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Export and Import Modelling

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Abstract. Forecasting constitutes a fundamental activity in transportation planning. This report develops and tests a non-survey methodology for freight transport demand modelling through structured analysis of regional economic production and consumption patterns. Since economic activity represents the primary determinant of freight movements, Input-Output modelling and Flegg's Location Quotients were applied alongside commodity-to-freight flow conversion techniques to generate inputs for a structural gravity model. This research was conducted as part of the development of a Decision Support System for long-distance freight mobility to assist Italian public administrations at various government levels. Leveraging ISTAT and UNCTAD data sources, the study successfully mapped comprehensive production-consumption profiles and domestical and international trade flows for all 107 Italian territories at NUTS 3 level (ex-province).

CONTENTS

1 INTRODUCTION

This research is part of the PRIN2022-funded project aiming to build a Decision Support System (DSS) on long distance freight transport mobility for Italian public administrations at different levels. Freight transport is closely related to economic activities, but its modelling lags behind that of passenger mobility. The planning of freight transport and logistics requires the determination of the freight transport demand in the zone. Similar to the classic Four Step Travel Demand Model, the method that focus on travels and is mainly based on the Origin-Destination matrix (OD matrix) (McNally, 2007) to model the passenger transport, one of the methodologies adopted in the field of freight transport planning consists the following 4 steps:

1. Generation/Attraction: one determines the goods sent from the origin and those received in the destination.
2. Distribution: one determines of the trade flows of goods between the origin zones and destinations.
3. Modal choice: the trade flows of goods are assigned to the various modes of transport.
4. Assignment: the trade flows of goods are converted into stream of trucks and assigned to the road network.

The activities of the study focus on the first step, aiming to provide a first representation of the production / consumption of goods in all Italian territories at NUTS 3 level (ex-province) in terms of monetary value of the products and their generation / attraction of freights. To achieve this objective, it is necessary to perform the analysis of regional and inter-regional economy that generate the trade flows.

The generation models are used to determine for each zone the amount of a particular good that is produced for domestic consumption or for export. Similarly, the models of attraction are used to determine for each zone the amount of a particular good consumed, distinguishing the case in which the amount of the good is produced at the national level and the case where it is imported.

The modelling of freight transport planning differs from passenger transport modelling in several key aspects, among which the following are evident:

1. The data consistency with the national statistical data published by official statistics institutions must be guaranteed.
2. The considerable complexity of commodity types, and consequently the diversity of the logistic organization (e.g. from bulk shipments of large quantities to deliveries of packages to more stops).

3. The complexity in the relevant decisions and responses to changes in the supply of transport involving changes in the chain between the producer and the final consumer (production, trade, logistics and transport).
4. The diversity of the role of decision-makers whose decisions affect the freight transport system (e.g. putting, broker/logistics operators, carrier, driver).
5. The diversity of the decisions in the field of transport (e.g. shipment dimensions, mode/service, type of vehicle, planning/timetable, route).
6. The considerable difficulty in collecting and processing the relative data, especially those disaggregated, due to not only the lack of the information standard between the various concerned parties, but also the fact that companies consider data as sensitive and are reluctant to provide them.

Facing these problems, the “non-survey” methodologies show their advantages laid on the lower requirement of data comparing to the “survey” methodologies because they are usually based on statistics data. This brings another advantage: the economic-sociological linkages between data, especially due to the second and third point listed above, are then simplified in the analysis.

After the literature review in the second section, the “non-survey” methodology for modelling the generation/attraction of goods trade flows is presented in the third section. The fourth section focuses on the application of the methodology in the context of the DSS building project for Italian public administrations at NUTS 3 level, followed by the data analysis of the Metropolitan City of Rome. The conclusion is presented in the end.

2 LITERATURE REVIEW

Considering the data availability, we focus on methods based on the Input-Output (IO) analysis pioneered by Leontief, which provides a fundamental framework for quantifying inter-industry relationships and economic interdependencies (Miller & Blair, 2009). At the national level, IO tables capture the flows of goods and services between sectors, allowing for the calculation of multipliers that measure the direct and indirect effects of changes in final demand and introduced exogenous variation. (Colaizzo & Massiani, 2022) has investigated the often-observed misuses of such multiplier in the policy making process. However, basic IO models fail to capture inter-regional effects when the study area has economic interchanges with other areas. To overcome this, Inter-Regional (IRIO) and Multi-Regional (MRIO) models are employed to trace relations between various economic sectors in different regions (Murray & Lenzen, 2013) (Miller & Blair, 2009) (Oosterhaven & Stelder, 2007) (Isard, et al., 1998) (Cascetta, et al., 1996) (Hewings & Jensen, 1986) (Round, 1978) (Kim, 1974) . They trace the relations between various economic sectors in different regions with a set of trade coefficients. In IRIO, a trade coefficient indicates the value of the output of the production sector in the origin region used to produce one monetary unit value of the output of the consumption sector in the destination region. In the MRIO, it is assumed that the supply of a generic product from one origin zone in the destination region is uniform to all consumption sectors, and the consumption sector is then ignored to simplify the model and reduce the data requirement. These two models can handle intra-regional trade flows indicating the origin and destination as the same area. Therefore, the total number of the trade coefficients in IRIO is equal to the number of permutations of supply sectors, consumption sectors, origin areas and destination areas; while in MRIO it is equal to the number of permutations of supply sectors, the origin areas and destination areas. The information used to estimate the trade coefficients usually comes from origin-to-destination commodity shipment information; the commodity shipment information and the data in the IO models should be uniform somehow (e.g. the categorisation of industries and products, the value unit, etc).

The structural integrity of the IO framework depends on the accounting system employed. Oosterhaven (1984) argues that the traditional dominance of square (industry-by-industry) tables is unjustified and that an optimal mix between table construction assumptions and model-building assumptions should be sought. Rectangular (commodity-by-industry) tables avoid the reconciliation problems inherent in square tables regarding sales and purchase data, though they require additional behavioural assumptions regarding sector or market shares (Oosterhaven, 1984). Constructing regional IO tables traditionally faces a trade-off between accuracy and cost. While survey-based methods provide reliable data, they are often prohibitively expensive for sub-national levels (Miller & Blair, 2009). Consequently, a significant amount of literature has developed around non-survey and hybrid techniques for the construction of regional IO tables.

In a typical research scheme, the total production / consumption of each product in each area is first estimated and then the trade flows; after, the local IO tables are built using these trade flows that allow to identify the intra-zonal and inter-zonal exchanges. To estimate the local production / consumption, the most common approach is to regionalize national IO tables using available socio-economic proxies. Miller and Blair (2009) note that while output data is the theoretically ideal proxy, it is rarely available at detailed sectoral levels for sub-national regions. Consequently, employment data is the most frequently employed proxy due to its widespread availability in census and labour statistics. However, the reliance on employment assumes a correlation between labour input and monetary transactions that may not hold across sectors with varying labour intensities (Stevens, et al., 1989). For the simulation of trade flows, the literature distinguishes between two primary approaches: the use of elastic trade coefficients within MRIO (Cascetta, et al., 2013) (Zhao & Kockelman, 2004) and the application of spatial interaction models, particularly gravity models.

In the context of MRIO, the intermediate transaction factors capture flows between sectors within and across regions. A common method to estimate such factors is the Location Quotients (LQs) methods. Early methods relied on the Simple Location Quotient (SLQ) and the Cross Industry Location Quotient (CILQ), which utilize proxies to estimate the proportion of regional demand satisfied by local supply. However, they have been critically assessed for systematically overestimating regional multipliers by understating interregional imports, leading to inflated economic impact estimates (Miller & Blair, 2009) (Bonfiglio & Chelli, 2008). To address biases in conventional LQs, advanced formulations like the Flegg Location Quotient (FLQ) have been developed, incorporating regional size and specialization parameters to better approximate interregional trade flows (Flegg & Tohmo, 2013) (Flegg & Webber, 1997) (Flegg, et al., 1995). Empirical evidence suggests the FLQ yields results superior to conventional techniques in both reproducing 'true' multipliers and generating more stable simulation errors (Bonfiglio & Chelli, 2008). In the FLQ framework, the proxy (typically employment or output) is used not only to measure sectoral specialization but also to gauge the region's overall capacity to retain transactions internally. Flegg and Tohmo (2013), in their study of Finnish regions, explicitly utilize employment data as a proxy for regional output within the FLQ formula, demonstrating that adjusting for regional size significantly reduces simulation error compared to conventional LQs. However, the accuracy of the FLQ is sensitive to the parameter δ that represents the regional size. Studies highlight that the optimal value of δ varies according to the dimensions and structure of the regional economies (Flegg & Tohmo, 2013) (Bonfiglio & Chelli, 2008) (Socci, et al., 2025). Recognizing the limitations of single-proxy mechanical adjustments, the literature has shifted towards hybrid methods. Lahr (1993) defines hybrid models as those combining non-survey techniques with superior data obtained from experts or targeted surveys. In this context, proxies serve as the initial estimate, which is then refined. For instance, the RAS technique (biproportional scaling) is often used to adjust an initial matrix derived from LQs to conform to known regional control totals (Miller & Blair, 2009). These control totals often consist of aggregate socio-economic proxies such as total regional value-added, total household income, or total sectoral employment. Gerking (1976) highlights the importance of reconciling "rows-only" (sales) and "columns-only" (purchase) data, suggesting that using multiple proxies (e.g., employment for production capacity and income for consumption capacity) can improve the consistency of the resulting table.

