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Darlington Agbonifi

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Investments in Green Projects and Value-added GDP: An Environmentally Integrated Multiregional SAM Approach*

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Darlington Agbonifi†

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Abstract

This paper presents an integrated methodology to simultaneously estimate the socioeconomic and environmental impacts of public-financed investments in green projects on the labor markets, value-added, and households induced consumption expenditures in a multiregional economy in equilibrium. I construct a novel dataset and then implement an environmentally integrated multiregional social accounting matrix (EI-MRSAM) modelling technique on the regional macroeconomic investment analyses for Italy. The results show that Lombardy's intra-regional investment impact on value-added (GDP) share accounts for almost 78%, while 22% accrues to the rest of Italy in terms of interregional value-added spillover effects through trade channels. The public investments impact on the regional and national economy decreases by around 10% of value-added after internalizing the environmental costs of climate change damages induced by industrial greenhouse gas (GHG) emissions. I then conduct a counterfactual ex-ante macro-policy evaluation of an endogenous increase by 25% of the baseline investments to each of thematic missions which represents the key areas of the public policy interventions. I find that the return-on-investment in digital and innovative public-administration as most efficient in terms of potential regional value-added growth compared to other counterfactual outcomes. The distributional impact on household's consumption expenditures and induced GHG emissions are also consistent with those of value-added.

JEL classification: C67, D57, F18, H54, Q56, R12.
Keywords: EI-MRSAM model, investments in green projects, value-added GDP, climate change, GHG emissions, environmental valuation, digital transformation.

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† Darlington AGBONIFI is close to completing a PhD degree in Economics and Management at the Department of Economics, University of Verona, Via Cantarane 24, 37129, Verona, Italy. He is expected to graduate no later than September 2024. Email: darlington.agbonifi@univr.it Web: https://sites.google.com/view/darlingtonagbonifi/home

1 Introduction

The trade-offs between economic development strategies and the ambitious goal of societal sustainable climate transition towards a net-zero emissions poses numerous welfare policy challenges varying both within and between countries, regions, households, industrial sectors, and private enterprises. At the same time, the concept of green economy initiatives, and clean energy technologies underscores a new economic growth paradigm of sustainable development and intergenerational equity (see, Agbonifi, 2023a; Kruse et al., 2022; Clootens, 2021; Nordhaus, 2019; UN, 2011). In Italy, like other industrialized countries in Europe, the propulsive drive towards the implementation of a circular economy multi-billion investments aiming at climate-neutral future comes at a critical time against the backdrop of the European Union (EU) COVID-19 pandemic relief National Recovery and Resilience Plan (NRRP)[1] worth about €222.1 billion for the 2021-26 period. More broadly, the NRRP through the NextGenerationEU (NGEU) investments funds dedicated to EU member states is broken down into six focus Missions, which represents the key thematic areas of the policy interventions (Governo Italiano, 2021). The Missions include: (M1) Digitalization, Innovation, Competitiveness, and Culture. (M2) Green Revolution and Ecological Transition. (M3) Infrastructure for Sustainable Mobility. (M4) Education and Research. (M5) Inclusive Cohesion, and (M6) Health.

This raises fundamental policy-relevant research questions about the integrated environment-economy welfare implications and the effectiveness of regional implementations of public-financed NGEU-investments in green projects. How does the NGEU-investments in the Lombardy region impacts on the labor markets (skilled and unskilled), households' employment and consumption in the face of green technological transition towards a net-carbon emissions across Italy? How does an endogenous increase in the reallocation of NGEU-investments to each missions' thematic areas in the Lombardy region impacts on the value-creation of private enterprises and the well-being of households across Italy? The main purpose for the counterfactual macro-policy impact evaluation is to identify the most efficient reallocations in terms of value-added return on the NGEU-investment benefits for the regional and national economy. This would lead to insights for making informed investment decisions and

[1] The National Recovery and Resilience Plan (NRRP) is an Italian acronym for Piano Nazionale di Ripresa e Resilienza (PNRR) document submitted to the EU detailing how Italy intends to invest the temporary financial support measures (grants and low interest long-term loans) of the NextGenerationEU (NGEU) recovery investments package dedicated to member states to mitigate the adverse effects of the global pandemic shocks. The document also presents the structural reform milestones in public-administration, justice and competition to be implemented in the span of the next five years 2021-2026 (Governo Italiano, 2021). Details on the NGEU-investments allocation to the various missions at the regional level are illustrated in Appendix **Table 8**

environmental policy evaluation in terms of the accountability of public expenditures in green projects. The measures of societal well-being including household income and wealth, consumption possibilities and the quality of life are also affected by factors such as levels of health care, environmental quality, and resource management (OECD, 2013).

This paper addresses these policy-relevant questions using an environmentally integrated multi-regional social accounting matrix (EI-MRSAM) evaluation approach with international as well as interregional trade flows in goods and services for the Italian national economy. In doing so, I contribute to the existing methodological literature by extending the impact techniques from my previous work (Agbonifi, 2023b) to include the environmental effects of public-financed investment analyses in a multiregional economy in equilibrium. In addition to this integrated environmental-economic impacts modelling techniques, this paper's contribution is also the construction of novel dataset with micro-foundation, including 84 sectors and 20 regions. The unique role of the Lombardy region is strategically important for Italy, especially as it relates to regional industrial agglomeration, diffusion of innovations, and green technological spillover effects (Glaeser et al., 1992; Costa et. al., 2004). In this regard, the Lombardy region can act as a catalyst for Italy's climate-resilient transformation towards sustainable regional and urban regeneration.

Empirical studies show the links between air pollution levels and health benefits (Henschel, et al., 2012; Chanel, et al., 2014). In particular, the relatively excess mortality rates of the health pandemic outbreak in the region were further exacerbated by the role of environmental factors such as greenhouse gas (GHG) emissions linked to climate change (see, González Ortiz et.al., 2020; De Angelis, et al., 2021). Although public interventions and the aggressive pandemic measures undertaking by national and local authorities in most countries lead to reduction in GHG and local pollutants (Chanel, 2022; Cottafava et al., 2022). However, disruptions in global value chains (GVC) induced by the pandemic have further intensified the pre-existing regional socioeconomic disparities across Italy (Svimez, 2020; OECD, 2021). GVCs reflect the international division of production processes across different countries (Bentivogli et al., 2018).

The remainder of the paper is organized as follows. Section 2 briefly presents the methodological approach for constructing the multi-regional environmental social accounting matrix (MR-ESAM) database starting from the Leontief national Input-Output (I/O) model. Section 3 focuses on the simulation of the integrated socio-environmental-economic impacts and benefits of the NGEU-investments on societal wellbeing. Finally, Section 4 concludes the paper and discusses the key policy implications at the regional and national levels, as well as potential future research. Further details on the Lombardy regional NGEU-investments policy plan are illustrated in the Appendix.

2 Dataset and Research Methodology

2.1 Data: Social Accounting Matrix (SAM)

Social accounting matrix (SAM) records all the economic-wide series of transactions and transfers of income between various economic sectors and institutions (i.e., households, private enterprises, government, and the rest of the world) during a specific period, usually for a year (Stahmer, 2004; Breisinger et. al., 2009; Scandizzo et. al., 2015). This implies that an aggregate SAM describes the economy's macroeconomic behavior in an initial equilibrium (Burfisher, 2011). As such, it guides policy-makers in understanding the interdependences and structural adjustment mechanisms related to the efficiency of resource allocation, among interrelated sectors and agents within an economic system.

As a further extension, SAM can be augmented with environmental accounts to take into consideration sectorial emissions within the economic system (Leontief, 1970). **Figure *1*** shows a detailed description and structure of the regional SAM augmented with environmental accounts. The data sources for the constructing of the SAM starting from the national (I/O) data are mainly from the Italian National Institute of Statistics (ISTAT), the Central bank of Italy, as well as from Eurostat. This includes aggregated accounts for activities, factors of production, income deciles of different household groups, three skill levels for the labor market of each sector, private enterprises, government, capital formation, imports, exports, regional, and international trade flows within Italy and the rest of the world. The environmental account is composed of values in metric tonnes for GHG and local pollutants sources of each individual sector at a national and regional levels.

Figure 1. Structure of the regional SAM augmented with Environmental accounts

		Activity	Value-added			Institutions			Direct taxation	Savings-Investments	Export		Environmental externalities	Total
		63 sectors	Labor (low, mid, high skill)	Capital	Indirect taxation	Household (10th income decile)	Enterprises	Government	Taxes	Capital formation	Other Regions	Rest of the world		
Activity	63 sectors	*Intermediate Consumption*				*Consumption*		*Consumption*		*Investments*	*Export to other regions*	*Export to ROW*		Demand
Value added	Labor (low, mid, high skill)	*Wages*												Gross domestic product
	Capital	*Mixed income*												
	Indirect taxation	*Taxes*												
Institutions	Household (10th income decile)		*Labor income*	*Other income*		*Intra-houlehold transfers*	*Distributed profits*	*Govt trasfers to households*				*Income from abroad*		Institution incomes
	Enterprises			*Earnings b. taxes*				*Govt trasfers to enterprises*				*Transfer from ROW*		
	Government				*Tax transfer*	*Taxes/social security*	*Taxes*		*Tax transfer*	*Budget deficits*		*Transfer from ROW*		
Direct taxation	Taxes					*Taxes*	*Taxes*							Direct taxation
Savings-Investments	Capital formation					*Household savings*	*Enterprises savings*	*Budget surplus*				*Capital from abroad*		Saving
Import	Other Regions	*Imports from other Regions*				*Consumption*								Interregional trade
	Rest of the world	*Imports from ROW*				*Trasfers to ROW*		*Trasfers to ROW*						International trade
Environmental externalities														Payments to ROW
Total		Supply	Factor outlays			Institution expenditures			Direct taxation	Investments	Interregional trade	Income from ROW		

2.2 Integrated Environment-Economy Models

In this subsection, I illustrate the methodological foundation and the mathematical framework for developing the operational environmentally integrated multi-regional social accounting matrix (EI-MRSAM) model for the Italian economy using linear algebra. Starting from a standard Leontief national input-output (I-O) open model,[2] I then accommodate spatial distribution of output and environmental GHG emissions with regional input-output dimensions (Polenske, 1970; Bon., 1984; Szabó, 2015).

