

The results for one of the most relevant industries among the others are presented in the last Fig. 10. Even in this case the Private Services scenario follows the same considerations shown in Fig. 9, which means that the interdependencies of these industries (I_12 and I_15) are similarly integrated in the productive system.

Table 1 presents the findings in terms of disposable income of the institutional sectors with respect to the benchmark (when no events occurred). The negative impacts, displayed by each scenario due to a 10% final demand reduction, represent the performance variation that each Institutional sector has suffered with reference to a previous period before the earthquakes.¹² It can be noticed that the SI area has relatively higher negative results than the NC one, that could be read as a lower capacity of the SI economic system to react to this negative shocks.

Following these considerations, the two areas are separately tackled. In the SI area the most relevant overall impact can be observed in the scenario where the Machinery and Equipment carries the 10% final demand reduction. The performance variation follows the same reduction pattern for the two scenarios regarding the service activities (Wholesale and Retail Trade and Private Services) although with a different scale, while for the remaining scenarios different patterns have to be examined. The common Institutional sector affected in all the scenarios considered is the Financial and Non-Financial Corporations while for the three sub-level of Government the percentage variations follow a similar trend.

The descriptive analysis has to be focused now on the NC area which, as previously mentioned, is the most affected territory with hundred seventeen Municipalities on the hundred thirty-one involved, and in this respect the impact analysis of this area has to be considered with a more relevant weight. Also, in this case, the performances per scenario are presented following the reflections made in Figs. 3 and 4 (in Sect. 4) on the importance of the industries in the productive processes among the affected areas and at a national scale.

Once again the scenario that has encountered the highest negative impact is the Machinery and Equipment followed by the Wholesale and Retail Trade and Private Services. An opposing trend is represented by the Regional Government that has recorded the lowest negative impact respect to the benchmark. Along these lines the Municipality 5 (i.e., with more than 60,000 inhabitants) receives the lowest impact among all the Municipalities. All the trends followed by each scenario, except for those institutional sectors already mentioned, reflect the patterns of the Central Government and more broadly in terms of disposable income percentage variation, although with some small discrepancy.

Table 2 additionally offers another kind of information on which are the most harmed institutional sectors among the scenarios proposed. In both areas, the households receive the higher overall impact in terms of percentage share (around 70% per scenario). The range for the NC area varies from – 47.6% of the Food and Beverages scenario to the – 50.0% in the Machinery and Equipment scenario, while for the SI area goes from the Agriculture, Forestry and Fishing scenario with a reduction of – 20.3% to the Food and Beverages scenario with.

¹² The percentage share results of the disposable income are shown in Table 2.

Table 1 Disposable income performance per Institutional sector (in percentage variation)

| Area | Institutional Sector | Agriculture, Forestry and Fishing (%) | Machinery and Equipment (%) | Food and Beverages (%) | Textiles and Wearing Apparel (%) | Wholesale and Retail Trade (%) | Private Services (%) |
|------|----------------------------------|---------------------------------------|-----------------------------|------------------------|----------------------------------|--------------------------------|----------------------|
| S_I | Households | -0.03 | -0.27 | -0.09 | -0.14 | -0.20 | -0.17 |
| S_I | Financial and Non-Financial Corp | -0.04 | -0.30 | -0.11 | -0.15 | -0.25 | -0.22 |
| S_I | Regional Government | -0.04 | -0.23 | -0.07 | -0.10 | -0.18 | -0.16 |
| S_I | Provincial Government | -0.03 | -0.27 | -0.09 | -0.14 | -0.20 | -0.17 |
| S_I | Municipality 1 | -0.03 | -0.28 | -0.09 | -0.14 | -0.20 | -0.17 |
| S_I | Municipality 2 | -0.03 | -0.28% | -0.09 | -0.14 | -0.21 | -0.18 |
| S_I | Municipality 3 | -0.03 | -0.28 | -0.09 | -0.14 | -0.21 | -0.18 |
| S_I | Municipality 4 | -0.03 | -0.28 | -0.09 | -0.14 | -0.21 | -0.17 |
| S_I | Municipality 5 | -0.03 | -0.27 | -0.09 | -0.14 | -0.20 | -0.17 |
| N_C | Households | -0.02 | -0.24 | -0.07 | -0.12 | -0.17 | -0.15 |
| N_C | Financial and Non-Financial Corp | -0.03 | -0.23 | -0.07 | -0.10 | -0.19 | -0.17 |
| N_C | Regional Government | -0.03 | -0.09 | 0.02 | -0.01 | -0.04 | -0.05 |
| N_C | Provincial Government | -0.02 | -0.23 | -0.07 | -0.11 | -0.16 | -0.14 |
| N_C | Municipality 1 | -0.02 | -0.21 | -0.05 | -0.10 | -0.14 | -0.13 |
| N_C | Municipality 2 | -0.02 | -0.23 | -0.06 | -0.11 | -0.16 | -0.14 |
| N_C | Municipality 3 | -0.02 | -0.24 | -0.07 | -0.11 | -0.17 | -0.15 |
| N_C | Municipality 4 | -0.02 | -0.24 | -0.07 | -0.12 | -0.17 | -0.15 |
| N_C | Municipality 5 | -0.02 | -0.19 | -0.04 | -0.08 | -0.12 | -0.11 |
| IT | Central Government | -0.02 | -0.27 | -0.09 | -0.14 | -0.19 | -0.16 |
| IT | Disposable income | -0.02 | -0.25 | -0.07 | -0.12 | -0.18 | -0.16 |