Nevertheless, their integration for freight transport demand modelling presents specific challenges that this report addresses. A key limitation in existing literature is the tendency to model trade flows in monetary terms without adequately considering the physical heterogeneity of goods, which is critical for transport planning (Jensen, et al., 2019). Furthermore, existing regional Input-Output studies focus more likely on NUTS 2 regions or single provinces due to data constraints, such as (Bonfiglio & Chelli, 2008) (Flegg & Tohmo, 2013) (Flegg, et al., 2014). Consequently, freight models often rely on aggregated data that might mask local economic heterogeneity, or these freight models lack the macroeconomic consistency required for policy analysis (Oosterhaven, 1984).

3 METHODOLOGY

While gravity models are extensively used for trade distribution, they typically require observed Origin-Destination data for calibration, which is unavailable at the NUTS 3 level in our case. To overcome this, a hybrid approach is applied as one of the key methodological contributions. The FLQ method is applied to allocate the intra-regional / inter-regional value of production – consumption flows before the application of the gravity model. This hybrid approach offers tow advantages: first, it ensures macroeconomic consistency, i.e. Input-Output balancing, at local level; and it reduces the computational complexity of the gravity model by limiting its scope to inter-regional and international trade flows only.

Furthermore, the difficulty of modelling arises significantly when the number of commodities increases. This research introduces a commodity-to-freight type conversion step prior to the gravity model estimation. This modification reduces the computational complexity and ensures the compatibility of the resulting flows with transport network assignment (dry bulk, liquid bulk, general goods), as choice made by the European chain choice model (Jensen, et al., 2019). As the consequence, the distribution of only domestical and international trade flows in terms of three freight types needs to be estimated.

Simultaneously, by applying this framework to all 107 Italian NUTS 3 territories, this study advances the debate on non-survey methods by demonstrating how accounting consistency can be maintained at a highly disaggregated level where survey data is typically unavailable. This addresses the critical need for disaggregated data in modern freight logistics modelling without compromising macroeconomic balance, offering a replicable methodology for generating consistent freight generation and attraction data where primary surveys are prohibitively expensive.

The output of this methodology represents Production-Consumption flows, i.e. economic origin-destination relationships, which constitute the generation / attraction step of freight demand modelling. Validation of this output against observed freight transport statistics – which represent physical transport origin-destination flows as the result of modal choice and network assignment – would be conceptually appropriate only after the subsequent Flow Distribution and Assignment modelling have been completed

3.1 Regionalization of national Input-Output tables

The IO system has been developed by the Russian economist Wassily Leontief to model the interactions between productive activities in the economy. This system quantifies systematically mutual interrelationships between the different sectors of a complex economic system, based on a fully specified general equilibrium model, and shows how the output of an industry becomes the input of another (Arbex & Perobelli, 2010). An IO table represents such interactions in terms of flows of goods and services between different internal sectors and external ones (i.e. import and export) of the economy.

Table 3-1 shows schematically the structure of a generic IO table. In rows, it shows the production or import of goods and services, i.e. the output from a given sector; while in columns it reports the use or consumption, i.e. inputs for a given sector. The unit of measurement is the monetary value of the quantities produced and consumed.

Table 3-1 Structure of generic IO table

		Intermediate Use €				Final Use€		
		…	Sector j	…	Total intermediate	Households, governments & other final uses	Export	Total final
Sector i	National Production	…	$Int_{ij,Dom}$	…	$\sum_j Int_{ij,Dom}$	$F_{i,Dom}$	$X_{i,Dom.For}$	$F_{i,Dom} + X_{i,Dom.For}$
	Import	…	$Int_{ij,For}$	…	$\sum_j Int_{ij,For}$	$F_{i,For}$	$X_{i,For.For}$	$F_{i,For} + X_{i,For.For}$
Total		…		…				

The columns are grouped into two categories: the intermediate use and final use. This is to make it easier to distinguish between the two types of flows: one includes goods and services produced by economic activities that are then used as inputs to other economic activities, while the other relates to the goods and services that are directly consumed without further processing. In particular, the final uses are divided into what is consumed by households and the public sector and exports.

In the "Intermediate use" part of the IO table, for a generic economic sector *j* in column, the monetary value of its consumption of goods / services as sectoral input is represented in this column. In the "Final use" part, the numbers in the columns are the monetary values of the goods / services consumed by households and the public sector, as well as for export. These goods / services are provided as output by the different sectors reported in rows.

For a generic economic sector *i* reported in the row, all the numbers in that row represent the monetary value of the goods / services produced or imported by the sector *i* as the sectoral output. These goods / services are consumed as input by different economic sectors in columns (in the case of " Intermediate Uses"), or consumed by households, the public sector and for export (in the case of "Final uses").

Considering the generic sector i, it reports the total values of the sectoral production for intermediate uses ($\sum_j Int_{ij,Dom}$) and that for final uses ($F_{i,Dom} + X_{i,Dom.For}$); the sum of these two elements represents the domestic production of sector *i*. It shows also the same values in respect of sectoral imports for intermediate uses ($\sum_j Int_{ij,For}$) and final uses ($F_{i,For} + X_{i,For.For}$).

In real economic systems, however, the relationship between the sectors and goods is not unique and exclusive, i.e. one sector produces more than one product, and one product is supplied by more than one sector. Using IO tables in terms of “sectors x sectors” as base, after the regionalization procedure, we will obtain the local productions / consumptions in terms of sectoral production instead of products. For our purpose of freight transport mobility, the conversion is required so that the products transportable with physical entity can be distinguished from the services. In this respect, we have considered the national IO table in terms of "commodities x sectors" of "supply" and "use", whose structure are shown schematically by Table 3-2 and Table 3-3.

Table 3-2 National table of supply in terms of commodities

Supply	Domestic production €				Import €			
	…	Sector s	…	Total	…	Sector s	…	Total
Product m	…	P_{ms}^N	…	$P_m^N = \sum_s P_{ms}^N$	…	$I_{ms,For}^N$	…	$I_{m,For}^N = \sum_s I_{ms,For}^N$
Total	…	…	…	…	…	…	…	…

Table 3-3 National table of use in terms of commodities

Use		Intermediate use €				Final use €		
		…	Sector s	…	Total intermediate	Households, governments & other final uses	Export	Total final
Product m	National production	…	$Int_{ms,Dom}^N$	…	$Int_{m,Dom}^N = \sum_s Int_{ms,Dom}^N$	$F_{m,Dom}^N$	$X_{m,Dom.For}^N$	$F_{m,Dom}^N + X_{m,Dom.For}^N$
	Import	…	$Int_{ms,For}^N$	…	$Int_{m,For}^N = \sum_s Int_{ms,For}^N$	$F_{m,For}^N$	$X_{m,For.For}^N$	$F_{m,For}^N + X_{m,For.For}^N$
Total		…	…	…	…	…	…	…

The superscript denotes “domestic, at national level”, the subscript *Dom* denotes “all domestic areas”, *For* denotes “foreign zones”. For instance, $X_{m,Dom.For}^N$ stands for the total export at national level of the domestically supplied product *m* to foreign zones.

Different from the Table 3-1, the rows represent goods supplied / consumed, while in columns remain economic sectors and final consumers. Usually, the data about the import of product per sector $I_{ms,For}$ is omitted in the table of supply.

Statistic institutes normally publish the national IO tables while it is rare to find such tables for local administrative territories. Meanwhile, the statistics data on local employment / population and other economic indicators are usually available. Consequently, dividing the national IO tables by using dasymetric disaggregation is considered. The dasymetric disaggregation method redistributes aggregated data into finer spatial units using ancillary information. This approach assumes that the auxiliary variable is strongly correlated with the target variable and that the relationship is approximately proportional across subunits. Appropriate dasymetric approach should be selected according to the heterogeneity of spatial data, since different methodologies have varied ability in explaining effectively the spatially variable densities (Li, et al., 2007). The method is widely employed in official statistics for distributing national accounts data to subnational levels when direct measurement at finer scales is unavailable (Nardo, et al., 2005) (Eurostat, 2013).