2.2.1 The Multiregional SAM (MRSAM) model for Italy

At the country level, a national open market economy can be split into integrated *m-regions* and consisting of *n-sectors* producing n different products. Let $\tau_{ij}^{rs} = \tau_i^{rs}$ for all other sectors j, represents the flow of purchases in goods and services of a generic sector i from region r to the producing and final demand sectors in any other region s, regardless of the destination sector in the purchasing regions during a specific time period (i.e., a year). The superscripts $(r, s = 1, \ldots, m)$ are origin and destination regions, while the subscripts refer to sectors of industries. The Chenery-Moses multiregional input-output (MRIO) column coefficient model of the overall commodities in goods and services traded between exporting and importing regions can be illustrated in **Table 1**. The diagonal entries contain the intra-regional trade flows within the individual regions, (i.e., τ_i^{ss}).

Table 1. Intra-regional and inter-regional trade flows in goods and services

	Importing Region															
Exporting Region	***R1***	***R2***	***R3***	***R4***	***R5***	***R6***	***R7***	***R8***	***R9***	***R10***	***R11***	***R12***	…	***Rs***	…	***Rm***
R1	$\tau_i^{1,1}$	$\tau_i^{1,2}$	$\tau_i^{1,3}$	$\tau_i^{1,4}$	$\tau_i^{1,5}$	$\tau_i^{1,6}$	$\tau_i^{1,7}$	$\tau_i^{1,8}$	$\tau_i^{1,9}$	$\tau_i^{1,10}$	$\tau_i^{1,11}$	$\tau_i^{1,12}$	…	$\tau_i^{1,s}$	…	$\tau_i^{1,m}$
R2	$\tau_i^{2,1}$	$\tau_i^{2,2}$	$\tau_i^{2,3}$	$\tau_i^{2,4}$	$\tau_i^{2,5}$	$\tau_i^{2,6}$	$\tau_i^{2,7}$	$\tau_i^{2,8}$	$\tau_i^{2,9}$	$\tau_i^{2,10}$	$\tau_i^{2,11}$	$\tau_i^{2,12}$	…	$\tau_i^{2,s}$	…	$\tau_i^{2,m}$
R3	$\tau_i^{3,1}$	$\tau_i^{3,2}$	$\tau_i^{3,3}$	$\tau_i^{3,4}$	$\tau_i^{3,5}$	$\tau_i^{3,6}$	$\tau_i^{3,7}$	$\tau_i^{3,8}$	$\tau_i^{3,9}$	$\tau_i^{3,10}$	$\tau_i^{3,11}$	$\tau_i^{3,12}$	…	$\tau_i^{3,s}$	…	$\tau_i^{3,m}$
R4	$\tau_i^{4,1}$	$\tau_i^{4,2}$	$\tau_i^{4,3}$	$\tau_i^{4,4}$	$\tau_i^{4,5}$	$\tau_i^{4,6}$	$\tau_i^{4,7}$	$\tau_i^{4,8}$	$\tau_i^{4,9}$	$\tau_i^{4,10}$	$\tau_i^{4,11}$	$\tau_i^{4,12}$	…	$\tau_i^{4,s}$	…	$\tau_i^{4,m}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	…	⋮	…	⋮
Rr	$\tau_i^{r,1}$	$\tau_i^{r,2}$	$\tau_i^{r,3}$	$\tau_i^{r,3}$	$\tau_i^{r,3}$	$\tau_i^{r,3}$	$\tau_i^{r,7}$	$\tau_i^{r,8}$	$\tau_i^{r,9}$	$\tau_i^{r,10}$	$\tau_i^{r,11}$	$\tau_i^{r,12}$	…	$\tau_i^{r,s}$	…	$\tau_i^{r,m}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	…	⋮	…	⋮
Rm	$\tau_i^{m,1}$	$\tau_i^{m,2}$	$\tau_i^{m,3}$	$\tau_i^{m,4}$	$\tau_i^{m,5}$	τ_i^{m6}	$\tau_i^{m,7}$	$\tau_i^{m,8}$	$\tau_i^{m,9}$	$\tau_i^{m,10}$	$\tau_i^{m,11}$	$\tau_i^{m,12}$	…	$\tau_i^{m,s}$	…	$\tau_i^{m,m}$
Total trade flows	T_i^1	T_i^2	T_i^3	T_i^4	T_i^5	T_i^6	T_i^7	T_i^8	T_i^9	T_i^{10}	T_i^{11}	T_i^{12}	…	T_i^s	…	T_i^m

[2] The Leontief IO analytical technique distinguish between closed and open production models. In a closed endogenous model, all outputs are also consumed internally as inputs within the industries without exogenous external demand, therefore the focus is to find the relative price of each product. On the other hand, in an open model, the entire production is consumed both internally by industries and other exogenous demand (i.e., consumers, government etc.). Hence the focus is to find the production level needed to satisfy a given or desired increase in demand (Moses, 1955; Miller et al. 2009).

Each column sum, T_i^s in **Table 1** represents the total supplies of a generic sector i, into region s from all other regions including intraregional trade flows within the individual regions, (i.e., τ_i^{ss}). Note that, since the total supplies in goods and services, regardless of regional origins must be equivalent to both intermediate demands denoted by $t_{ij}^{\bullet s}$, where the dot superscript indicates all possible geographical locations of sector i, and exogenous final demands $f_i^{\ s}$, for each sector i in region s I have:

$$T_i^s = \sum_{s=1}^{m} \tau_i^{r,s} = \overbrace{\left(\sum_{j=1}^{n} \overbrace{(a_{ij}^{\bullet s} x_j^s)}^{t_{ij}^{\bullet s}} + f_i^{\ s} \right)}^{T_i^s} \qquad \begin{matrix} (r = 1, 2 \ldots, m) \\ (i = 1, 2 \ \ldots, n) \end{matrix} \qquad (1)$$

In Equation (1), the technology or technical coefficients for each receiving region in the model indicated by $a_{ij}^{\bullet s} = (t_{ij}^{\bullet s}/x_j^s)$, can be expressed as a non-negative ratio measuring the quantity of sector i inputs required to produce one unit of sector $j's$ total output located in region s. In addition, from **Table 1**, I can estimate the interregional trade coefficient denoted by $d_i^{rs} = (\tau_i^{rs}/\ T_i^s)$, expressed as a ratio measuring the fraction of total supplies, T_i^s, of commodity i in region r that is shipped to region s. The trade coefficients assume fixed regional supply patterns of any given inputs among all purchasers, including the final users of each commodity in a specific region (see, Isard, 1951; Miller et. al., 2009, Boero et. al., 2018, Agbonifi, 2023b). Note that these column trade coefficients must add up to unity when summed column-wise over the purchasing regions, where $\sum_{r=1}^{m} d_i^{rs} = 1 \ (for\ all\ i)$. In addition, by substituting the structural equation $\tau_i^{rs} = (d_i^{rs}/T_i^{\ s})$ into the right-hand side of Equation (1) I obtain:

$$\begin{aligned} x_i^r = \overbrace{\sum_{s=1}^{m} \overbrace{d_i^{rs} T_i^{\ s}}^{\tau_i^{rs}}}^{T_i^s} &= \sum_{s=1}^{m} d_i^{rs} \overbrace{\left(\sum_{j=1}^{n} \overbrace{(a_{ij}^{\bullet s} x_j^s)}^{t_{ij}^{\bullet s}} + f_i^{\ s} \right)}^{T_i^s} \\ &= \sum_{s=1}^{m} \sum_{j=1}^{n} d_i^{rs} (a_{ij}^{\bullet s} x_j^s) + \sum_{s=1}^{m} d_i^{rs} f_i^s \end{aligned} \qquad \begin{matrix} (r = 1, 2 \ldots, m) \\ (i = 1, 2 \ \ldots, n) \end{matrix} \qquad (2)$$

where x_i^r is the total production output (supply) of commodity i in region r, for $(r = 1, \ldots, m)$. From Equation (2), I can express the Chenery-Moses multiregional economic model for m-regions and n-sectors of industries as stated below

$$\mathbf{x}^{r\star} = \sum_{s=1}^{m} \boldsymbol{D}^{rs}(\boldsymbol{A}^{s}\mathbf{x}^{s} + \mathbf{f}^{s}) = \sum_{s=1}^{m} \boldsymbol{D}^{rs}\boldsymbol{A}^{s}\,\mathbf{x}^{s} + \sum_{s=1}^{m} \boldsymbol{D}^{rs}\mathbf{f}^{s} \qquad (r = 1, 2 \ldots, m) \qquad (3)$$

In matrix notation I have:

$$\mathbf{x}^{\star\star} = \begin{bmatrix} \mathrm{x}^1 \\ \mathrm{x}^2 \\ \vdots \\ \mathrm{x}^{\mathrm{m}} \end{bmatrix}, \text{ where, } \mathbf{A}^{\star\star} = \begin{bmatrix} \mathbf{A}^{\mathrm{r},1} & 0 & \cdots & 0 \\ 0 & \mathbf{A}^{\mathrm{r},2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{A}^{\mathrm{r,m}} \end{bmatrix} \text{ and, } \mathbf{f} = \begin{bmatrix} \mathrm{f}^{\mathrm{r}1} \\ \mathrm{f}^{\mathrm{r}2} \\ \vdots \\ \mathrm{f}^{\mathrm{rm}} \end{bmatrix}$$

$$\mathbf{I} = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \qquad (4)$$

$$\mathbf{D}^{\star\star} = \begin{bmatrix} \mathbf{D}^{1,1} & \mathbf{D}^{2,1} & \cdots & \mathbf{D}^{\mathrm{m},1} \\ \mathbf{D}^{1,2} & \mathbf{D}^{2,2} & \cdots & \mathbf{D}^{\mathrm{m},2} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{D}^{1,\mathrm{m}} & \mathbf{D}^{2,\mathrm{m}} & \cdots & \mathbf{D}^{\mathrm{m,m}} \end{bmatrix}, \text{ where, } \mathbf{D}^{r,s} = \begin{bmatrix} d_1^{r,s} & 0 & \cdots & 0 \\ 0 & d_2^{r,s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & d_n^{r,s} \end{bmatrix} \qquad (5)$$

Note that throughout the text matrices are denoted by bold capital letters, vectors by bold small letters unless indicated otherwise. Here, matrices $\mathbf{x}$ and $\mathbf{f}$ denotes the vectors of total outputs and final demands of sectors located in region r respectively, for $(r = 1, \ldots, m)$. Matrix $\boldsymbol{A}^{\star\star}$ is a block of diagonal-matrix of regional IO technical coefficients in all regions, with each of the submatrices along the principal diagonal and the elements on the off-diagonal equal to zero. **I** denote an $n \times n$ identity matrix. Furthermore, $\boldsymbol{D}^{\star\star}$ is a block of interregional trade coefficients matrix, with each of the submatrices (i.e., $\boldsymbol{D}^{rs}$ and $\boldsymbol{D}^{ss}$) containing the trade coefficients for n-*traded* commodities, while the off-diagonal elements equal to zero.