Table 2 Normalized disposable income per scenario

| Area | Institutional Sector | Agriculture, Forestry and Fishing (%) | Machinery and Equipment (%) | Food and Beverages (%) | Textiles and Wearing Apparel (%) | Wholesale and Retail Trade (%) | Private Services (%) |
|------|----------------------------------|---------------------------------------|-----------------------------|------------------------|----------------------------------|--------------------------------|----------------------|
| S_I | Households | -20.31 | -20.94% | -23.07 | -21.58 | -21.36 | -20.99 |
| S_J | Financial and Non-Financial Corp | -2.38 | -1.81 | -2.27 | -1.86 | -2.09 | -2.07 |
| S_J | Regional Government | -0.66 | -0.40 | -0.38 | -0.36 | -0.43 | -0.44 |
| S_J | Provincial Government | -0.15 | -0.16 | -0.18 | -0.17 | -0.16 | -0.16 |
| S_J | Municipality 1 | -0.15 | -0.16 | -0.18 | -0.17 | -0.16 | -0.16 |
| S_J | Municipality 2 | -0.20 | -0.22 | -0.25 | -0.23 | -0.23 | -0.22 |
| S_J | Municipality 3 | -0.13 | -0.15 | -0.17 | -0.16 | -0.16 | -0.15 |
| S_J | Municipality 4 | -0.18 | -0.20 | -0.22 | -0.21 | -0.20 | -0.20 |
| S_J | Municipality 5 | -0.24 | -0.26 | -0.28 | -0.27 | -0.26 | -0.26 |
| N_C | Households | -48.63 | -50.05 | -47.59 | -49.80 | -48.82 | -49.16 |
| N_C | Financial and Non-Financial Corp | -10.51 | -7.48 | -7.17 | -6.87 | -8.40 | -8.68 |
| N_C | Regional Government | -1.04 | -0.39 | 0.30 | -0.09 | -0.24 | -0.34 |
| N_C | Provincial Government | -0.34 | -0.34 | -0.32 | -0.33 | -0.33 | -0.33 |
| N_C | Municipality 1 | -0.17 | -0.16 | -0.13 | -0.15 | -0.15 | -0.16 |
| N_C | Municipality 2 | -0.24 | -0.24 | -0.21 | -0.23 | -0.23 | -0.23 |
| N_C | Municipality 3 | -0.16 | -0.16 | -0.15 | -0.15 | -0.15 | -0.15 |
| N_C | Municipality 4 | -0.19 | -0.20 | -0.19 | -0.19 | -0.19 | -0.19 |
| N_C | Municipality 5 | -0.29 | -0.23 | -0.15 | -0.20 | -0.21 | -0.23 |
| IT | Central Government | -13.65 | -16.14 | -17.15 | -16.69 | -15.92 | -15.57 |
| IT | Disposable income | -100 | -100 | -100 | -100 | -100 | -100 |

– 23.1% (which in the NC area encounters the lowest impact among the Households). The second highest result among the institutional sectors is observed in the Central Government and more precisely in the Food & Beverages scenario, while the third one is identified in both areas in the financial and non-financial corporations in the agriculture, forestry & fishing scenario.

6 Conclusion

Determining which is the real impact of a catastrophic event can increasingly become a more difficult task when going down in the sectoral detail of smaller local areas. The assessment of the right structural mix that can affect the final demand becomes then an even more daunting task when a complex damage evaluation of the productive processes is added to a not yet fully stable situation with multiple events that may suddenly take place. In addition to the earthquake magnitude that affects human life and their own living spaces, also the magnitude of the impact on industries suffering real blackouts within the supply chain, has to be considered in the damage bill.