We have made the following assumptions to proceed the division of national data at local level:

1. For any industry / final users, the composition of products in the sectoral production / consumption remains still. When the sectoral production / consumption varies, the different products provided and consumed by the industry / final user vary at the same percentage.
2. The production technologies and efficiency, the tax rates as well as consumption preference are the same at both national and local level.

Consequently, for any industry, the local share of national sectoral output / consumption in an area is identical to the local share of national sectoral dimension; if a sector produces / uses more than one product, this assumption applies to each of them. For final consumptions, the local share of national consumption in an area is identical to the local share of national users' dimension. For the local exports abroad, the local share of national exports abroad is equal to the local share of national supply of the product. The regionalization coefficients l_r are then defined to represents these above-mentioned local shares:

- Sectoral dimension, based on:
    a. number of employees, or
    b. total value of sectoral production
- Users' dimension, based on:
    a. population, or
    b. taxable income, or
    c. number of employees of all industries, or
    d. number of institutional units
- Supply capacity of product, based on the sectoral dimension and the share of different industries in the production of the product.

The following values are estimated:

- P_{ms}^{r}: value of local production of product *m* by industry *s* in a domestic area *r*.
- $Int_{ms,Dom}^{r}, F_{m,Dom}^{r}$: value of domestic product *m* used by the productive activities *s* as intermediate input and by households and public sectors in the area *r*.
- $Int_{ms,For}^{r}, F_{m,For}^{r}, X_{m,For.For}^{r}$: value of foreign product *m* used in the area *r* by industry *s*, households and public sectors as well as re-exported abroad. The sum of these values equals to the value of local import of foreign product *m* in the area *r* ($I_{m,For}^{r}$).

With the present methodology, the IO tables at desired local level must be estimated directly from the national IO tables without any intermediate steps, since the following step will imply some geographic limits to the origins of the commodities consumed in the area. Consequently, the regionalization coefficients should represent the relation between the national indicators and the local ones.

Once the national IO tables have been divided into local tables, they must fulfil the limits imposed by regional economic accounting data. If the regional economic accounting data are available at a higher administrative level, the variation (if necessary) is applied to all related local values while keeping their share.

3.2 Estimation of the amount of inter-regional / international trade per product

To simplify the estimation of intra-regional and inter-regional flows, it is assumed that only locally produced commodities can be exported to any other areas (both domestic and foreign) and foreign products can be re-exported exclusively to international destinations. Considering the resources imported from other domestic areas and abroad, there is the balance between the supply and use in the local IO table:

$$\begin{aligned} Int^r_{m,Dom} &= Int^r_{m,XP} + Int^r_{m,Loc} \\ F^r_{m,Dom} &= F^r_{m,XP} + F^r_{m,Loc} \\ I^r_{m,XP} &= Int^r_{m,XP} + F^r_{m,XP} \\ I^r_{m,For} &= Int^r_{m,For} + F^r_{m,For} + X^r_{m,For.For} \\ P^r_m &= Int^r_{m,Loc} + F^r_{m,Loc} + X^r_{m,Loc.Dom} + X^r_{m,Loc.For} \end{aligned} \qquad (3\text{-}1)$$

Where:

XP, Loc : the subscript *XP* refers to “other domestic areas”, *Loc* stands for “local”.

$Int^r_{m,Loc}, F^r_{m,Loc}$: total local intermediate, final uses of product *m* locally supplied in the area r.

$Int^r_{m,XP}, F^r_{m,XP}$: total local intermediate, final uses of product *m* in the area *r* imported from other domestic areas.

$I^r_{m,XP}$: value of local imports of product *m* from other domestic areas.

$X^r_{m,Loc.XP}, X^r_{m,Loc.For}$: the value of domestic product *m* exported to other domestic areas and abroad from the area *r*.

With eq. one can estimate the import and export with other domestic areas ($I^r_{m,XP}$, $X^r_{m,Loc.XP}$) after having identified the origin of the domestic goods / services consumed in the region ($Int^r_{m,XP}, Int^r_{m,Loc}$ and $F^r_{m,XP}, F^r_{m,Loc}$).

3.2.1 Estimation of intra-regional production-consumption flow

3.2.1.1 Intermediate uses

The Location Quotients methods (LQ methods) are one of the most common "non-survey" tools to identify the intra-regional and inter-regional goods flows by estimating the coefficients of intra-regional input for the intermediate uses. The coefficient of intra-regional input indicates the ratio of the regional intermediate use of local goods to the regional production of such goods, according to the "location quotient" that assesses the degree of specialization of production in the region, the relative size of the activities and of the region (Round, 1978). Before applying the methods, we should define the coefficients:

1. Technical coefficient

In this project, the technical coefficient is defined as following:

$$a_{ms} = Int_{ms,Dom}/P_s \tag{3-2}$$

Depending on the meaning of the numerator and denominator, the technical coefficient can mean:

a) the value of the product *m* consumed by the sector *s* to produce one monetary unit of sectoral output of *s* (Kim, 1974) (Oosterhaven & Stelder, 2007) (Sargento, 2009) (Flegg, et al., 2014) (Merciai & Heijungs, 2014); or
b) the value of the output of the sector *m* consumed by the sector *s* to produce one monetary unit of sectoral output of *s* (Hewings & Jensen, 1986) (F.Buffoni, et al., 1991) (Kowalewski, 2012) (Morrissey, 2014) .

In the case where an industry produces a single product and a product is produced by an industry exclusively, the "output of the sector *m*" is equal to "product *m*", and consequently the definitions a) and b) are identical. In the opposite case, the value of the "output of the sector *m*" is no longer equal to the value of the "product *m*".

In this introductive section of the methodology, the relationship between product and sector is assumed as unique and exclusive.

2. Coefficient of intra-regional input

Similar to the technical coefficient, the coefficient of intra-regional input represents the value of the product *m* from the area r that is used by the sector *s* in the same region to produce one monetary unit of sectoral output, as following:

$$t_{ms}^{r} = Int_{ms,Loc}^{r}/P_s^r \tag{3-3}$$

3. Coefficient of inter-regional import

The inter-regional coefficient import w_{ms}^{r} indicates the value of the product *m* imported from other domestic areas and consumed by the sector *s* in the area *r* to produce one monetary unit of sectoral output. Evidently, there is a relation between the regional technical coefficient a_{ms}^{r}, the coefficient of intra-regional input t_{ms}^{r} and the coefficient of inter-regional import w_{ms}^{r}:

$$w_{ms}^{r} = Int_{ms,XP}^{r}/P_{s}^{r} = a_{ms}^{r} - t_{ms}^{r} \qquad (3\text{-}4)$$

It is assumed that the production technologies are identical on the national and local level. Furthermore, it is assumed that one relation exists between the national technical coefficient and the coefficient of intra-regional input:

$$t_{ms}^{r} = a_{ms}^{N} \cdot q_{ms}^{r}, \quad a_{ms}^{r} = a_{ms}^{N} \qquad (3\text{-}5)$$

q_{ms}^{r} is the degree of self-sufficiency that indicates in the area *r* the share of the intermediate demand of sector *s* for the product *m* satisfied by the local production. From the definition of the coefficient a_{ms}^{r} and t_{ms}^{r}, q_{ms}^{r} can not exceed 1.

With the eq.(3-2), (3-3), (3-4) and (3-5), we have:

$$w_{ms}^{r} = a_{ms}^{N}(1 - q_{ms}^{r}) \qquad (3\text{-}6)$$

and

$$\begin{matrix} Int_{ms,Loc}^{r} = P_{s}^{r} \cdot t_{ms}^{r} = P_{s}^{r} \cdot a_{ms}^{r} \cdot q_{ms}^{r} = Int_{ms,Dom}^{r} \cdot q_{ms}^{r} \\ Int_{ms,XP}^{r} = Int_{ms,Dom}^{r} \cdot (1 - q_{ms}^{r}) \end{matrix}, \; s = 1 \; to \; 63 \qquad (3\text{-}7)$$

The LQ methods aim to estimate q_{ms}^{r}. In the family of LQ methods, three LQs are frequently used: the Simple Location Quotient (SLQ), the Cross-Industry Location Quotient (CILQ) and the Flegg's Location Quotient (FLQ).

a). Simple Location Quotient (SLQ)

With the SLQ, the q_{ms}^{R} is estimated as:

$$q_{ms}^{r} = q_{m}^{r} = \begin{cases} 1, & SLQ_{m}^{r} \geq 1 \\ SLQ_{m}^{r}, & otherwise \end{cases}, \quad SLQ_{m}^{r} = \frac{E_{m}^{r}}{E_{m}^{N}} / \frac{E^{r}}{E^{N}} \qquad (3\text{-}8)$$

Where:

E_{m}^{r}, E_{m}^{N}: employment of the sector *m* on the regional and national level, respectively.