2.2.2 The Environmentally Integrated Multiregional SAM (EI-MRSAM) model for Italy

Similarly, environmental externalities induced by human activities can be incorporated in a measurable way (i.e., in metric tonnes of CO2) into the standard IO analysis and by extension the MRSAM model (Leontief, 1970, Hyland, et. al., 2012, Agbonifi, 2023a). The enviromental account is composed of values in metric tonnes for the emissions sources of each individual sector at a regional and national levels. The GHG and local pullants as well as their corresponding average nominal monetary cost rates per metric tonnes are illustrated in **Table *2*** below.

Table 2. Environmental prices per metric tonnes of pollutants

Pollutants	Formula	Measurement unit	Prices (€/unit)
Carbon dioxide	CO_2	tonnes of CO_2-eq	€ 180
Methane	CH_4	tonnes of CO_2-eq	€ 180
Nitrous Oxide	N_2O	tonnes of CO_2-eq	€ 180
Hydrofluorocarbons	HFCs	tonnes of CO_2-eq	€ 180
Perfluorocarbons	PFCs	tonnes of CO_2-eq	€ 180
Sulphur hexafluoride	SF_6	tonnes of CO_2-eq	€ 180
Nitrogen trifluoride	NF_3	tonnes of CO_2-eq	€ 180
Greenhouse gas emissions	**GHG**	**tonnes of CO_2-eq**	**€ 180**
Ammoniac	NH_3	tonnes	€ 32000
Particulate matter	PM10	tonnes	€ 41200

Note: The environmental costs are calculated as average costs per unit of pollutant emitted. The GHG emissions refers to the so-called "Kyoto basket" group of seven gases which includes carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and fluorinated gases F-gases (HFC, PFCs, SF6 and NF3) are expressed in a common unit, tonnes of CO2-equivalents produced by each industrial sectors in Italy and the regional levels.
Source pollutant cost rates: Matthey & Bünger (2018).

Environmental prices at pollutant level indicate the loss of economic welfare to society, when additional unit of the pollutant finds its way into the environment (the Bruyn, et al., 2018). The study conducted by Matthey & Bünger (2018) of the German Environmental Agency about the methodological convention for assessing environmental costs recommend using a cost rate of 180 euros per ton of CO_2-eq. The cost rates for CO_2 and other local pollutants shown in **Table *2*** are determined mainly using the damage caused by climate change approach that estimates the averages of GHG emissions in specific countries (see, for example, Matthey et. al., 2018; TSD, 2016). Given the emissions of substances m_i , the corresponding pollutant coefficients for each receiving region in the model indicated by $e_{ij}^{\bullet s} = (m_{ij}^{\bullet s} / x_j^s)$, can be expressed as a ratio measuring the quantity of pollutants (i.e., in metric tonnes of CO2) emitted to produce one unit of sector $j's$ total output of each industry located in region s (Tukker et. al., 2006; Hyland et. al., 2012). The corresponding EI-MRSAM model can be illustrated below:

$$\mathbf{x}^{r\star\star} = \sum_{s=1}^{m} \mathbf{E}^{rs}(\mathbf{I} - \mathbf{D}^{rs}\mathbf{A}^{s})^{-1}\mathbf{D}^{rs}\,\mathbf{f}^{s} \qquad (r = 1,2 \ldots, m) \qquad (6)$$

The matrix form becomes

$$\mathbf{E}^{**} = \begin{bmatrix} \mathbf{E}^{1,1} & \mathbf{E}^{1,2} & \cdots & \mathbf{E}^{1,m} \\ \mathbf{E}^{2,1} & \mathbf{E}^{2,2} & \cdots & \mathbf{E}^{2,m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{E}^{m,1} & \mathbf{E}^{m,2} & \cdots & \mathbf{E}^{m,m} \end{bmatrix}, \text{ where, } \mathbf{E}^{r,s} = \begin{bmatrix} e_1^{r,s} & 0 & \cdots & 0 \\ 0 & e_2^{r,s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & e_n^{r,s} \end{bmatrix} \quad (7)$$

From Equations (3), (6) and (7), the solution equation for the vector of endogenous outputs $\mathbf{\Delta x}$ yields

$$\begin{aligned} \mathbf{\Delta x} &= \mathbf{D}^{**}\mathbf{A}^{**}\mathbf{\Delta x} + \mathbf{E}^{**}\mathbf{D}^{**}\mathbf{f} \\ (\mathbf{I} - \mathbf{D}^{**}\mathbf{A}^{**})\mathbf{\Delta x} &= \mathbf{E}^{**}\mathbf{D}^{**}\mathbf{\Delta f} \\ \mathbf{\Delta x} &= (\mathbf{I} - \mathbf{D}^{**}\mathbf{A}^{**})^{-1}\mathbf{E}^{**}\mathbf{D}^{**}\mathbf{f} \end{aligned} \quad (8)$$

Here, $\boldsymbol{E}^{**}$ is a block of interregional pollutant coefficients matrix, with each of the submatric*es (i.e.,* $\boldsymbol{E}^{rs}$ and $\boldsymbol{E}^{ss}$*)* containing the pollutant coefficients for n*-traded* commodities, while the off-diagonal elements equal to zero. Equation (8) relates E^{**} to both production and final demand **(**Agbonifi, 2023a, Hyland *et. al.,* 2012). Finally, from Equation (8) I can calculate the changes in the equilibrium regional outputs $\mathbf{\Delta x}$, given the matrices, $\mathbf{A}^{**}$, $\mathbf{D}^{**}$ and $\mathbf{E}^{**}$ as well as the vector of regional exogenous final demand shock, $\mathbf{f}$. As illustrated by (Miller *et. al.,* 2009) to assess the impacts of new regional-specific demand shock, it is necessarily to replace $\mathbf{D}^{**}\mathbf{f}$ with, $\mathbf{f}$.

3 Empirical results

3.1 The estimation of interregional trade flows

The construction of the multiregional model for the 20 Italian regions is constituted by the regional SAMs with interregional trade flows estimates, adopting a non-survey methodology. This approach was dictated by cost-related issues and the fact that there is no information on interregional trade flows for different sectors either at national or regional level (Huang & Koutroumpis, 2023). Here, interregional trade was estimated using the cross-hauling adjusted regionalization method (CHARM) model proposed by (Kronenberg., 2009) and subsequently refined by (Többen & Kronenberg, 2015) with some adaptations. Cross-hauling in interregional trade is the process in which each region simultaneously exports and imports the output of a generic sector *i* (Fujimoto, 2019). The model assumes that cross-hauling in interregional trade is proportional to the cross-hauling potential determined by the amount of output or demand. Particularly, interregional import-export is zero-sum at the national level, the sum of regional exports by branch corresponds to the sum of regional import.