The effort of this contribution is to show how the interdependencies of key industries, when damaged, can paralyse different production processes and with ripple effects undermine the performances of those territories affected by the earthquakes.

Taking full advantage of the B-SAM framework, the study conducted has focused on assessing the higher order effects in terms of degraded output per scenario and the disposable income reduction per Institutional sector. The B-IEMM approach achieved the multiple task of including in the overall impact the return- effects on the final demand and, at the same time, of considering the intra-regional and inter-regional effects for the two macro areas.

In this respect the case study that concerned six of the sixteen industries has shown approximative scenarios compared to a realistic overall impact of the four earthquakes, nevertheless being able to represent the first impact assessment for these events and to quantify the damages not only on the production side but also on the income distribution sphere.

All the scenarios proposed represent, on their own, possible structures of impacts on the output that may have affected the hundred thirty-one Municipalities, underlining the relevance of the service activities and of those industries that triggered show consistent direct effects among all the activities, such as Textiles and Wearing apparel and Food and Beverages activities. Furthermore, this analysis has revealed that the highest negative impact, in terms of output percentage share, is not recorded in the activities with the higher number of employees but can be obtained in those scenarios led by more interconnected industries.

The findings, in terms of disposable income percentage variation from the benchmark, point out a higher negative impact on the institutional sectors of the SI area even though they are the lesser implicated in the disaster, highlighting a weaker reaction of this territory to the negative shocks. Additionally, the highest negative results, in terms of percentage share, are detected on the Households in the NC area, especially when the final demand reduction is carried by the Machinery and Equipment industry, while for the SI area when the loss being borne by the Food and Beverages industry. The same scenario also has the most significant negative effects in the Central Government at national level, while other relevant results can be observed, in both areas, on the financial and non-financial corporations underlining the prevalence of the agriculture, forestry and fishing scenario.

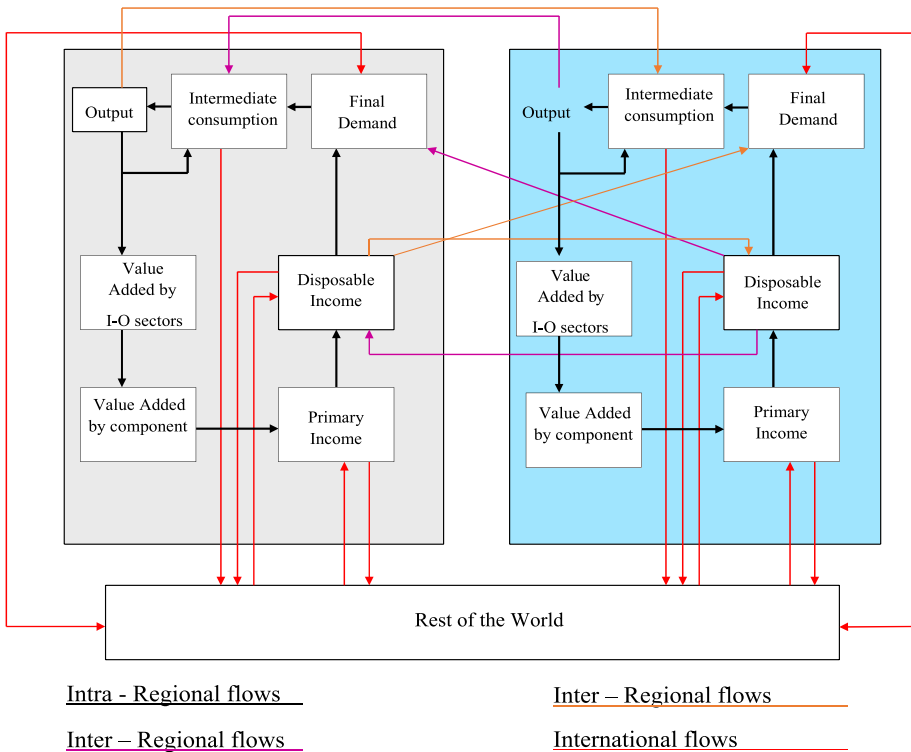


Fig. 11 The bi-regional circular flow of income. Source: own elaboration

The identification of those key production processes and institutional sectors most affected can finally guarantee a full picture of the cascading effects in the regional and national economic system and represent a first step for undertaking reconstruction programs and projects.