E^{r}, E^{N}: total employment on the regional and national level, respectively.

The SLQ considers the relative size of sector *m* in area r ($\frac{E_m^r}{E_m^N}$) that provides the product *m* as well as the relative size of the region ($\frac{E^r}{E^N}$). When q_{ms}^r is less than 1, it means that the employment of the area r is less concentrated in the sector *m* compared to the national average; as the consequence, the area would be less specialized in producing the product *m*, thus it would be less likely that the area is self-sufficient; vice versa. Moreover, by definition q_{ms}^r should not exceed 1. The defect of the SLQ is obvious: it does not take into account the relative size of the consumer sector that makes use of the product *m*.

b). Cross-Industry Location Quotient (CILQ)

With CILQ the q_{ms}^r is estimated as:

$$q_{ms}^r = \begin{cases} 1, & CILQ_{ms}^r \geq 1 \\ CILQ_{ms}^r, & otherwise \end{cases}, \quad CILQ_{ms}^r = \frac{SLQ_m^r}{SLQ_s^r} = \frac{E_m^r}{E_m^N} \Big/ \frac{E_s^r}{E_s^N} \tag{3-9}$$

The CILQ considers the relative size of both the sector *m* ($\frac{E_m^r}{E_m^N}$) that provides the product *m* and the sector *s* ($\frac{E_s^r}{E_s^N}$) that uses the product *m*. The relative size of the area r is not recognized because $\frac{E^r}{E^N}$ is cancelled as the common denominator of the two SLQ. When q_{ms}^R is less than 1, the sector *s* is more represented than the sector *m* in the region *R*, thus the regional supply of *m* is less likely enough to satisfy the regional demand, and the region would more probably import the product.

c). Flegg's Location Quotient (FLQ)

The FLQ is developed by (Flegg, et al., 1995) to overcome the defect of CILQ and reformulated by (Flegg & Webber, 1997):

$$q_{ms}^r = \begin{cases} 1, & FLQ_{ms}^r \geq 1 \\ FLQ_{ms}^r, & otherwise \end{cases}$$
$$FLQ_{ms}^r = \begin{cases} CILQ_{ms}^R \cdot \lambda^* = \frac{E_m^r}{E_m^N} \Big/ \frac{E_s^r}{E_s^N} \cdot \lambda^*, & m \neq s \\ SLQ_{ms}^R \cdot \lambda^* = \frac{E_m^r}{E_m^N} \Big/ \frac{E^r}{E^N} \cdot \lambda^*, & m = s \end{cases}, \quad \lambda^* = \left[log_2(1 + \frac{E^r}{E^N})\right]^\delta \tag{3-10}$$

The FLQ has incorporated the CILQ, so it recognizes the relative size of the sector *m* and *s*; when dealing with only one sector, CILQ will be equal to 1 and it turns to SLQ. The relative size of the region is recognized by using the variable λ^*.

Various literatures show that among the three methods LQ, the FLQ provides a better accuracy in regionalize the national IO table (Flegg & Webber, 1997) (Tohmo, 2004) (Bonfiglio & Chelli, 2008) (Flegg & Tohmo, 2013) (Flegg, et al., 2021). Flegg and Tohmo have also mentioned that "*...It is, therefore, by no means evident that a gravity modelling approach is superior to the FLQ, especially when its complexity, cost and* *extensive data requirements are borne in mind…*" (Flegg & Tohmo, 2013). On the other hand, they have also stated that the FLQ and other LQ methods rely on the critical assumption that regional and national production technologies are identical. This assumption may not hold for small regions or highly open economies where structural differences are more pronounced (Morrison & Smith, 1974) (Oosterhaven, 1984). Furthermore, the accuracy of the FLQ is sensitive to the parameter δ, which adjusts for interregional trade based on regional size. Studies highlight that the optimal value of δ varies according to dimensions and structure of the regional economies; for instance, the optimal value for Finnish regions clustered around 0.25 with a tendency for δ to rise with regional size (Flegg & Tohmo, 2013). Similarly, Bonifiglio and Chelli (2008) have demonstrated through Monte Carlo simulation that while δ=0.3 generally minimizes bias in multipliers, the direction of estimation bias (over- or under-estimation) depends heavily on the value of δ. Consequently, while a uniform δ is often applied for consistency in non-survey models, this assumption may introduce variability in accuracy across regions of different sizes and economic structures (Flegg & Tohmo, 2013).

3.2.1.2 Final uses

Similar to the q^r_{ms} for intermediate uses, the coefficient of intra-regional input for final use k^r_{mf} is defined as the share of the demand of final use *f* for the product *m* satisfied by the local production in the area *r*, so there is :

$$F^r_{mf,Loc} = F^r_{mf,Dom} \times k^r_{mf} \ , \ \ F^r_{mf,XP} = F^r_{mf,Dom} \times (1 - k^r_{mf}) \tag{3-11}$$

The application of the FLQ to estimate such coefficient rests on a rigorous interpretation of the non-survey regionalization framework. While early applications of Location Quotients (LQs) focused primarily on intermediate transactions (Tohmo, 2004) (Flegg & Webber, 1997) (Morrison & Smith, 1974), the extension to final demand is theoretically grounded in the fundamental assumptions of non-survey regionalization and the specific mechanics of the FLQ formula.

The primary assumption of non-survey methods, including the FLQ, is that regional technical coefficients (for industries) and consumption propensities (for final users) are identical to those at the national level (Miller & Blair, 2009). Under this assumption, the total monetary demand for a product *m* in region *r* is accurately derived by scaling national demand via regionalization coefficients c^r_s. The uncertainty lies only in the regional self-sufficiency: what proportion of this demand is met by local production versus imports? The FLQ formula does not alter the structure of demand; it exclusively estimates the regional self-sufficiency coefficient (q^r_{ms} for intermediate uses or k^r_{mf} for final uses) based on relative supplier's size, consumer's size, and most importantly, the regional size λ^* which acts as a proxy for the propensity to import due to lack of diversification in smaller economies. Excluding the regional size λ^* would erroneously assume that small Italian provinces satisfy household consumption locally at the same rate as larger, diversified regions, violating the central tenet of the FLQ (Flegg & Tohmo, 2013).

The economic logic of "import leakage" applies universally to all domestic demanders. If a region lacks a sufficiently large manufacturing base for a specific good, neither an industrial buyer nor a household consumer can source that good locally, regardless of their specific consumption basket. The constraint is on the supply side, not the demand side. In the absence of observed trade flows for final consumption, the allocation of supply sources must rely on consistent behavioural assumptions regarding market shares and regional capacity (Oosterhaven, 1984) and the use of location quotient logic to determine the regional origin of goods consumed by final sectors are explicitly discussed (Isard, et al., 1998). Furthermore, (Lahr, 1993) emphasizes that non-survey techniques provide the necessary baseline for all cells lacking superior data.

Furthermore, recent validation studies using Monte Carlo simulations (Kronenberg, 2009) (Bonfiglio & Chelli, 2008) demonstrate that FLQ-based regionalization significantly reduces bias in estimated multipliers compared to SLQ and CILQ methods. Since output multipliers are derived from the sum of direct and indirect effects involving both intermediate and final demand chains, the superior performance of the FLQ implies that its underlying logic correctly captures the trade dynamics across the entire input-output system, including the initial generation of imports triggered by final demand. Restricting the FLQ solely to intermediate uses while reverting to simpler LQs (or assuming full self-sufficiency) for final uses would introduce an inconsistency in the treatment of trade flows, potentially overstating the local impact of final demand injections in smaller regions. Therefore, defining the intra-regional input coefficient for final uses (k_{ms}^{r}) using the FLQ framework is consistent with the model's treatment of interregional trade. Given the absence of observed inter-regional trade data at the NUTS 3 level in Italy, applying the FLQ to final uses ensures that the estimated import leakages for households and governments are consistent with the leakages estimated for industries, preserving the macroeconomic balance of the regional system.

Thus, the FLQ_{ms}^{r} in Eq. (3-10) is adapted for final users by substituting the industrial demand proxy $\frac{E_s^r}{E_s^N}$ with the appropriate final demand regionalization coefficient.

3.2.2 Estimation of the inter-regional and international import / export

The total amount of import from foreign areas is equal to the sum of local uses of the imported foreign resources.