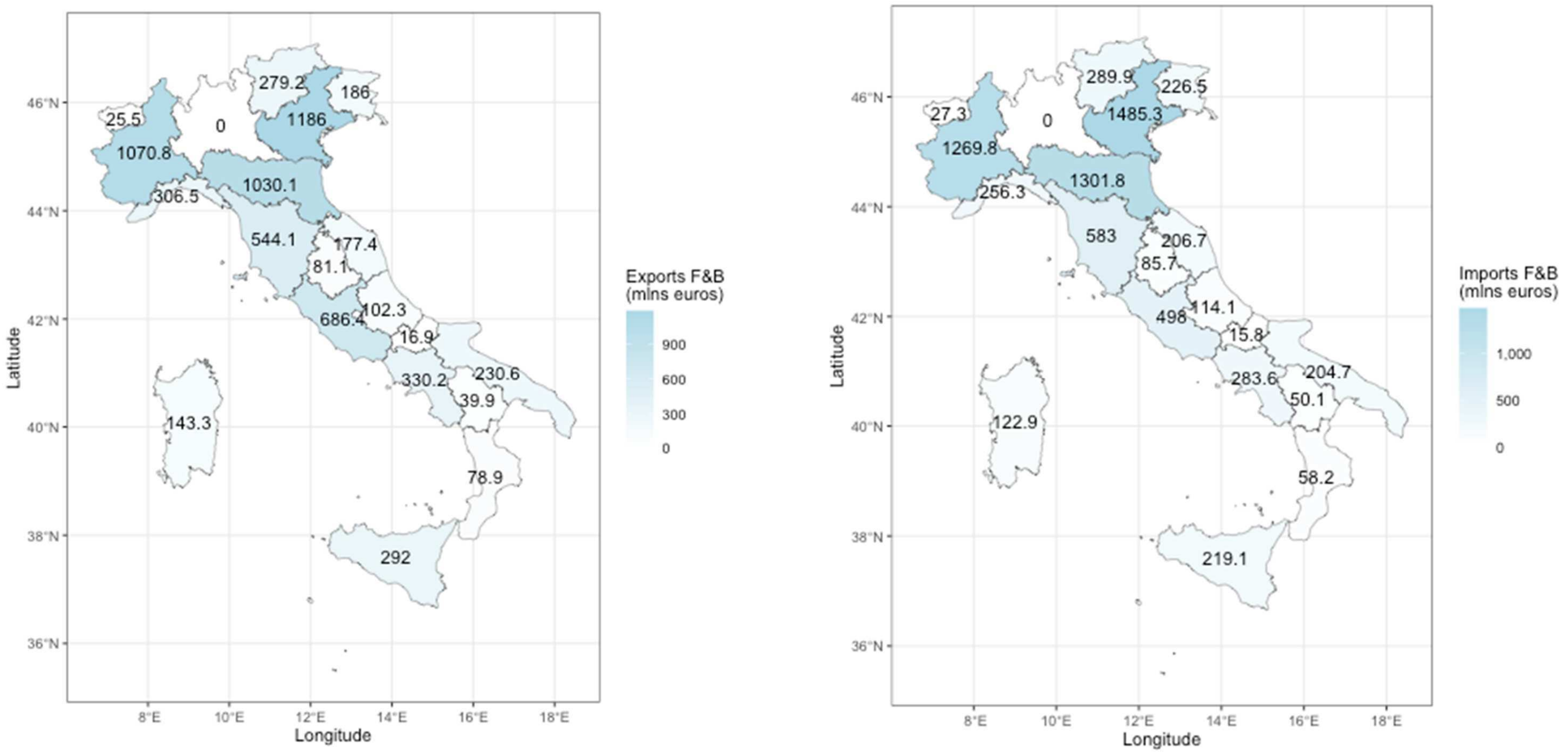
Figure 2 below illustrate the values of interregional trade exports and imports of food and beverages (F&B) between Lombardy region and the other 19 Italian regions estimated with the CHARM model. As shown in the Appendix in **Figure *14***, Lombardy records an active interregional trade balance in terms of food & beverages products with respect to the regions of Lazio (+188.39 M€), Sicily (+72.87 M€), Liguria (+50.24 M€), and a negative interregional trade balance relative to Veneto (-299.24 M€), Emilia-Romagna (-271.67 M€), Piedmont (-199.06 M€), and Friuli-Venezia Giulia (-40.58 M€). The total interregional trade relative to all sectors between Lombardy with the rest of Italy is illustrated in the Appendix **Table 9**

Furthermore, to determine how the outflows from each region are divided among the remaining regions, a gravitational model was used based on the inverse of the distance between the regions, measured by the centroid of each region, multiplied by an indicator as follows: (Purchasing power region *i* / national purchasing power) x population region *i*. In this way, a value of the regional population weighted by the purchasing power index is obtained, which defines the potential for "comparative purchasing" of each region. The interregional flows were subsequently calibrated with a spatial interaction procedure (Wilson, 1971; Fotheringham, 1983a; Fotheringham A. , 1983b; Dennet, 2012), which made it possible to respect the total of outgoing and incoming flows for each region.

The EI-MRSAM model is formulated using the following four assumptions: (1) No substitution among inputs is allowed to occur. (2) Constant trade coefficients. Thus, no substitution among supplying regions is allowed to occur. A region is assumed to continue supplying a given fraction of the consumption of another region over time. No empirical verification of this assumption has been possible because of the lack of data. (3) Constant industrial shares. Thus, each industry in a given region is assumed to continue purchasing a fixed share of the total amount of a given good supplied to the region. Again, because of the lack of data, no empirical testing of this assumption has been made. By incorporating this assumption, however, the amount of data required to implement the model is drastically reduced. (4) Excess capacity. All producers and transportation facilities are assumed to be operating at less than full capacity.

Figure 2. Lombardy interregional trade flows and the rest of Italy

Exports: food and beverages (F&B) Imports-food and beverages (F&B)



Note: Figure 2 shows the total values in terms of interregional trade (exports and imports) of approximately (+6807.32 M€) and (-7298.86 M€) respectively in food and beverages products between Lombardy and other 19 Italian regions, corresponding to a trade balance of (-491.54 M€). Here the Lombardy intra-regional exports and imports of is set to zero by construction to better reflect the trade flows in the diagram.

3.2 Intra-regional and inter-regional impacts of investments in green projects

The socioeconomic impact of the (€1981.18Mln) investments in green projects on the economy is obtained by applying the demand-driven shock vector illustrated in **Table 3**. About 60.5% of the baseline investments funds is allocated to the health sector, while about 24% is allocated to green revolution and ecological transition. The baseline allocation illustrates the approved implementations of the regional investment funds by decision-makers. In contrast, the reallocation illustrates the counterfactual ex-ante macro-policy evaluation of 25% endogenous increase in the baseline NGEU-investments corresponding to (€495.30Mln) reallocated to each of the observed missions illustrated in **Table 3**. The main purpose for the counterfactual evaluation exercise is to identify the most efficient reallocations in terms of value-added return on the NGEU-investment benefits for the regional and national economy. This would lead to insights for making informed investment and environmental policy decision analysis in terms of the accountability of public expenditures in green projects.

Table 3. NGEU-investments in the Lombardy region, Italy

	(0)		(1)	(2)	(3)	(5)	(6)
	Actual policy		Counterfactual policy evaluation				
NGEU Missions	Baseline (€Mln)	Share (%)	M1 (€ Mln)	M2 (€ Mln)	M3 (€ Mln)	M5 (€ Mln)	M6 (€ Mln)
Mission 1.	87.89	4.44	583.18	87.89	87.89	87.89	87.89
Mission 2.	467.88	23.62	467.88	963.17	467.88	467.88	467.88
Mission 3.	59.40	3.00	59.40	59.40	554.70	59.40	59.40
Mission 5.	168.12	8.49	168.12	168.12	168.12	663.42	168.12
Mission 6.	1197.90	60.46	1197.90	1197.90	1197.90	1197.90	1693.19
Total	**1981.18**	**100%**	**2476.48**	**2476.48**	**2476.48**	**2476.48**	**2476.48**
NGEU-investments							
Difference (€Mln)			495.30	495.30	495.30	495.30	495.30
Changes (%)			25.00%	25.00%	25.00%	25.00%	25.00%

Note: M1: Digitalization, Innovation, Competitiveness and Culture. M2: Green Revolution and Ecological Transition. M3: Infrastructures for Sustainable Mobility. M5: Inclusive Cohesion. M6: Health. Details on the investments allocation to the various missions are illustrated in **Appendix A**
Source: Adapted from Corte dei Conti (2021) - Regione Lombardia

3.2.1 Intra-regional impact on value-added in Lombardy

Table *4* illustrates the intraregional impact on value-added (GDP) in the Lombardy region calculated with the MRSAM model both for the baseline and the reallocation scenarios. In the baseline scenario, the regional investments of €1981.18M generates €3602.29M impact on intraregional value-added. Furthermore, the intraregional value-added impact of €3602.29M divided by the investment costs of €1981.18M is equal to a value-added benefit/costs ratio of 1.82. Almost 46.5% of the intraregional value-added impact accrues to capital income, while 19.5% and 11.8% are accredited to the wages of high and low skilled labor respectively. In contrast, as illustrated in **Table *4***, an endogenous increase in the NGEU-investment of €495.30Mln in digital transformation of the public-administration (M1) generates the most impact on intra-regional value-added €1052.05Mln compared to other counterfactual outcomes. This corresponds to 29.21% regional value-added increase relative to the baseline scenario.

Table 4. Intra-regional impact on value-added (€ Mln)

	(0)		(1)	(2)	(3)	(5)	(6)
	Actual policy		Counterfactual policy evaluation				
Sectors	Baseline (€Mln)	Share (%)	M1 (€ Mln)	M2 (€ Mln)	M3 (€ Mln)	M5 (€ Mln)	M6 (€ Mln)
Income (low skilled)	426.92	11.85	548.75	533.13	543.77	544.98	530.66
Income (middle skilled)	703.04	19.52	909.22	866.10	872.85	904.63	878.20
Income (high skilled)	294.32	8.17	382.29	359.08	358.59	380.83	368.94
Capital income	1673.10	46.45	2161.73	2065.49	2085.36	2150.19	2088.37
Indirect taxes	504.90	14.02	652.35	623.31	629.30	648.87	630.21
Value-added (GDP)	**3602.29**	**100%**	**4654.34**	**4447.12**	**4489.87**	**4629.49**	**4496.39**
Household consumption	3118.48	100%	4029.23	3849.83	3886.85	4007.72	3892.50
Counterfactual impact							
Value-added							
Difference (€ Mln)			1052.05	844.83	887.58	1027.20	894.10
Changes (%)			29.21%	23.45%	24.64%	28.52%	24.82%
Household consumption							
Difference (€ Mln)			910.76	731.36	768.37	889.24	774.02
Changes (%)			29.21	23.45	24.64	28.52	24.82

Note: Total may not sum due to rounding. The source of induced effects on household consumption is the link from regional wages to labor and household spending.