Appendix 1

See Fig. 11.

Table 3 shows a comparison between the results of the B-IEMM and the B-IIM approach in order to underline advantages and limitations of the two methodologies.

Appendix 2: The bi-regional extended multisectorial model approach

Considering an open economic system with b Industries, n Primary factors and h institutional sectors, the main equation of the model can be introduced.

Table 3 Output performance: B-IEMM versus B-IIM (in percentage variation)

| Area Id | Industry | Agriculture, Forestry and Fishing | | Machinery and Equipment | | Food and Beverages | | Textiles and Wearing Apparel | | Wholesale and Retail Trade | | Private Services | |
|----------|-----------------------------------|-----------------------------------|-----------|-------------------------|-----------|--------------------|-----------|------------------------------|-----------|----------------------------|-----------|------------------|-----------|
| | | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) |
| S_J L_01 | Agriculture, Forestry and Fishing | 0.06 | 0.03 | 0.29 | 0.00 | 0.12 | 0.02 | 0.15 | 0.00 | 0.21 | 0.00 | 0.18 | 0.00 |
| S_J L_02 | Energy products | 0.04 | 0.00 | 0.38 | 0.01 | 0.12 | 0.01 | 0.19 | 0.00 | 0.28 | 0.01 | 0.24 | 0.00 |
| S_J L_03 | Metallic products | 0.07 | 0.00 | 0.71 | 0.03 | 0.23 | 0.01 | 0.35 | 0.01 | 0.52 | 0.01 | 0.45 | 0.02 |
| S_J L_04 | Non-metallic mineral products | 0.04 | 0.00 | 0.44 | 0.02 | 0.14 | 0.01 | 0.21 | 0.01 | 0.31 | 0.01 | 0.27 | 0.02 |
| S_J L_05 | Chemical products | 0.04 | 0.00 | 0.36 | 0.00 | 0.12 | 0.00 | 0.18 | 0.00 | 0.27 | 0.00 | 0.23 | 0.00 |
| S_J L_06 | Machinery and Equipment | 0.04 | 0.00 | 0.44 | 0.02 | 0.14 | 0.00 | 0.22 | 0.00 | 0.32 | 0.01 | 0.28 | 0.01 |
| S_J L_07 | Transport equipment | 0.03 | 0.00 | 0.26 | 0.00 | 0.09 | 0.00 | 0.13 | 0.00 | 0.20 | 0.00 | 0.17 | 0.00 |
| S_J L_08 | Food and Beverages | 0.04 | 0.00 | 0.33 | 0.00 | 0.13 | 0.02 | 0.17 | 0.00 | 0.25 | 0.00 | 0.21 | 0.00 |

Table 3 (continued)

| Area Id | Industry | Agriculture, Forestry and Fishing | | Machinery and Equipment | | Food and Beverages | | Textiles and Wearing Apparel | | Wholesale and Retail Trade | | Private Services | |
|----------|---|-----------------------------------|-----------|-------------------------|-----------|--------------------|-----------|------------------------------|-----------|----------------------------|-----------|------------------|-----------|
| | | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) |
| S_J I_09 | Textiles and Wearing apparel | 0.03 | 0.00 | 0.32 | 0.00 | 0.11 | 0.00 | 0.19 | 0.03 | 0.24 | 0.00 | 0.20 | 0.00 |
| S_J I_10 | Other | 0.03 | 0.00 | 0.33 | 0.00 | 0.11 | 0.00 | 0.17 | 0.00 | 0.25 | 0.00 | 0.21 | 0.00 |
| S_J I_11 | Manufacturing | 0.04 | 0.00 | 0.44 | 0.02 | 0.14 | 0.00 | 0.22 | 0.01 | 0.32 | 0.01 | 0.28 | 0.02 |
| S_J I_12 | Construction and Wholesale | 0.03 | 0.00 | 0.29 | 0.00 | 0.10 | 0.00 | 0.15 | 0.00 | 0.23 | 0.01 | 0.18 | 0.00 |
| S_J I_13 | Retail Trade and Transportation | 0.03 | 0.00 | 0.31 | 0.00 | 0.10 | 0.00 | 0.15 | 0.00 | 0.23 | 0.01 | 0.19 | 0.00 |
| S_J I_14 | Storage and Financial | 0.03 | 0.00 | 0.30 | 0.00 | 0.10 | 0.00 | 0.15 | 0.00 | 0.23 | 0.01 | 0.19 | 0.00 |
| S_J I_15 | Insurance activities and Private Services | 0.03 | 0.00 | 0.28 | 0.00 | 0.10 | 0.00 | 0.14 | 0.00 | 0.21 | 0.00 | 0.20 | 0.02 |