As for the export, the export capacity of the area *r* is defined as the surplus of the local production after having fulfilled the demand of the local product in the area, and the area firstly exports abroad according to its share of the export capacity of all domestic areas, and the rest part of its export capacity is destinated to other domestic areas, as in the following equation:

$$XC_m^r = max\left(P_m^r - Int_{m,Loc}^r - F_{m,Loc}^r \ , \ 0\right)$$
$$X_{m,Loc.For}^r = X_{m,For.For}^N \times \frac{XC_m^r}{\sum_r XC_m^r} \tag{3-12}$$
$$X_{m,Loc.XP}^r = XC_m^r - X_{m,Loc.For}^r$$

In case that the local production was not sufficient to fulfil the local demand for the local products, the shortage will be covered by imports from other domestic areas, as in the following equation that is updated from the eq. (2-1)

$$I_{m,XP}^r = Int_{m,XP}^r + F_{m,XP}^r + \left|min\left(P_m^r - Int_{m,Loc}^r - F_{m,Loc}^r \ , \ 0\right)\right| \tag{3-13}$$

For any generic product *m*, the inter-regional and international imports and exports should satisfy the global balancing conditions: the total inter-regional import of all domestic areas must equal to their total inter-regional export, and the total international import / export of all domestic areas must equal to the total international export / import of all foreign areas.

3.3 Conversion of exchanges of commodities into exchanges of freight

The trade flows of goods concern only commodities with physical entity that can be transported, therefore in this section only products are considered. The conversion of the exchange flows from product-based to freight-type based is necessary. The parameters of gravity model should be estimated for each product. To reduce the complexity, we have decided to carry out the conversion before the gravity model.

Basing on the Swedish national freight transport system SAMGODS (Vierth, et al., 2017) that provides the correspondence between the transport statistics classification system NST/R (European Union, 1967) and the three freight types, the exchanges in terms of product are then convertible with the correspondences from different classification systems to NST/R, published by Eurostat and World Customs Organization.

4 APPLICATION

4.1 Zoning system

Italy is the country of interest. For Italy, the zoning structure is defined at NUTS3 level, the one of former provinces. Therefore, inside Italy, there are 107 zones. Outside Italy, 68 zones are defined, at country level for the European continent and the Mediterranean area, and continental or sub-continental level for the rest of the world.

The 57 European continent and the Mediterranean countries are: Andorra, Albania, Austria, Bosnia and Herzegovina, Belgium, Bulgaria, Belarus, Switzerland, Cyprus, Czechia, Germany, Denmark, Estonia, Spain, Finland, Faroe Islands, France, United Kingdom, Gibraltar, Greece, Croatia, Hungary, Ireland (Eire), Iceland, Liechtenstein, Lithuania, Luxembourg, Latvia, Moldova, Republic of, Montenegro, North Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation (Russia), Sweden, Slovenia, Slovakia, San Marino, Turkey, Ukraine, Holy See (Vatican City State), Kosovo, Serbia, Algeria, Egypt, Israel, Lebanon, Libya, Morocco, Syrian Arab Republic (Syria), Tunisia, Ceuta, Melilla.

The 11 continental / sub-continental zones are: Antarctic, northern and eastern Africa, northern and western Africa, middle Africa, southern Africa, western Asia, central Asia, eastern and southern and south-east Asia, Oceania, north America, south America.

4.2 Data

In this project, the input data for the structural gravity model consists of imports and exports value of each Italian territory at NUTS 3 level and trade value of each foreign area with Italy, as shown in Table 4-1:

Table 4-1 Input data for structural gravity model

<table>
<tr><th>Trade</th><th>Generation</th><th>Attraction</th></tr>
<tr><td rowspan="2">National</td><td>Local products for national markets</td><td>Local expenditure for non-local domestic products from national markets</td></tr>
<tr><td colspan="2">Purchase prices
Transport: between Italian local areas at NUTS 3 level</td></tr>
<tr><td rowspan="2">International exports of Italian territories at NUTS 3 level</td><td>Local exports abroad</td><td>Imports of each foreign area from Italy</td></tr>
<tr><td colspan="2">CIF[1] prices of the destination country</td></tr>
</table>

[1] CIF: stands for “Cost, Insurance, Freight”, includes the value of transport and insurance services to the border of the importer.

	Transport: from Italian local territory to border of destination country	
International imports of Italian territories at NUTS 3 level	Exports of each foreign area to Italy	Local imports from abroad
	CIF prices in Italy Transport: from origin area to border of Italy	

Resource: author's elaboration

The reference year is 2019. As described in the section of methodology, the necessary data are:

- ISTAT: National input-output tables
- ISTAT: Employment of the economic sectors, represented by the number of employees
- ISTAT: Population in Italy at NUTS 2 and 3 level
- ISTAT: Production value of agricultural companies per region and per division
- ISTAT: Value added per inhabitant at NUTS 3 level
- ISTAT: Number of public administration institutions per region
- ISTAT: Taxable Income of physic persons at NUTS 3 level
- AssoCostieri: Refinery distribution and capacity in Italy
- UNCTAD: International trade of Italy
- ISTAT: Territorial economic accounts and aggregates

4.2.1 National Input-Output tables

The national IO tables (or tables of supply and use) of Italy updated to 2019 (Istituto Nazionale di Statistica, 2022) is published in the Data Warehouse of the Italian National Institute of Statistics (ISTAT). The IO tables are matrices of two dimensions: by branch of economic activities (or sectors) and branch of homogeneous productions. These describe in detail the domestic production processes and the transactions in products of the national economy on an annual basis. This version of IO tables adopt the classification of NACE Rev.2 (European Union, 2006) for economic activities and CPA 2.1 (European Union, 2014) for products. The NACE (Nomenclature statistique des Activités économiques dans la Communauté Européenne) is the classification system used by the European Union to standardize definitions of economic activities in different Member States.

The CPA (statistical Classification of Products by Activity) is the classification of products adopted by the European Union, which regroups products in categories with similar characteristics. The two classifications are aligned, or there is a direct correspondence between the main groups of products and the corresponding economic sectors of the NACE classification. NACE Rev. 2 classifies economic sectors in 88 divisions belonging to 21 sections, and CPA 2.1 ranks products in 88 divisions correspondingly.

In the national IO tables of Italy, activities of extraterritorial organizations and bodies (NACE Rev. 2, Section U, Division 99) are excluded; the other 87 divisions of activities are regrouped into 63 and the products are correspondingly regrouped into 63. They correspond exactly to the terms of NACE Rev.2 and use the same index code.

For final uses, there are 5 consumers besides the exports abroad:

1. Household final consumption expenditure (equation subscript: *FAM*)
2. Final consumption expenditure of non-profit social institutions serving households (NPIs) (equation subscript: *ISP*)
3. Final consumption expenditure of public administrations (equation subscript: *PA*)
4. Gross fixed capital formation (equation subscript: *INV*)
5. Changes in inventories and valuables (equation subscript: *VAR*)

In this study, for the calculation it is assigned to each product and their corresponding economic sectors a sequence number, noted as subscript *m* and *s*, as in Table 4-2.

Table 4-2 Activities and products in the national IO tables of Italy

Seq. No.	Activities (NACE Rev.2)		Products (CPA 2.1)	
	Note	1. “V” indicates “Activity”, “R” indicates “Product”; 2: The numbers indicate the corresponding divisions of the classification (e.g., 10_12 indicate the division 10, 11 and 12) while the letters refer to the sections (e.g., B indicates the section B).		
1	V01	Crop and animal production, hunting and related service activities	R01	Products of agriculture, hunting and related services
2	V02	Forestry and logging	R02	Products of forestry, logging and related services
3	V03	Fishing and aquaculture	R03	Fish and other fishing products; aquaculture products; support services to fishing
4	VB	Mining and quarrying	RB	Mining and quarrying
5	V10_12	Manufacture of food products; Manufacture of beverages; Manufacture of tobacco products	R10_12	Food products; Beverages; Tobacco products
6	V13_15	Manufacture of textiles; Manufacture of wearing apparel; Manufacture of leather and related products	R13_15	Textiles; Wearing apparel; Leather and related products
7	V16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	R16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
8	V17	Manufacture of paper and paper products	R17	Paper and paper products
9	V18	Printing and reproduction of recorded media	R18	Printing and reproduction services of recorded media
10	V19	Manufacture of coke and refined petroleum products	R19	Coke and refined petroleum products