3.2.2 Interregional impact on value added on the rest of Italy

As shown in **Table *5***, the NGEU-investments of €1981.18M in the Lombardy region impact on interregional value-added on the rest of Italy estimated using the MRSAM model is € 1029.45M in the baseline scenario. Almost 54% of interregional value-added accrues to the Northern regions, 26% to the Central regions, while about 20% spillover to the regions in Southern Italy. **Table *5*** also illustrates the investments impact on interregional value-added with respect to the counterfactual simulations. The counterfactual results show the difference and percentage change in value-added impact between a 25% endogenous increase in the NGEU-investments reallocated to each of the observed missions compared with the value-added impact of the actual policy. An endogenous increase in investment of €495.30Mln in Health (M6) and Infrastructures for Sustainable Mobility (M3) generates an increase of 26.3% and 26.1% on expected interregional value-added respectively, relative to the baseline scenario. The distributional impact on households' consumption expenditure is also consistent with those of value-added as illustrated in the Appendix **Table 10**

Table 5. NGEU-investments impact on inter-regional value-added (GDP)

	(0)		(1)		(2)		(3)		(5)		(6)	
	Actual policy		Counterfactual investment impacts on value-added (GDP)									
Regions in Italy	**Baseline (€ Mln)**	**Share (%)**	**Diff M1 (€ Mln)**	**Change (%)**	**Diff M2 (€ Mln)**	**Change (%)**	**Diff M3 (€ Mln)**	**Change (%)**	**Diff M5 (€ Mln)**	**Change (%)**	**Diff M6 (€ Mln)**	**Change (%)**
Piedmont	135.37	*13.15*	32.09	*23.70*	31.25	*23.08*	37.55	*27.74*	32.32	*23.87*	35.02	*25.87*
Aosta Valley	4.10	*0.40*	0.96	*23.49*	0.91	*22.29*	1.03	*25.10*	0.99	*24.15*	1.08	*26.27*
Liguria	52.51	*5.10*	10.40	*19.81*	10.73	*20.43*	13.21	*25.16*	11.92	*22.69*	14.43	*27.48*
Trentino-Alto Adige	43.73	*4.25*	8.63	*19.74*	9.22	*21.09*	12.61	*28.84*	9.77	*22.35*	11.85	*27.09*
Veneto	148.55	*14.43*	35.21	*23.70*	34.53	*23.24*	42.10	*28.34*	35.26	*23.73*	38.32	*25.79*
Friuli-Venezia Giulia	29.69	*2.88*	6.99	*23.55*	6.76	*22.77*	8.01	*26.99*	7.05	*23.75*	7.73	*26.05*
Emilia-Romagna	141.23	*13.72*	33.56	*23.76*	32.87	*23.27*	39.97	*28.30*	33.47	*23.70*	36.41	*25.78*
Tuscany	84.36	*8.19*	19.82	*23.50*	19.11	*22.65*	22.14	*26.24*	20.23	*23.98*	22.03	*26.11*
Umbria	12.46	*1.21*	2.97	*23.80*	2.84	*22.76*	3.26	*26.15*	2.98	*23.90*	3.25	*26.07*
Marche	24.93	*2.42*	5.93	*23.79*	5.77	*23.15*	6.88	*27.62*	5.90	*23.66*	6.45	*25.86*
Lazio	143.00	*13.89*	27.03	*18.90*	27.81	*19.45*	32.86	*22.98*	31.76	*22.21*	40.19	*28.11*
Abruzzo	14.97	*1.45*	3.59	*23.99*	3.45	*23.02*	4.00	*26.70*	3.58	*23.88*	3.88	*25.93*
Molise	2.73	*0.26*	0.70	*25.64*	0.62	*22.82*	0.66	*24.32*	0.67	*24.69*	0.71	*25.94*
Campania	57.23	*5.56*	14.10	*24.64*	12.72	*22.22*	13.58	*23.73*	14.03	*24.51*	15.02	*26.24*
Apulia	37.37	*3.63*	9.76	*26.13*	8.50	*22.74*	8.89	*23.80*	9.33	*24.96*	9.67	*25.87*
Basilicata	4.82	*0.47*	1.21	*25.04*	1.14	*23.73*	1.34	*27.73*	1.15	*23.83*	1.23	*25.49*
Calabria	16.39	*1.59*	4.58	*27.93*	3.71	*22.61*	3.67	*22.37*	4.20	*25.62*	4.22	*25.76*
Sicily	54.13	*5.26*	14.38	*26.57*	12.07	*22.30*	12.16	*22.47*	13.73	*25.36*	14.08	*26.01*
Sardinia	21.88	*2.13*	5.82	*26.59*	4.96	*22.67*	5.13	*23.45*	5.52	*25.21*	5.66	*25.84*
Macro Regions												
North-West	191.98	*18.65*	43.45	*22.63*	42.89	*22.34*	51.78	*26.97*	45.22	*23.56*	50.52	*26.32*
North-East	363.20	*35.28*	84.39	*23.24*	83.37	*22.96*	102.69	*28.27*	85.55	*23.55*	94.31	*25.97*
Centre	264.75	*25.72*	55.75	*21.06*	55.52	*20.97*	65.14	*24.61*	60.86	*22.99*	71.92	*27.16*
South and Islands	209.52	*20.35*	54.15	*25.84*	47.17	*22.51*	49.43	*23.59*	52.20	*24.91*	54.46	*25.99*
Italy's other regions	**1029.45**	***100.00***	**237.74**	***23.09***	**228.95**	***22.24***	**269.05**	***26.14***	**243.84**	***23.69***	**271.21**	***26.35***

Note: Totals may not sum due to rounding. The counterfactual results show the difference and percentage change in value-added impact between a 25% endogenous increase in the NGEU-investments corresponding to and additional (€495.30Mln) reallocated to each of the observed missions compared with the baseline value-added impact of the actual policy.

3.3 The NGEU-investment impact on national value-added in Italy

The total investment impact at a national level national corresponds to the sum of intra-regional and interregional impacts as illustrated in **Table *6***. The regional investments of €1981.18M generates €4631.74M on national value-added in the baseline scenario. Meanwhile, in the baseline scenario, almost 89% of the total value-added impact accrues to the Northern regions, 6% to the Central regions, while the residual 5% is accredited to Southern Italy. In contrast, as illustrated the counterfactual endogenous increase in investment of €495.30Mln in digital transformation of the public-administration (M1) and Inclusive Cohesion (M5) generates an increase of 27.8% and 27.4% on expected national value-added respectively, relative to the baseline scenario. In **Table *6***, the distributional impact on household consumption is also consistent with those of value-added.

Table 6. NGEU-investment impact on national value-added and household consumption

	(0)		(1)	(2)	(3)	(5)	(6)
	Actual policy		Counterfactual policy evaluation				
Sectors	Baseline (€Mln)	Share (%)	M1 (€ Mln)	M2 (€ Mln)	M3 (€ Mln)	M5 (€ Mln)	M6 (€ Mln)
Income (low skilled)	**553.61**	*11.95%*	704.91	688.40	704.51	701.59	690.51
Income (middle skilled)	**900.62**	*19.44%*	1152.35	1107.48	1121.75	1149.02	1127.92
Income (high skilled)	**375.72**	*8.11%*	482.38	458.31	460.55	481.59	471.92
Capital income	**2161.07**	*46.66%*	2762.47	2662.04	2700.91	2753.76	2704.86
Indirect taxes	**640.72**	*13.83%*	819.43	789.30	800.66	816.82	801.84
Value-added (GDP)	**4631.74**	***100%***	**5921.53**	**5705.52**	**5788.37**	**5902.77**	**5797.05**
Counterfactual impact							
Difference (€ Mln)			1289.79	1073.78	1156.63	1271.04	1165.32
Changes (%)			*27.85%*	*23.18%*	*24.97%*	*27.44%*	*25.16%*
Italy's macro regions							
Value-added							
North-West	3794.27	*81.92%*	4889.77	4681.99	4733.63	4866.69	4738.89
North-East	363.20	*7.84%*	447.60	446.58	465.89	448.75	457.51
Centre	264.75	*5.72%*	320.49	320.27	329.89	325.61	336.66
South and Islands	209.52	*4.52%*	263.67	256.69	258.96	261.72	263.98
Household consumption							
North-West	3293.31	*81.10%*	4243.68	4063.75	4108.87	4223.75	4113.33
North-East	317.10	*7.81%*	390.91	389.95	406.72	391.84	399.40
Centre	239.96	*5.91%*	290.57	290.34	299.06	295.15	305.10
South and Islands	210.20	*5.18%*	264.56	257.51	259.73	262.59	264.83
Total	**4060.56**	**100%**	**5189.72**	**5001.55**	**5074.38**	**5173.32**	**5082.66**

Note: Total may not sum due to rounding. The source of induced effects on household consumption is the link from regional wages to labor and household spending.

3.4 The NGEU-investment economy-environmental impacts

Finally, **Table 7** estimate the investment total impact on value-added and household consumption induced GHG emissions using the EI-MRSAM model. The Lombardy's intra-regional investment impact on value-added (GDP) share accounts for almost 78%, while 22% accrues to the rest of Italy in terms of interregional value-added spillover effects through trade channels. On the other hand, **Figure 3** illustrates the investment interregional impact on the adjusted value-added and household consumption after internalizing the social of GHG emissions. The social costs of GHG emissions are assumed to be (€180) per metric tonne of CO_2-equivalent as illustrated in **Table 2**. The total investment impact on the regional and national economy decreases by around 10% of value-added net-effects after internalizing the social environmental costs of climate change damages induced by industrial GHG emissions. Further details on the total value-added and household consumption induced pollutant or emissions sources in metric tonnes are illustrated in the Appendix **Table 11** and **Table 12**

Table 7. NGEU-investment impact on value-added and household consumption induced GHG emissions