Table 3 (continued)

| Area Id | Agriculture, Forestry and Fishing | | Machinery and Equipment | | Food and Beverages | | Textiles and Wearing Apparel | | Wholesale and Retail Trade | | Private Services | | |
|---------|-----------------------------------|------------|-------------------------|------------|--------------------|------------|------------------------------|------------|----------------------------|------------|------------------|------------|------|
| | Industry | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | |
| S_I_L16 | Public Services | 0.03 | 0.00 | 0.28 | 0.00 | 0.09 | 0.00 | 0.14 | 0.00 | 0.20 | 0.00 | 0.17 | 0.00 |
| N_C_L01 | Agriculture, Forestry and Fishing | 0.14 | 0.12 | 0.26 | 0.01 | 0.14 | 0.07 | 0.13 | 0.00 | 0.19 | 0.01 | 0.16 | 0.00 |
| N_C_L02 | Energy products | 0.03 | 0.00 | 0.34 | 0.05 | 0.10 | 0.01 | 0.16 | 0.02 | 0.23 | 0.02 | 0.20 | 0.01 |
| N_C_L03 | Metallic products | 0.03 | 0.00 | 0.45 | 0.21 | 0.08 | 0.01 | 0.13 | 0.01 | 0.18 | 0.01 | 0.16 | 0.01 |
| N_C_L04 | Non-metallic mineral products | 0.02 | 0.00 | 0.24 | 0.05 | 0.07 | 0.01 | 0.10 | 0.01 | 0.15 | 0.01 | 0.13 | 0.01 |
| N_C_L05 | Chemical products | 0.03 | 0.00 | 0.29 | 0.03 | 0.08 | 0.01 | 0.15 | 0.02 | 0.19 | 0.01 | 0.17 | 0.01 |
| N_C_L06 | Machinery and equipment | 0.01 | 0.00 | 0.32 | 0.20 | 0.04 | 0.00 | 0.06 | 0.00 | 0.09 | 0.01 | 0.08 | 0.00 |
| N_C_L07 | Transport equipment | 0.02 | 0.00 | 0.16 | 0.00 | 0.05 | 0.00 | 0.08 | 0.00 | 0.12 | 0.00 | 0.10 | 0.00 |

Table 3 (continued)

| Area Id | Industry | Agriculture, Forestry and Fishing | | Machinery and Equipment | | Food and Beverages | | Textiles and Wearing Apparel | | Wholesale and Retail Trade | | Private Services | | |
|----------|------------------------------------|-----------------------------------|-----------|-------------------------|-----------|--------------------|-----------|------------------------------|-----------|----------------------------|-----------|------------------|-----------|------|
| | | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | |
| N_C_I_08 | Food and Beverages | 0.03 | 0.01 | 0.29 | 0.01 | 0.23 | 0.14 | 0.14 | 0.14 | 0.00 | 0.21 | 0.01 | 0.18 | 0.00 |
| N_C_I_09 | Textiles and Wearing apparel | 0.02 | 0.00 | 0.25 | 0.00 | 0.07 | 0.00 | 0.36 | 0.24 | 0.17 | 0.00 | 0.00 | 0.15 | 0.00 |
| N_C_I_10 | Other manufacturing | 0.02 | 0.00 | 0.23 | 0.02 | 0.07 | 0.01 | 0.11 | 0.01 | 0.15 | 0.01 | 0.01 | 0.13 | 0.01 |
| N_C_I_11 | Construction | 0.03 | 0.00 | 0.33 | 0.05 | 0.09 | 0.01 | 0.15 | 0.01 | 0.22 | 0.02 | 0.02 | 0.20 | 0.03 |
| N_C_I_12 | Wholesale and Retail Trade | 0.02 | 0.00 | 0.25 | 0.03 | 0.07 | 0.01 | 0.12 | 0.01 | 0.24 | 0.08 | 0.08 | 0.15 | 0.00 |
| N_C_I_13 | Transportation and Storage | 0.02 | 0.00 | 0.26 | 0.05 | 0.07 | 0.01 | 0.12 | 0.01 | 0.16 | 0.01 | 0.01 | 0.14 | 0.01 |
| N_C_I_14 | Financial and Insurance activities | 0.03 | 0.00 | 0.26 | 0.04 | 0.08 | 0.01 | 0.12 | 0.02 | 0.17 | 0.01 | 0.01 | 0.15 | 0.01 |