11	V20	Manufacture of chemicals and chemical products	R20	Chemicals and chemical products
12	V21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	R21	Basic pharmaceutical products and pharmaceutical preparations
13	V22	Manufacture of rubber and plastic products	R22	Rubber and plastic products
14	V23	Manufacture of other non-metallic mineral products	R23	Other non-metallic mineral products
15	V24	Manufacture of basic metals	R24	Basic metals
16	V25	Manufacture of fabricated metal products, except machinery and equipment	R25	Fabricated metal products, except machinery and equipment
17	V26	Manufacture of computer, electronic and optical products	R26	Computer, electronic and optical products
18	V27	Manufacture of electrical equipment	R27	Electrical equipment
19	V28	Manufacture of machinery and equipment n.e.c[2].	R28	Machinery and equipment n.e.c.
20	V29	Manufacture of motor vehicles, trailers and semi-trailers	R29	Motor vehicles, trailers and semi-trailers
21	V30	Manufacture of other transport equipment	R30	Other transport equipment
22	V31_32	Manufacture of furniture; Other manufacturing	R31_32	Furniture; Other manufactured goods
23	V33	Repair and installation of machinery and equipment	R33	Repair and installation services of machinery and equipment
24	VD	Electricity, gas, steam and air conditioning supply	RD	Electricity, gas, steam and air conditioning
25	V36	Water collection, treatment and supply	R36	Natural water; water treatment and supply services
26	V37_39	Sewerage; Waste collection, treatment and disposal activities; materials recovery; Remediation activities and other waste management services	R37_39	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services
27	VF	Construction	RF	Constructions and construction works
28	V45	Wholesale and retail trade and repair of motor vehicles and motorcycles	R45	Wholesale and retail trade and repair services of motor vehicles and motorcycles
29	V46	Wholesale trade, except of motor vehicles and motorcycles	R46	Wholesale trade services, except of motor vehicles and motorcycles
30	V47	Retail trade, except of motor vehicles and motorcycles	R47	Retail trade services, except of motor vehicles and motorcycles
31	V49	Land transport and transport via pipelines	R49	Land transport services and transport services via pipelines
32	V50	Water transport	R50	Water transport services
33	V51	Air transport	R51	Air transport services
34	V52	Warehousing and support activities for transportation	R52	Warehousing and support services for transportation
35	V53	Postal and courier activities	R53	Postal and courier services
36	VI	Accommodation and food service activities	RI	Accommodation and food services
37	V58	Publishing activities	R58	Publishing services

[2] n.e.c: not elsewhere classified

38	V59_60	Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities	R59_60	Motion picture, video and television programme production services, sound recording and music publishing; Programming and broadcasting services
39	V61	Telecommunications	R61	Telecommunications services
40	V62_63	Computer programming, consultancy and related activities; Information service activities	R62_63	Computer programming, consultancy and related services; Information services
41	V64	Financial service activities, except insurance and pension funding	R64	Financial services, except insurance and pension funding
42	V65	Insurance, reinsurance and pension funding, except compulsory social security	R65	Insurance, reinsurance and pension funding services, except compulsory social security
43	V66	Activities auxiliary to financial services and insurance activities	R66	Services auxiliary to financial services and insurance services
44	VL	Real estate activities	RL	Real estate services
45	V69_70	Legal and accounting activities; Activities of head offices; management consultancy activities	R69_70	Legal and accounting services; Services of head offices; management consulting services
46	V71	Architectural and engineering activities; technical testing and analysis	R71	Architectural and engineering services; technical testing and analysis services
47	V72	Scientific research and development	R72	Scientific research and development services
48	V73	Advertising and market research	R73	Advertising and market research services
49	V74_75	Other professional, scientific and technical activities; Veterinary activities	R74_75	Other professional, scientific and technical services; Veterinary services
50	V77	Rental and leasing activities	R77	Rental and leasing services
51	V78	Employment activities	R78	Employment services
52	V79	Travel agency, tour operator and other reservation service and related activities	R79	Travel agency, tour operator and other reservation services and related services
53	V80_82	Security and investigation activities; Services to buildings and landscape activities; Office administrative, office support and other business support activities	R80_82	Security and investigation services; Services to buildings and landscape; Office administrative, office support and other business support services
54	VO	Public administration and defence; compulsory social security	RO	Public administration and defence services; compulsory social security services
55	VP	Education	RP	Education services
56	V86	Human health activities	R86	Human health services
57	V87_88	Residential care activities; Social work activities without accommodation	R87_88	Residential care services; Social work services without accommodation
58	V90_92	Creative, arts and entertainment activities; Libraries, archives, museums and other cultural activities; Gambling and betting activities	R90_92	Creative, arts and entertainment services; Library, archive, museum and other cultural services; Gambling and betting services
59	V93	Sports activities and amusement and recreation activities	R93	Sporting services and amusement and recreation services
60	V94	Activities of membership organisations	R94	Services furnished by membership organisations
61	V95	Repair of computers and personal and household goods	R95	Repair services of computers and personal and household goods
62	V96	Other personal service activities	R96	Other personal services

63	VT	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	RT	Services of households as employers; undifferentiated goods and services produced by households for own use

The national IO tables of Italy are constructed based on two evaluation criteria:

- Base prices: the price that the producer may receive from the purchaser for the good or service, including any subsidies, but net of any taxes and distribution margins (trade and transport).
- Purchase prices: the price actually paid by the purchaser for the good or service produced.

In the entire set of tables of supply and use updated to 2019, the following tables at current prices[3] are considered:

- The table of supply "sup19" of "SUPPLY_63B.xls" that contains, for each of the 63 commodities, the domestic production by each of the 63 industries, as well as the total import from abroad, both at basic prices. Imports are valued at "cost insurance freight" (CIF) price, which includes the value of transport and insurance services to the border of the importer. For each product, the total value of domestic productions and imports at basic prices can be converted at purchase prices by adding the “Commercial margin and transport” and “Taxes minus subsidies on products” by product.
- The table of use "uspb19" of "USEPB_63B.xls" that shows, for each of the 63 commodities, the value of consumption at basic prices by each of the 63 industries (intermediate use) / by final users (final use). The products consumed come both from domestic production and import. Exports are valued at the price "free on board" (FOB), the price recorded at the customs frontier of the exporter. For each consumer, the total consumption at basic prices can be converted at purchase prices by adding the value of “Taxes minus subsidies on products” by user.
- The table of use “uspa19” of “USEPA_63B.xls” that brings, for each of the 63 commodities, the value of consumption at purchase prices by each of the 63 industries / final users. For each user, the value of “Taxes minus subsidies on products” in the “uspb19” table is distributed and added to its consumption at basic prices of different products.
- The table of use for imports "imprt19" of "IMPORT_63B.xls" that shows, for each of the 63 commodities imported from abroad, the value of consumption at basic prices by each of the 63 industries (intermediate use) / by final users (final use).

[3] The current prices in the market in the period in which the assessment is carried out.

For each product, the total consumption equals to the imports value in the table "Sup19". Different from the "Uspb19" table, there is not "taxes minus subsidies on products" by user that allows the conversion from basic prices to purchase prices.

Table 4-3 and

Table 4-4 shows schematically the structure of the supply table "sup19" and the use table "uspb19". The subscript "*All*" denotes "resources both domestically supplied and imported from abroad", and the superscript "°" stands for "at basic prices", without the superscript means "at purchase prices".

Table 4-3 Table of supply at basic prices

Supply (millions of €)	Domestic production (basic prices)				Import (CIF)	Total Supply (basic prices)	Margin of trade and transport	Taxes minus subsidies by product	Total Supply (purchase prices)
	Industry 1	…	Industry 63	Total production					
Product 1	$P^{\circ N}_{1.1}$		$P^{\circ N}_{1.63}$	$\sum_{s=1}^{63} P^{\circ N}_{1s}$	$I^{\circ N}_{1,For}$	$\sum_{s=1}^{63} P^{\circ N}_{1s} + I^{\circ N}_{1}$	$\Delta^{N}_{1,All}$	$T^{N}_{Sup,1,All}$	$\sum$
…									
Product 63									
Total	$\sum_{m=1}^{63} P^{\circ N}_{m1}$								

Table 4-4 Table of use of all resources at basic prices

Use (millions of €)	Intermediate uses				Final uses					Total
	Industry 1	..	Industry 63	Total intermediate uses	Use 1	…	Use 5	Export (FOB)	Total final uses	
Product 1	$Int^{\circ N}_{1.1,All}$			$\sum_{s=1}^{63} Int^{\circ N}_{1s,All}$	$F^{\circ N}_{1.1,All}$			$X^{\circ N}_{1,All.Fo}$	$\sum_{u=1}^{5} F^{\circ N}_{1u} + X^{\circ N}_{1,All.For}$	$\sum$
…										
Product 63										
Total uses (basic prices)	$\sum_{m=1}^{63} Int^{\circ N}_{m1}$									
Taxes minus subsidies on products	$T^{N}_{Use,1}$									
Total uses (purchase prices)	$\sum_{m=1}^{63} Int^{\circ N}_{m1} + T^{N}_{Use,1}$									
Value added (basic prices)	v^{N}_{1}									

Production (basic prices)	$\sum_{m=1}^{63} Int^{\circ N}_{m1} + T^{N}_{Use,1} + v^{N}_{1}$			

The table "uspa19" does not have the rows of "Total intermediate/final uses (basic prices)" and "Taxes minus subsidies on products". The table of use for imports "imprt19" has the same structure as the table "uspb19" except the last 4 rows.