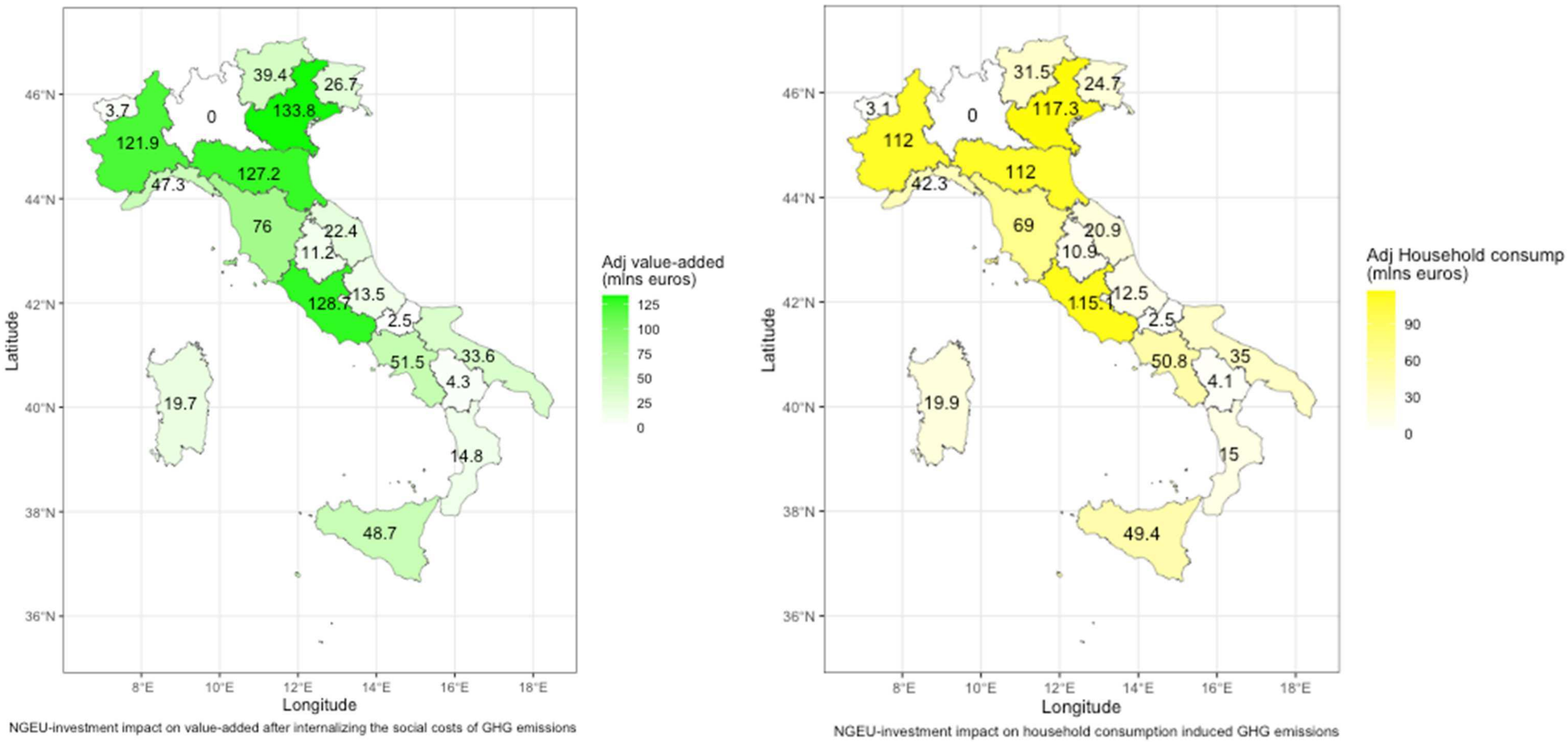
	NGEU- Investment impacts on value-added induced GHG emissions					NGEU-investment impact on Household consumption induced GHG emissions				
Regions in Italy	Value-added (€ Mln)	Share (%)	GHG costs (€ Mln)	GHG_CO2E (metric tonnes)	Adj_value-added (€ Mln)	Consumption (€ Mln)	Share (%)	GHG costs (€ Mln)	GHG_CO2E (metric tonnes)	Adj_consumption (€ Mln)
Piedmont	135.37	*2.92*	13.49	74942.28	121.88	124.36	*3.06*	12.39	68845.50	111.97
Aosta Valley	4.10	*0.09*	0.41	2269.75	3.69	3.46	*0.09*	0.35	1917.11	3.12
Liguria	52.51	*1.13*	5.23	29068.35	47.28	47.02	*1.16*	4.68	26027.43	42.33
Lombardy	*3602.29*	*77.77*	*358.96*	*1994219.90*	*3243.33*	*3118.48*	*76.80*	*310.75*	*1726383.44*	*2807.73*
Trentino-Alto Adige	43.73	*0.94*	4.36	24209.97	39.37	34.98	*0.86*	3.49	19362.11	31.49
Veneto	148.55	*3.21*	14.80	82238.71	133.75	130.27	*3.21*	12.98	72114.50	117.28
Friuli-Venezia Giulia	29.69	*0.64*	2.96	16436.34	26.73	27.47	*0.68*	2.74	15206.80	24.73
Emilia-Romagna	141.23	*3.05*	14.07	78183.05	127.15	124.39	*3.06*	12.39	68859.90	111.99
Tuscany	84.36	*1.82*	8.41	46701.01	75.95	76.68	*1.89*	7.64	42449.37	69.04
Umbria	12.46	*0.27*	1.24	6898.94	11.22	12.15	*0.30*	1.21	6728.44	10.94
Marche	24.93	*0.54*	2.48	13799.55	22.44	23.24	*0.57*	2.32	12867.29	20.93
Lazio	143.00	*3.09*	14.25	79163.47	128.75	127.88	*3.15*	12.74	70793.61	115.14
Abruzzo	14.97	*0.32*	1.49	8287.37	13.48	13.90	*0.34*	1.39	7695.57	12.52
Molise	2.73	*0.06*	0.27	1509.11	2.45	2.76	*0.07*	0.27	1525.72	2.48
Campania	57.23	*1.24*	5.70	31682.99	51.53	56.44	*1.39*	5.62	31243.43	50.81
Apulia	37.37	*0.81*	3.72	20686.87	33.64	38.91	*0.96*	3.88	21539.96	35.03
Basilicata	4.82	*0.10*	0.48	2668.90	4.34	4.57	*0.11*	0.46	2529.94	4.11
Calabria	16.39	*0.35*	1.63	9075.69	14.76	16.61	*0.41*	1.65	9193.61	14.95
Sicily	54.13	*1.17*	5.39	29965.73	48.74	54.88	*1.35*	5.47	30383.70	49.41
Sardinia	21.88	*0.47*	2.18	12114.95	19.70	22.13	*0.55*	2.21	12252.24	19.93
Macro Regions										
North-West	3794.27	*81.92*	378.09	2100500.28	3416.18	3293.31	*81.10*	328.17	1823173.48	2965.14
North-East	363.20	*7.84*	36.19	201068.06	327.01	317.10	*7.81*	31.60	175543.30	285.50
Centre	264.75	*5.72*	26.38	146562.97	238.36	239.96	*5.91*	23.91	132838.71	216.04
South and Islands	209.52	*4.52*	20.88	115991.61	188.64	210.20	*5.18*	20.95	116364.18	189.25
Italy	**4631.74**	***100%***	**461.54**	**2564122.92**	**4170.20**	**4060.56**	***100%***	**404.63**	**2247919.67**	**2965.14**

Note: Totals may not sum due to rounding. Induced effect measures the impact on household consumption. The source of induced effects is the link from regional wages to labor and household spending.

Figure 3. NGEU-investment impact on interregional value-added (GDP) and household induced GHG emissions

Value-added - induced GHG emissions

Household consumption - induced GHG emissions



Note: Figure 3 shows the impact of the NGEU-investments made in the Lombardy region on the other 19 Italian regions. In terms of interregional spillover effects on value-added and households' consumption induced GHG emissions in CO2 equivalent. The social costs of GHG emissions are assumed to be (€180) per metric tonnes of CO_2-eq. Here the Lombardy intra-regional investment impact on value-added and household consumption induced GHG emissions is set to zero by construction to better reflect the interregional spillover effects.

4 Concluding remarks

The aim of this paper was to propose an integrated methodology to simultaneously estimates the economy-environmental impacts of public-financed investments in green projects on the labor markets, value-added, and household consumption in a multiregional economy in equilibrium. It does so by implementing an EI-MRSAM modelling techniques with interregional and international trade flows in goods and services on the macroeconomic investment analyses for Italy.

The results show that the societal value-added benefits in the Lombardy region accounts for 78%, while 22% accrues to the rest of Italy in terms of interregional value-added spillover effects through trade channels. The intra and interregional value-added benefits impact decreases by almost 10% net effects after controlling for environmental impact in terms of the social costs of GHG emissions induced by industrial and human related sources. However, the net impact on society depends on the pricing mechanisms and social cost of GHG emissions. Under a counterfactual macro-policy evaluation, the return-on-investment in digital and innovative public-administration is more efficient in terms of potential regional value-added growth compared to other counterfactual outcomes. The distributional impact on household's consumption expenditures and induced GHG emissions are also consistent with those of value-added.

From a policymaking perspective, the research findings show how an ex-ante impact evaluation of public-financed investments provides useful indications for orienting NGEU-investments so that they can be calibrated to maximize regional economic development in Italy. The findings also show how to relate digital transformation of the public-administration to real value-added outcomes and environmental policy in the transition to climate neutrality. This is because the nature of complexities in public administration and its implications creates uncertainty that influences the long-term investment decisions by economic agents that in response hampers sustained economic growth prospect. In this regard, the unique role of the Lombardy region is strategically important for Italy, especially as it relates to regional industrial agglomeration, diffusion of innovations, and green technological spillover effects. This result is also consistent with the EU policy objectives, namely, managing the green transition and the digital transformation, promoting sustainable and inclusive growth, guaranteeing social and territorial cohesion, and ensuring economic, social, and institutional resilience.

The application of MRSAM and EI-MRSAM models are in a static setting with some limitations, including the assumption of constant returns to scale in production technology and no substitution among inputs. This implies that relative prices play no role in the allocation of resources between activities. In addition, the constant trade and pollutant coefficients assumption implies that region continue to trade a given fraction of their consumption to other regions. A further concern is the lack of supply-side constraints assumption in the model implies that supply is not able to respond perfectly elastically to changes in demand also because supply capacity is limited to the existing labor, capital, and other productive inputs. Further research is needed to measure spatial multiregional relationships and environmental policy in a dynamic setting using general equilibrium models.