Table 3 (continued)

| Area Id | Agriculture, Forestry and Fishing | | Machinery and Equipment | | Food and Beverages | | Textiles and Wearing Apparel | | Wholesale and Retail Trade | | Private Services | | |
|----------|-----------------------------------|------------|-------------------------|------------|--------------------|------------|------------------------------|------------|----------------------------|------------|------------------|------------|------|
| | Industry | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | B-IIM (%) | B-IEMM (%) | |
| N_C I_15 | Private Services | 0.02 | 0.00 | 0.25 | 0.03 | 0.07 | 0.01 | 0.12 | 0.01 | 0.17 | 0.01 | 0.21 | 0.07 |
| N_C I_16 | Public Services | 0.02 | 0.00 | 0.26 | 0.00 | 0.08 | 0.00 | 0.13 | 0.00 | 0.19 | 0.00 | 0.16 | 0.00 |

$$\left\{ \frac{m^{SI}}{m^{NC}} \right\} + \left\{ \frac{x^{SI}}{x^{NC}} \right\} = \left\{ \frac{r^{SI}}{r^{NC}} \right\} + \left\{ \frac{f_d^{SI}}{f_d^{NC}} \right\} \tag{12}$$

This structural form better describes the bi-regional dimension of the model where each variables is divided by the two areas, South-Islands (SI) and North-Centre (NC). Equation 12 variables represent the imports vector m , the domestic industry output x , the vector of the total intermediate consumption r and the final demand vector f_d composed by an endogenous and an exogenous part, $f_d=f_c+f_0$.

$$\left\{ \frac{x^{SI}}{x^{NC}} \right\} = \left\{ \frac{r^{SI}}{r^{NC}} \right\} + \left\{ \frac{f_c^{SI}}{f_c^{NC}} \right\} + \left\{ \frac{f_0^{SI}}{f_0^{NC}} \right\} - \left\{ \frac{m^{SI}}{m^{NC}} \right\} \tag{13}$$

Equation 14 shows how the intermediate consumption vector r is given by the product of the technical coefficients matrix $A[b, b]$ and the industry output vector x .

$$\left\{ \frac{r^{SI}}{r^{NC}} \right\} = \left\{ \begin{matrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{matrix} \right\} \left\{ \frac{x^{SI}}{x^{NC}} \right\} \tag{14}$$

The net exports vector f can now be defined as,

$$\left\{ \frac{f^{SI}}{f^{NC}} \right\} = \left\{ \frac{f_0^{SI}}{f_0^{NC}} \right\} - \left\{ \frac{m^{SI}}{m^{NC}} \right\} \tag{15}$$

Replacing Eqs. 14 and 15 in Eq. 13, the bi-regional extended multisectoral model can also be expressed as follows.

$$\left\{ \frac{x^{SI}}{x^{NC}} \right\} = \left\{ \begin{matrix} A^{SI,SI} & A^{SI,NC} \\ A^{NC,SI} & A^{NC,NC} \end{matrix} \right\} \left\{ \frac{x^{SI}}{x^{NC}} \right\} + \left\{ \frac{f_c^{SI}}{f_c^{NC}} \right\} + \left\{ \frac{f_0^{SI}}{f_0^{NC}} \right\} \tag{16}$$

The value added by industry can be defined as

$$\left\{ \frac{v_{io}^{SI}}{v_{io}^{NC}} \right\} = \left\{ \begin{matrix} L^{SI} & 0 \\ 0 & L^{NC} \end{matrix} \right\} \left\{ \frac{x^{SI}}{x^{NC}} \right\} \tag{17}$$

with $L[b, b]$ being a diagonal matrix and $l_j = 1 - \sum_{i=1}^n a_{ij}$. In order to obtain the value added by its components v_c can be introduced as follows

$$\left\{ \frac{v_c^{SI}}{v_c^{NC}} \right\} = \left\{ \begin{matrix} W^{SI,SI} & W^{SI,NC} \\ W^{NC,SI} & W^{NC,NC} \end{matrix} \right\} \left\{ \frac{v_{io}^{SI}}{v_{io}^{NC}} \right\} \tag{18}$$

, where $W[n, b]$ represents a matrix of shares of Primary factors.