The IO tables meet two fundamental balances:

1. Balance of supplies and uses per product at basic / purchase prices on a national scale:

$$\sum_s P^{\circ N}_{ms} + I^{\circ N}_{m,For} = \sum_s Int^{\circ N}_{ms} + \sum_u F^{\circ N}_{mu} + X^{\circ N}_{m,All.For}$$
$$\sum_s P^{\circ N}_{ms} + I^{\circ N}_{m,For} + \Delta^{N}_{m,All} + T^{N}_{sup,m,All} = \sum_s Int^{N}_{ms} + \sum_u F^{N}_{mu} + X^{N}_{m,All.For} \quad (4\text{-}1)$$

2. Balance of the total input and output by industry at basic prices: for a generic industry "s", the value of output at basic prices is equal to the intermediate costs at the purchase prices plus the value added:

$$\sum_m P^{\circ N}_{ms} = \sum_m Int^{\circ N}_{ms} + T^{N}_{Use,s} + v^{N}_{s} \quad (4\text{-}2)$$

Between the supply table "sup19" and use table "imprt19" there is:

$$I^{\circ N}_{m,For} = \sum_{s=1}^{63} Int^{\circ N}_{ms,For} + \sum_{u=1}^{5} F^{\circ N}_{mu,For} + X^{\circ N}_{m,For.For} \quad (4\text{-}3)$$

For simplification purposes, hereafter the subscript for final uses "*u*" is replaced by the subscript "*s*" plus the range of values.

4.2.2 Employment and population data

In this research, we have adopted the number of employees of economic activities to describe the employment in the areas of interest (Istituto Nazionale di Statistica, 2019).

The dataset contains the number of employees in local units of active enterprises. The dataset uses the classification of economic activities ATECO 2007 (Istituto Nazionale di Statistica, 2009). Adopted by the ISTAT in January of 2008, this classification is the national version of the European classification NACE Rev. 2, and there is a direct correspondence between the groupings of activities of these two classifications. According to the ATECO 2007, the economic activities are aggregated into 21 sections consisting of 88 divisions.

The following activities of ATECO 2007, however, are not present:

- Crop and animal production, hunting and related service activities (section A, division 01, sequence number 1)
- Forestry and logging (section A, division 02, sequence number 2)
- Fishing and aquaculture (section A, division 03, sequence number 3)
- Public administration and defence; compulsory social security (section O, division 84, sequence number 54)
- Activities of membership organisations (section S, division 94, sequence number 60)
- Activities of households as employers of domestic personnel (section T, division 97, sequence number 63)
- Undifferentiated goods - and services-producing activities of private households for own use (section T, division 98, sequence number 63)
- Activities of extraterritorial organisations and bodies (section U).

The population data of Italy in 2019 (Istituto Nazionale di Statistica, 2019) has been used. Such data concerns the total residential population of Italy, 20 Italian regions and 107 local areas at NUTS 3 level.

4.2.3 Data about the international trade of Italy

The "International Trade and Transport" dataset of UNCTAD (United Nation Conference on Trade and Development, UNCTAD, 2024) provides international trade information for each commodity classified with the headings (4 digits) of the "Harmonised Commodity Description and Coding System" version 2017 (HS17) (World Customs Organization, 2016), including the FOB value at the country of origin, international transport expenditures and weight. The HS17 system contains 21 major sections, 97 chapters (2 digits), more than 1200 headings (4 digits), more than 5000 sub-headings (6 digits). Countries use the HS system as the basis for customs tariffs and statistical data.

Using this dataset, one can avoid dealing with the often-found data discrepancies between the origin and destination countries. These discrepancies may be due to the following reasons:

- Valuation differences: Exports are typically recorded FOB (free on board), excluding freight and insurance, while imports use CIF (cost, insurance, freight) valuation, inflating import values.
- Temporal misalignment: Divergent recording times (e.g., shipment vs. arrival dates) and reporting lags cause mismatches in period-specific aggregates.
- Classification inconsistencies: Varied interpretations of HS codes, product categorization, or treatment of re-exports lead to asymmetric reporting.
- Coverage gaps: Non-standard inclusions/exclusions of goods (e.g., transit trade, informal flows) and confidentiality protocols suppress certain transactions.

- Illicit activities: Trade misinvoicing for tax evasion, capital flight, or smuggling distorts declared values.
- Operational errors: Clerical inaccuracies, sampling biases in customs data, and currency conversion fluctuations further exacerbate asymmetries.

According to the methodology (United Nation Conference on Trade and Development, UNCTAD, 2024), the transport expenditures are estimated

> *"as the difference between the CIF value and the FOB value, as defined by IMTS Concepts and Definitions, article 4.6 (UNSD, 2011)...." as "the expenditures invoiced for the services performed to deliver internationally traded goods from the border of the economy of origin (Origin) to the border of the importing economy (Destination), including the shipping the goods and the procurement of insurance against the risk of loss or damage during carriage."*

4.2.4 Other data

We have referred to the edition of June 2023 of the dataset "Conti della branca agricoltura, silvicoltura e pesca" of ISTAT (Istituto Nazionale di Statistica, 2023) for evaluate the agriculture performance in 2019. This dataset provides the production value at basic prices of agricultural companies per division and per region.

The edition of December 2023 of the dataset "Valori pro capite - Conti e aggregati economici territoriali" (Istituto Nazionale di Statistica, 2023) contains the value added per inhabitant per NUTS 3 territory in 2019.

The dataset "Numero e tipo di unità istituzionali" (Istituto Nazionale di Statistica, 2022) provides the number of all public administration entities per region.

The dataset "Contribuenti e principali categorie di reddito – Reddito delle persone fisiche (Irpef) – comuni" (Istituto Nazionale di Statistica, 2020) provides the total taxable income of physic persons per NUTS 3 territory.

For petroleum – related industries, the refinery distribution at NUTS 3 level and capacity data of AssoCositeri (AssoCostieri, 2022) provides the basis for the definition of division coefficients.

We have considered the December 2023 version of the dataset "Territorial economic accounts and aggregates" (Istituto Nazionale di Statistica, 2023) for calibration purposes. It provides regional value added of industries, regional total final consumption expenditure of households and of public administrations as well as regional total gross fixed capital formation, all at basic prices. The industries in the dataset of regional value added are also classified according to NACE Rev.2 but aggregated into 40 groups. There is value added of industries at NUTS 3 level, but the industries are aggregated into only 15 groups.

4.3 Division of the national IO tables to NUTS 3 level

The activity of section U (NACE Rev.2, ATECO2007) is omitted in the distribution because it is not included in the national IO table.

As described in the section 3.1, the national IO tables must be divided directly at NUTS 3 level, consequently all coefficients should be based on national data.

4.3.1 Definition of regionalization coefficients c_s^r

a). Coefficient of population c_{pop}^r

This coefficient is designed for the division of the activities of division 94, 97, 98 (sequence number 60 and 63) and the final use by non-profit social institutions (equation subscript *ISP*).

The division 94 includes activities of organisations representing interests of special groups or promoting religious, political, cultural, educational or recreational ideas and activities to the public.

The activities of section T (NACE Rev.2, including division 97 and 98) don’t consume any other product as input, the value of their production consists in the value added; their unique product is totally consumed by the families.

Final consumption expenditure of non-profit social institutions serving households (NPIs) consists of expenditure incurred for the direct satisfaction of individual or collective needs by private households or non-profit institutions serving households (such as religious societies, sports and other clubs, political parties, etc.).