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Appendix A

Table 8 NGEU-investments projects in the Lombardy region (Italy)

Missions	Projects	Project costs (mln euros)	Share (%)
M1.	**DIGITALIZATION, INNOVATION, COMPETITIVENESS AND CULTURE**	**87.89**	**4.44%**
M1.C1.I 2.2.1	Technical assistance at central and local level	*38.63*	-
M1.C3.I 2.2	Protection and enhancement of architecture and the rural landscape	*49.25*	-
M2.	**GREEN REVOLUTION AND ECOLOGICAL TRANSITION**	**467.88**	**23.62%**
M2.C2.I 4.1	Cycling mobility enhancement (Vento)	*16.88*	-
M2.C2.I 4.1	Strengthening of cycling mobility (Garda)	*7.84*	-
M2.C2.I 4.4.1	Renewal of bus and green train fleets (buses)	*60.88*	-
M2.C2.I 4.4.2	Renewal of bus and green train fleets (trains)	*64.60*	-
M2.C3	Energy efficiency and building renovations	*252.94*	-
M2.C4.I. 2.1b	Measures for the management of flood risk and for the resolution of hydrogeological risk	*64.74*	-
M3.	**INFRASTRUCTURES FOR SUSTAINABLE MOBILITY**	**59.40**	**3.00%**
M3.C1.I 1.6	Upgrading of regional lines (FNM – Safety measures – replacement of ACEI equipment with ACC-M Milan branch)	*59.40*	-
M4.	**EDUCATION AND RESEARCH**	**-**	-
M5.	**INCLUSIVE COHESION**	**168.12**	**8.49%**
M5.C1.R 1.1	Active Labour and Training Policies (GOL)	*101.29*	-

M5.C2.I 2.3	Innovative programme for the quality of living (PINQUA)	*66.83*	-
M6.	**HEALTH**	**1197.90**	**60.46%**
M6.C1.I 1.	Community houses and taking care of people	*277.20*	-
M6.C1.I 2 – 1.2.2	Home as a first place of care, home care and telemedicine (Business Interconnection)	*7.18*	-
M6.C1.I 2. – 1.2.2	Home as a first place of care, home care and telemedicine (Device)	*9.77*	-
M6.C1.I 2 – 1.2.2	Home as a first place of care, home care and telemedicine (C.O.T)	*17.48*	-
M6.C1.I 3	Development of intermediate care	*151.20*	-
M6.C2.I 1.1	Modernization of the hospital technology and digital park (DEA digitization)	*219.26*	-
M6.C2.I 1.1	Modernisation of hospital technology and digital park (Large equipment)	*179.80*	-
M6.C2.I 1.2.	Towards a new safe and sustainable hospital (New Projects)	*96.60*	-
M6.C2.I 1.2.	Towards a new safe and sustainable hospital	*219.24*	-
M6.C2.I 1.3.2	Strengthening of the technological infrastructure and tools for the collection, processing, data analysis and simulation (New information flows)	*4.58*	-
M6.C2.I 2.2.	Development of technical professional, digital and managerial skills of health system personnel (a - additional scholarships in general medicine training)	*5.14*	-
M6.C2.I 2.2.	Development of technical, professional, digital, and managerial skills of health system personnel (b - hospital infection training course)	*10.45*	-
TOTAL NGEU FUNDS		**1981.18**	**100%**

Note: According to (Corte dei conti, 2021) the interventions of the PNRR of the Lombardy Region represent a total amount of resources equal to 1 billion 981 million euros with confirmation in the 2021 and forecast budget for 2022-2024.
Source: Adapted from the Court of Auditors elaboration – Regional Control Section for the Lombardy region

Table 9 Estimates of Lombardy interregional trade flows with the rest of Italy

Regions of Italy	Inter-regional Exports (€ Mln)	Share (%)	Inter-regional Imports (€ Mln)	Share (%)	Trade balance (€ Mln)
Piedmont	11695.69	*15.22*	12360.56	*15.95*	-664.87
Aosta Valley	304.47	*0.40*	293.51	*0.38*	10.96
Liguria	3466.02	*4.51*	3311.43	*4.27*	154.59
Lombardy	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Trentino-Alto Adige	3321.88	*4.32*	3417.95	*4.41*	-96.07
Veneto	13088.15	*17.03*	14247.90	*18.39*	-1159.75
Friuli-Venezia Giulia	2094.40	*2.73*	2271.05	*2.93*	-176.65
Emilia-Romagna	11140.04	*14.50*	12448.29	*16.07*	-1308.25
Tuscany	5927.66	*7.71*	6041.49	*7.80*	-113.83
Umbria	919.25	*1.20*	886.72	*1.14*	32.53
Marche	1950.22	*2.54*	2000.74	*2.58*	-50.52
Lazio	8450.71	*11.00*	7499.30	*9.68*	951.41
Abruzzo	1160.56	*1.51*	1118.35	*1.44*	42.21
Molise	205.43	*0.27*	180.58	*0.23*	24.85
Campania	3883.87	*5.05*	3355.77	*4.33*	528.10
Apulia	2687.49	*3.50*	2361.34	*3.05*	326.16
Basilicata	493.22	*0.64*	464.23	*0.60*	29.00
Calabria	981.05	*1.28*	813.09	*1.05*	167.96
Sicily	3410.18	*4.44*	2928.34	*3.78*	481.84
Sardinia	1662.73	*2.16*	1483.96	*1.92*	178.76
Total	76843.05	*100.00*	77484.59	*100.00*	-641.55
Macro Regions					
North-West	15466.18	*20.13*	15965.50	*20.60*	-499.31
North-East	29644.48	*38.58*	32385.20	*41.80*	-2740.71
Centre	17247.85	*22.45*	16428.25	*21.20*	819.59
South and Islands	14484.53	*18.85*	12705.64	*16.40*	1778.89
Italy's other regions	76843.05	*100%*	77484.59	*100%*	-641.55

Note: the Lombardy intra-regional exports and imports is set to zero by construction.

Table 10 NGEU-investments induced impact on household interregional consumption expenditure

	(0)		(1)		(2)		(3)		(5)		(6)	
	Actual policy		Counterfactual induced effects on household consumption									
Regions in Italy	**Baseline (€ Mln)**	**Share (%)**	**Diff M1 (€ Mln)**	**Change (%)**	**Diff M2 (€ Mln)**	**Change (%)**	**Diff M3 (€ Mln)**	**Change (%)**	**Diff M5 (€ Mln)**	**Change (%)**	**Diff M6 (€ Mln)**	**Change (%)**
Piedmont	124.36	*13.20*	29.48	*23.71*	28.70	*23.08*	34.49	*27.74*	29.69	*23.87*	32.17	*25.87*
Aosta Valley	3.46	*0.37*	0.82	*23.53*	0.77	*22.26*	0.87	*25.12*	0.84	*24.11*	0.91	*26.28*
Liguria	47.02	*4.99*	9.31	*19.81*	9.61	*20.43*	11.83	*25.15*	10.67	*22.69*	12.92	*27.47*
Trentino-Alto Adige	34.98	*3.71*	6.91	*19.75*	7.38	*21.09*	10.09	*28.85*	7.82	*22.35*	9.48	*27.10*
Veneto	130.27	*13.83*	30.88	*23.70*	30.28	*23.24*	36.92	*28.34*	30.92	*23.73*	33.60	*25.79*
Friuli-Venezia Giulia	27.47	*2.92*	6.47	*23.55*	6.26	*22.77*	7.41	*26.99*	6.52	*23.75*	7.15	*26.05*
Emilia-Romagna	124.39	*13.20*	29.56	*23.76*	28.95	*23.28*	35.21	*28.31*	29.48	*23.70*	32.07	*25.78*
Tuscany	76.68	*8.14*	18.02	*23.50*	17.37	*22.65*	20.12	*26.24*	18.39	*23.98*	20.02	*26.11*
Umbria	12.15	*1.29*	2.89	*23.80*	2.77	*22.77*	3.18	*26.16*	2.90	*23.89*	3.17	*26.07*
Marche	23.24	*2.47*	5.53	*23.81*	5.38	*23.16*	6.42	*27.63*	5.50	*23.67*	6.01	*25.87*
Lazio	127.88	*13.57*	24.17	*18.90*	24.87	*19.45*	29.39	*22.98*	28.40	*22.21*	35.94	*28.11*
Abruzzo	13.90	*1.48*	3.33	*23.98*	3.20	*23.01*	3.71	*26.67*	3.32	*23.88*	3.60	*25.92*
Molise	2.76	*0.29*	0.71	*25.62*	0.63	*22.79*	0.67	*24.27*	0.68	*24.64*	0.71	*25.83*
Campania	56.44	*5.99*	13.91	*24.64*	12.54	*22.22*	13.39	*23.73*	13.83	*24.51*	14.81	*26.25*
Apulia	38.91	*4.13*	10.17	*26.13*	8.85	*22.74*	9.26	*23.79*	9.71	*24.96*	10.06	*25.86*
Basilicata	4.57	*0.49*	1.14	*25.03*	1.09	*23.74*	1.27	*27.72*	1.09	*23.83*	1.17	*25.49*
Calabria	16.61	*1.76*	4.64	*27.93*	3.76	*22.61*	3.72	*22.38*	4.26	*25.62*	4.28	*25.76*
Sicily	54.88	*5.83*	14.58	*26.57*	12.24	*22.29*	12.33	*22.47*	13.92	*25.36*	14.28	*26.01*
Sardinia	22.13	*2.35*	5.89	*26.60*	5.02	*22.67*	5.19	*23.45*	5.58	*25.22*	5.72	*25.84*
Macro Regions												
North-West	174.84	*18.56*	39.61	*22.65*	39.08	*22.35*	47.19	*26.99*	41.19	*23.56*	46.00	*26.31*
North-East	317.10	*33.66*	73.81	*23.28*	72.86	*22.98*	89.63	*28.26*	74.74	*23.57*	82.31	*25.96*
Centre	239.96	*25.47*	50.62	*21.09*	50.39	*21.00*	59.11	*24.63*	55.20	*23.00*	65.15	*27.15*
South and Islands	210.20	*22.31*	54.37	*25.86*	47.31	*22.51*	49.53	*23.56*	52.39	*24.92*	54.63	*25.99*
Italy's other regions	**942.08**	***100%***	**218.40**	***23.18%***	**209.64**	***22.25%***	**245.45**	***26.05%***	**223.52**	***23.73%***	**248.08**	***26.33%***

Note: Totals may not sum due to rounding. Induced effect measures the impact on household consumption expenditure in goods and services. The source of induced effects is the link from regional wages to labor and household spending.