The value added by Institutional sector v_{is} is given by

$$\left\{ \frac{v_{is}^{SI}}{v_{is}^{NC}} \right\} = \left\{ \begin{matrix} p^{SI} & 0 \\ 0 & p^{NC} \end{matrix} \right\} \left\{ \frac{v_c^{SI}}{v_c^{NC}} \right\} \tag{19}$$

with $P[h, n]$ being a shares matrix of the distribution of primary income that contributes in determining the disposable income through the inter-regional and intra-regional transfer flows. Having finalized the first phase regarding the circular flow of income, the disposable income vector can now be reconstructed.

$$\begin{Bmatrix} y^{SI} \\ y^{NC} \end{Bmatrix} = \left[\left\{ \begin{matrix} I_1 & 0 \\ 0 & I_2 \end{matrix} \right\} + \left\{ \begin{matrix} T^{SI,SI} & T^{SI,NC} \\ T^{NC,SI} & T^{NC,NC} \end{matrix} \right\} \right] \begin{Bmatrix} v_{is}^{SI} \\ v_{is}^{NC} \end{Bmatrix} \tag{20}$$

The matrix $T[h, h]$ represents the shares of the net transfers between the institutional sectors in the secondary distribution of income.

$$\left\{ \begin{matrix} D^{SI,SI} & D^{SI,NC} \\ D^{NC,SI} & D^{NC,NC} \end{matrix} \right\} = \left[\left\{ \begin{matrix} I_1 & 0 \\ 0 & I_2 \end{matrix} \right\} + \left\{ \begin{matrix} T^{SI,SI} & T^{SI,NC} \\ T^{NC,SI} & T^{NC,NC} \end{matrix} \right\} \right] \left\{ \begin{matrix} p^{SI} & 0 \\ 0 & p^{NC} \end{matrix} \right\} \left\{ \begin{matrix} W^{SI,SI} & W^{SI,NC} \\ W^{NC,SI} & W^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} L^{SI} & 0 \\ 0 & L^{NC} \end{matrix} \right\} \tag{21}$$

Introducing $D[h, h]$ as the product of the previous structural matrices and substituting it in the disposable income Eq. 20, the vector y can also be expressed as

$$\begin{Bmatrix} y^{SI} \\ y^{NC} \end{Bmatrix} = \left\{ \begin{matrix} D^{SI,SI} & D^{SI,NC} \\ D^{NC,SI} & D^{NC,NC} \end{matrix} \right\} \begin{Bmatrix} x^{SI} \\ x^{NC} \end{Bmatrix} \tag{22}$$

The closing of the circular flow of income loop has been obtained through the construction of the endogenous final demand vector f_c ,

$$\begin{Bmatrix} f_c^{SI} \\ f_c^{NC} \end{Bmatrix} = \left\{ \begin{matrix} G^{SI,SI} & G^{SI,NC} \\ G^{NC,SI} & G^{NC,NC} \end{matrix} \right\} \begin{Bmatrix} y^{SI} \\ y^{NC} \end{Bmatrix} \tag{23}$$

, where G can be decomposed in

$$\left\{ \begin{matrix} G^{SI,SI} & G^{SI,NC} \\ G^{NC,SI} & G^{NC,NC} \end{matrix} \right\} = \left\{ \begin{matrix} F^{SI,SI} & F^{SI,NC} \\ F^{NC,SI} & F^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} K^{SI,SI} & K^{SI,NC} \\ K^{NC,SI} & K^{NC,NC} \end{matrix} \right\} \tag{24}$$

Here, the matrix $F=F1C$, is composed by $F1[b, h]$ which transforms the consumption by Institutional sector into consumption by I-O, meanwhile each element of the diagonal matrix $C[h, h]$ represents the propensity of consumption by Institutional sector.

$$\left\{ \begin{matrix} F^{SI,SI} & F^{SI,NC} \\ F^{NC,SI} & F^{NC,NC} \end{matrix} \right\} = \left\{ \begin{matrix} F1^{SI,SI} & F1^{SI,NC} \\ F1^{NC,SI} & F1^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} C^{SI} & 0 \\ 0 & C^{NC} \end{matrix} \right\} \tag{25}$$

The matrix K can be rewritten as $K1s(I-C)$, where $K1[b, h]$ represents the matrix that transforms the gross investment by Institutional sector into I-O, the scalar s resumes the "active saving" and $I-C$ captures the saving propensity by Institutional sector.