Table 11 NGEU-investments impact on value-added (GDP) – induced emission sources in metric tonnes across Italy

	Global pollutants							Local pollutants	
Regions in Italy	**CO2**	**CH4 CO2E**	**N2O CO2E**	**HFC CO2E**	**NF3_SF6 CO2E**	**PFC CO2E**	**GHG CO2E**	**NH3 (tonnes**	**PM10**
Piedmont	16146.99	37132.39	21497.40	165.50	0.00	0.00	74942.28	670.15	198.17
Aosta Valley	489.04	1124.62	651.09	5.01	0.00	0.00	2269.75	20.30	6.00
Liguria	6263.04	14402.78	8338.34	64.19	0.00	0.00	29068.35	259.93	76.87
Lombardy	*429672.69*	*988095.84*	*572047.45*	*4403.92*	*0.00*	*0.00*	*1994219.90*	*17832.63*	*5273.35*
Trentino-Alto Adige	5216.26	11995.55	6944.70	53.46	0.00	0.00	24209.97	216.49	64.02
Veneto	17719.07	40747.63	23590.40	181.61	0.00	0.00	82238.71	735.39	217.47
Friuli-Venezia Giulia	3541.36	8143.87	4714.81	36.30	0.00	0.00	16436.34	146.98	43.46
Emilia-Romagna	16845.24	38738.13	22427.02	172.66	0.00	0.00	78183.05	699.13	206.74
Tuscany	10062.15	23139.41	13396.31	103.13	0.00	0.00	46701.01	417.61	123.49
Umbria	1486.44	3418.29	1978.98	15.24	0.00	0.00	6898.94	61.69	18.24
Marche	2973.24	6837.40	3958.44	30.47	0.00	0.00	13799.55	123.40	36.49
Lazio	17056.48	39223.91	22708.26	174.82	0.00	0.00	79163.47	707.89	209.33
Abruzzo	1785.59	4106.22	2377.25	18.30	0.00	0.00	8287.37	74.11	21.91
Molise	325.15	747.73	432.89	3.33	0.00	0.00	1509.11	13.49	3.99
Campania	6826.39	15698.29	9088.35	69.97	0.00	0.00	31682.99	283.31	83.78
Apulia	4457.17	10249.93	5934.08	45.68	0.00	0.00	20686.87	184.99	54.70
Basilicata	575.04	1322.39	765.58	5.89	0.00	0.00	2668.90	23.87	7.06
Calabria	1955.44	4496.82	2603.39	20.04	0.00	0.00	9075.69	81.16	24.00
Sicily	6456.39	14847.42	8595.75	66.17	0.00	0.00	29965.73	267.96	79.24
Sardinia	2610.27	6002.71	3475.21	26.75	0.00	0.00	12114.95	108.33	32.04
Macro Regions									
North-West	452571.75	1040755.63	602534.27	4638.63	0.00	0.00	2100500.28	18783.01	5554.39
North-East	43321.93	99625.18	57676.92	444.03	0.00	0.00	201068.06	1797.98	531.69
Centre	31578.32	72619.00	42041.99	323.66	0.00	0.00	146562.97	1310.59	387.56
South and Islands	24991.44	57471.51	33272.51	256.15	0.00	0.00	115991.61	1037.22	306.72
Italy	**552463.44**	**1270471.32**	**735525.70**	**5662.46**	**0.00**	**0.00**	**2564122.92**	**22928.80**	**6780.35**

Note: The GHG emissions refers to the so-called "Kyoto basket" group of seven gases which includes carbon dioxide (CO2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases F-gases (HFC, PFCs, SF_6 and NF_3) are expressed in a common unit, tonnes of CO2-equivalents produced by each industrial sectors in Italy and the regional levels. The local pollutants including Ammoniac (NH3) and Particulate matter (PM10) are expressed in metric tonnes

Table 12 NGEU-investments impact on household consumption expenditures - induced emissions sources in metric tonnes across Italy

	Global pollutants in CO2 equivalent							Local pollutants	
Regions in Italy	CO2	CH4 CO2E	N2O CO2E	HFC CO2E	NF3_SF6 CO2E	PFC CO2E	GHG CO2E	NH3	PM10
Piedmont	14833.39	34111.56	19748.52	152.03	0.00	0.00	68845.50	615.63	182.05
Aosta Valley	413.06	949.89	549.93	4.23	0.00	0.00	1917.11	17.14	5.07
Liguria	5607.84	12896.07	7466.04	57.48	0.00	0.00	26027.43	232.74	68.82
Lombardy	*371964.90*	*855388.26*	*495217.83*	*3812.45*	*0.00*	*0.00*	*1726383.44*	*15437.60*	*4565.10*
Trentino-Alto Adige	4171.74	9593.53	5554.07	42.76	0.00	0.00	19362.11	173.14	51.20
Veneto	15537.72	35731.28	20686.24	159.25	0.00	0.00	72114.50	644.86	190.69
Friuli-Venezia Giulia	3276.44	7534.66	4362.11	33.58	0.00	0.00	15206.80	135.98	40.21
Emilia-Romagna	14836.49	34118.69	19752.65	152.07	0.00	0.00	68859.90	615.76	182.09
Tuscany	9146.10	21032.81	12176.72	93.74	0.00	0.00	42449.37	379.59	112.25
Umbria	1449.70	3333.80	1930.07	14.86	0.00	0.00	6728.44	60.17	17.79
Marche	2772.37	6375.48	3691.02	28.42	0.00	0.00	12867.29	115.06	34.03
Lazio	15253.12	35076.81	20307.34	156.34	0.00	0.00	70793.61	633.05	187.20
Abruzzo	1658.08	3813.00	2207.50	16.99	0.00	0.00	7695.57	68.82	20.35
Molise	328.73	755.96	437.66	3.37	0.00	0.00	1525.72	13.64	4.03
Campania	6731.68	15480.49	8962.27	69.00	0.00	0.00	31243.43	279.38	82.62
Apulia	4640.98	10672.62	6178.80	47.57	0.00	0.00	21539.96	192.61	56.96
Basilicata	545.10	1253.54	725.72	5.59	0.00	0.00	2529.94	22.62	6.69
Calabria	1980.85	4555.25	2637.21	20.30	0.00	0.00	9193.61	82.21	24.31
Sicily	6546.44	15054.51	8715.65	67.10	0.00	0.00	30383.70	271.70	80.34
Sardinia	2639.86	6070.74	3514.59	27.06	0.00	0.00	12252.24	109.56	32.40
Macro Regions									
North-West	392819.19	903345.78	522982.32	4026.19	0.00	0.00	1823173.48	16303.11	4821.05
North-East	37822.39	86978.17	50355.08	387.66	0.00	0.00	175543.30	1569.74	464.19
Centre	28621.30	65818.91	38105.15	293.35	0.00	0.00	132838.71	1187.86	351.27
South and Islands	25071.71	57656.11	33379.38	256.97	0.00	0.00	116364.18	1040.55	307.70
Italy	**484334.59**	**1113798.97**	**644821.93**	**4964.18**	**0.00**	**0.00**	**2247919.67**	**20101.26**	**5944.21**

Note: The GHG emissions refers to the so-called "Kyoto basket" group of seven gases which includes carbon dioxide (CO2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases F-gases (HFC, PFCs, SF_6 and NF_3) are expressed in a common unit, tonnes of CO2-equivalents produced by each industrial sectors in Italy and the regional levels. The local pollutants including Ammoniac (NH3) and Particulate matter (PM10) are expressed in metric tonnes

Table 13 Micro-SAM sectoral classifications

	Ref.	Description	Ref.	Description	
	1.	Agricolture and hunting	43.	Other financial services	
	2.	Forestry	44.	Real estate activities	
	3.	Fishings	45.	Legal activities and accounting	
	4.	Mining and quarrying	46.	Architecture and engineering	
	5.	Food, beverages and Tobacco	47.	Scientific research and development	
	6.	Textiles, leather and footwear	48.	Marketing and market research	
	7.	Wood and Products of Wood and Cork	49.	Other technical, scientific professions; Veterinary	
	8.	Paper and paper products	50.	Leasing and rent activities	
	9.	Printing and publishing	51.	Research, selection of human resources	
	10.	Coke, Refined Petroleum and Nuclear Fuel	52.	Travel agencies	
	11.	Manufacture of men-made fibres	53.	Investigation and surveillance services	
	12.	Pharmaceuticals	54.	Public Admin and Defence; Compulsory Social Security	
	13.	Rubber and Plastics	55.	Education	
	14.	Non-metallic minerals	56.	Health	
	15	Basic metals	57.	Social work	
	16	Fabricated metals	58.	Entertainment, arts and creative activities; libraries, archives and museums	
	17.	Computers and optical equipment	59.	Sports	
	18.	Electrical equipment	60.	Associations	
	19.	Machinery	61.	Repair of computers and other objects of personal use	
	20.	Production of Motor Vehicles	62.	Other personal services	
	21.	Production of other vehicles	63.	Private Households with Employed Persons	
	22.	Production of furniture; Other manufactoring industries	64.	Reddito da lavoro dipendente (low)	
	23.	Repair and installation of machinery	65.	Reddito da lavoro dipendente (mid)	
	24.	Electricity, gas supply	66.	Reddito da lavoro dipendente (high)	
	25.	Water supply	67.	Capitale	
	26.	Drainage system management	68.	Indirect taxes	
	27.	Construction	69.	Households1	
	28.	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles	70.	Households2	
	29.	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	71.	Households3	
	30.	Retail Trade, Except of Motor Vehicles and Motorcycles	72.	Households4	
	31.	Inland transport	73.	Households5	
	32.	Water transport	74.	Households6	
	33.	Air transport	75.	Households7	
	34.	Other Supporting and Auxiliary Transport Activities	76.	Households8	
	35	Post services	77.	Households9	
	36.	Hotels and Restaurants	78.	Households10	

	37.	Publishing	79.	Public Admin	
	38.	Film, video, tv programme production	80.	Direct taxes	
	39.	Telecommunications	81.	Enterprises	
	40.	Software, computer consulting	82.	Capital Formation	
	41.	Financial services	83.	Interregional imports	
	42.	Insurance, reinsurance and pension funds	84.	Import from ROW	

Figure 14. Lombardy interregional trade balance in food and beverages with the rest of Italy