$$\left\{ \begin{matrix} K^{SI,SI} & K^{SI,NC} \\ K^{NC,SI} & K^{NC,NC} \end{matrix} \right\} = \left\{ \begin{matrix} K1^{SI,SI} & K1^{SI,NC} \\ K1^{NC,SI} & K1^{NC,NC} \end{matrix} \right\} s \left[\left\{ \begin{matrix} I_1 & 0 \\ 0 & I_2 \end{matrix} \right\} - \left\{ \begin{matrix} C^{SI} & 0 \\ 0 & C^{NC} \end{matrix} \right\} \right] \tag{26}$$

After making the required substitutions, the endogenous final demand formation vector f_c can therefore be expressed as

$$\begin{Bmatrix} f_c^{SI} \\ f_c^{NC} \end{Bmatrix} = \left\{ \begin{matrix} G^{SI,SI} & G^{SI,NC} \\ G^{NC,SI} & G^{NC,NC} \end{matrix} \right\} \left\{ \begin{matrix} D^{SI,SI} & D^{SI,NC} \\ D^{NC,SI} & D^{NC,NC} \end{matrix} \right\} \begin{Bmatrix} x^{SI} \\ x^{NC} \end{Bmatrix} \tag{27}$$

By defining and replacing E as $E = \text{GD}$ in Eq. 27, and substituting in Eq. 16, the structural form of the bi-regional extended multisectoral model can be obtained.

$$\left\{ \begin{array}{c} x^{\text{SI}} \\ x^{\text{NC}} \end{array} \right\} = \left\{ \begin{array}{c|c} A^{\text{SI,SI}} & A^{\text{SI,NC}} \\ \hline A^{\text{NC,SI}} & A^{\text{NC,NC}} \end{array} \right\} \left\{ \begin{array}{c} x^{\text{SI}} \\ x^{\text{NC}} \end{array} \right\} + \left\{ \begin{array}{c|c} E^{\text{SI,SI}} & E^{\text{SI,NC}} \\ \hline E^{\text{NC,SI}} & E^{\text{NC,NC}} \end{array} \right\} \left\{ \begin{array}{c} x^{\text{SI}} \\ x^{\text{NC}} \end{array} \right\} \left\{ \begin{array}{c} f^{\text{SI}} \\ f^{\text{NC}} \end{array} \right\} \quad (28)$$

Alternatively, Eq. 28, can be defined in its reduced form.

$$\left\{ \begin{array}{c} x^{\text{SI}} \\ x^{\text{NC}} \end{array} \right\} = \left[\left[\begin{array}{c|c} I_1 & 0 \\ \hline 0 & I_2 \end{array} \right] - \left\{ \begin{array}{c|c} A^{\text{SI,SI}} & A^{\text{SI,NC}} \\ \hline A^{\text{NC,SI}} & A^{\text{NC,NC}} \end{array} \right\} - \left\{ \begin{array}{c|c} E^{\text{SI,SI}} & E^{\text{SI,NC}} \\ \hline E^{\text{NC,SI}} & E^{\text{NC,NC}} \end{array} \right\} \right]^{-1} \left\{ \begin{array}{c} f^{\text{SI}} \\ f^{\text{NC}} \end{array} \right\} \quad (29)$$

The model for the disposable income, at this point, can be solved.

$$\left\{ \begin{array}{c|c} D^{\text{SI,SI}} & D^{\text{SI,NC}} \\ \hline D^{\text{NC,SI}} & D^{\text{NC,NC}} \end{array} \right\} \left\{ \begin{array}{c} x^{\text{SI}} \\ x^{\text{NC}} \end{array} \right\} = \left\{ \begin{array}{c|c} D^{\text{SI,SI}} & D^{\text{SI,NC}} \\ \hline D^{\text{NC,SI}} & D^{\text{NC,NC}} \end{array} \right\} \left[\left[\begin{array}{c|c} I_1 & 0 \\ \hline 0 & I_2 \end{array} \right] - \left\{ \begin{array}{c|c} A^{\text{SI,SI}} & A^{\text{SI,NC}} \\ \hline A^{\text{NC,SI}} & A^{\text{NC,NC}} \end{array} \right\} - \left\{ \begin{array}{c|c} E^{\text{SI,SI}} & E^{\text{SI,NC}} \\ \hline E^{\text{NC,SI}} & E^{\text{NC,NC}} \end{array} \right\} \right]^{-1} \left\{ \begin{array}{c} f^{\text{SI}} \\ f^{\text{NC}} \end{array} \right\} \quad (30)$$

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