Therefore, it is assumed that the local dimension of the above-mentioned industries and consumer is of the same proportion as population (*Pop*) when compared to the corresponding nationwide data:

$$c_s^r = c_{pop}^r = Pop^r / Pop^N \quad , \; s = 60{,}63 \; and \; ISP \qquad (4\text{-}4)$$

b). Coefficient of agriculture c_{agr}^r , $agr = 1, 2, 3$

The coefficient of agriculture is designed for the division of the industries of division 01, 02 and 03. To allocate the regional production values at basic prices of agricultural companies to NUTS 3 territories ($Prod_{agr}^r$), it is assumed that the local share of the regional agricultural production is identical to the local share of the value added at regional level. The value added is the product of the value added per inhabitant ($v^r_{inhabitant}$) and the population.

$$Prod^r_{agr} = Prod^{Reg}_{agr} \times \left(v^r_{total}/v^{Reg}_{total}\right)$$

$$v^r_{total} = v^r_{inhabitant} \times Pop^r \ , \quad v^{Reg}_{total} = \textstyle\sum_{r\in Reg} v^r_{total}$$

$$c^r_s = c^r_{agr} = Prod^r_{agr}/Prod^N_{agr} \ , \ s = agr = 1,2,3 \qquad (4\text{-}5)$$

c). Coefficient of refinery c^r_{oil}

This coefficient, based on the distribution of refineries at NUTS 3 level and their capacity (*Ref.Cap*), is designed for the division of the "Manufacture of coke and refined petroleum products" (division 19, sequence number 10):

$$c^r_s = c^r_{oil} = Ref.Cap^r/Ref.Cap^N \ , \ s = 10 \qquad (4\text{-}6)$$

d). Coefficient of public administration c^r_{pa}

This coefficient is designed for the division of the activities of section O and the final consumption expenditure of public administrations. To allocate the regional total number of all public administration entities to local areas (n^r_{PA}), it is assumed that the local share of the regional public administration entity number is identical to the local share of the regional population:

$$c^r_s = c^r_{pa} = n^r_{PA}/n^N_{PA} \ , \quad n^r_{PA} = n^{Reg}_{PA} \times (Pop^r/Pop^{Reg}), \quad s = 54, PA \qquad (4\text{-}7)$$

e). Coefficient of taxable income c^r_{ti}

This coefficient is designed for the division of final consumption expenditure of households. It is assumed that the households' expenditure is proportional to pre-tax income, at both local (TI^r) and national level (TI^N). Therefore, we get:

$$c^r_s = c^r_{ti} = TI^r/TI^N \ , \ s = FAM \qquad (4\text{-}8)$$

While ISTAT publishes household and public administration final expenditures by COICOP classification at NUTS 2 level (Istituto Nazionale di Statistica, 2023), these data were not incorporated directly into the definition of regionalization coefficient for three reasons: (i) the multiple-multiple correspondence between COICOP and CPA at the 2-digit level introduces allocation ambiguity; (ii) geographic disaggregation to NUTS 3 is not available; and (iii) aggregate totals differ by ~4.5% between the COICOP-based national accounts and the IO supply-use framework, reflecting differences in valuation and coverage. Instead, regional expenditure shares derived from COICOP were applied to the IO-consistent national totals for households and public administrations. This dasymetric approach preserves the accounting consistency of the IO system while leveraging the spatial information contained in the COICOP dataset (Eurostat, 2013; Miller & Blair, 2009, Ch. 4).

While household expenditure patterns may differ between urban and rural sub-areas, the NUTS 3 territorial units employed in this study typically encompass both settlement types. Following Miller & Blair (2009), we treat each NUTS 3 territory as a single analytical zone, thereby internalising intra-territorial heterogeneity within the estimated production–consumption flows. This approach is consistent with the spatial resolution of available statistical sources and the requirements of the structural gravity model.

Households' and public administrations' final consumption expenditure by product group (COICOP) are published by ISTAT only at NUTS 2 level. Following standard non-survey practice (Bonfiglio & Chelli, 2008; Flegg & Tohmo, 2013), we apply these regional shares to NUTS 3 territories proportionally, acknowledging that any spatial bias inherent in the source data is inherited by the estimated local final demand vectors. In the absence of superior disaggregated data, this represents the most consistent approach to maintaining accounting balance between national and sub-national accounts.

f). Coefficients of occupation $c^r_{oc,s}$ and c^r_{oc}

The sectoral occupation coefficient $c^r_{oc,s}$ is designed for the division of industries where no other coefficients are assigned to. The global occupation coefficient c^r_{oc} is for the division of final uses of “Gross fixed capital formation” and “Changes in inventories and valuables”.

While ISTAT publishes territorial economic accounts including gross fixed capital formation (GFCF) at the NUTS 2 level (Istituto Nazionale di Statistica, 2023), these data are classified by industry (NACE) rather than by product (CPA). In the IO tables adopted in this research, final demand components must be consistent with the product classification (CPA 2.1) used in the rows of the Input-Output tables. Directly utilizing the industry-based GFCF data would require a bridge matrix to convert industry investments into product investments. However, due to secondary production, where a single product can be supplied by several industries, the correspondence between NACE and CPA is often "multiple-to-multiple" (Miller & Blair, 2009). This complexity, combined with the need to disaggregate data from NUTS 2 to NUTS 3, introduces significant potential for inconsistency and error in the regionalization process (Oosterhaven, 1984). Consequently, to maintain accounting consistency and spatial detail, the total national final demand for investment products is distributed to local areas using a proxy for local economic activity.

The coefficients of occupation are based on the local share of the employee number (*E*) at national level:

$$c_s^r = \begin{cases} c_{oc,s}^r = E_s^r / E_s^N \quad , \quad s \in [4,9] \cup [11,53] \cup [55,59] \cup [61,62] \\ c_{oc}^r = \sum_s E_s^r / \sum_s E_s^N \quad , \ s = INV, VAR \end{cases} \tag{4-9}$$

g). Coefficient of export $c_{x,m}^r$

Basing on the assumption that local export capacity of a product *m* is proportional to its production capacity of that product, this coefficient represents the local share of the national production of a product *m* and can be calculated only after the regionalization of all productions using the coefficient a), b), c), d) and f):

$$c_{x,m}^r = \sum_s P{\circ}_{ms}^r / \sum_s P{\circ}_{ms}^N = \sum_s (P{\circ}_{ms}^N \times c_s^r) / P{\circ}_m^N$$

$$c_s^r = \begin{cases} c_{pop}^r \ , s = 60{,}63 \\ c_{agr}^r \ , \ s = 1{,}2{,}3 \\ c_{oil}^r \ , \quad s = 10 \\ c_{pa}^r \ , \quad s = 54 \\ c_{oc,s}^r \ , other\ s \end{cases} \tag{4-10}$$

4.3.2 Division of national IO tables data at NUTS 3 level

For the supply side, the value of a generic product *m* produced by industry *s* in the local area *r* is the product of the production value at national level and the correspondent regionalization coefficient, as in the following equation:

$$P{\circ}_{ms}^r = P{\circ}_{ms}^N \times c_s^r \ , \ \ s = 1\ to\ 63 \tag{4-11}$$

The consumption and export of domestic products at national level are calculated by subtracting the values in the table "Imprt11" from corresponding values in the table "Uspb11":

$$\begin{aligned} & Int{\circ}_{ms,Nat}^N = Int{\circ}_{ms,All}^N - Int{\circ}_{ms,For}^N \ , \ \ s = 1\ to\ 63 \\ & F{\circ}_{ms,Nat}^N = F{\circ}_{ms,All}^N - F{\circ}_{ms,For}^N \ , s = FAM, ISP, PA, INV, VAR \\ & X{\circ}_{m,Nat.For}^N = X{\circ}_{m,All.For}^N - X{\circ}_{m,For.For}^N \end{aligned} \tag{4-12}$$

Then we can calculate the local intermediate and final consumptions of domestic / foreign product *m*, as well as the export of foreign product *m* ($Int{\circ}_{ms,Nat}^r$, $Int{\circ}_{ms,For}^r$, $F{\circ}_{ms,Nat}^r$, $F{\circ}_{ms,For}^r$, $X{\circ}_{m,For.For}^r$) using the correspondent regionalization coefficient c_s^r, like the calculation of local production. Same calculation is applied to the taxes minus subsidies on products $T_{s,Use}^r$ and the value added per industry v_s^r . The structure of the result of national data division is shown in Table 4-5.

Table 4-5 Structure of the result of national data division

Local area r	Million € basic prices current prices					
Product	Production / consumption	Industries s= 1 to 63	Total industries	Final users s=FAM,ISP,PA,INV, VAR	Total Final Users	Export abroad
m=1 to 63	Local production	$P^{\circ r}_{ms}$	$\sum$	/	/	/
	consumption of domestic products	$Int^{\circ r}_{ms,Dom}$	$\sum$	$F^{\circ r}_{ms,Dom}$	$\sum$	
	consumption of foreign products	$Int^{\circ r}_{ms,For}$	$\sum$	$F^{\circ r}_{ms,For}$	$\sum$	$X^{\circ r}_{m,For.For}$
Taxes		$T^{r}_{Use,s}$	$\sum$	$T^{r}_{Use,s}$	$\sum$	$T^{r}_{Use,x}$
Value added		v^{r}_{s}	$\sum$	/	/	/

4.3.3 Calibration with Regional Economic Account

To calibrate the divided national data, the value added of the 40 industry groups in the "Territorial economic accounts and aggregates" dataset should be distributed across all 63 industries and local areas, and the total final consumption expenditure of households and public administration must also be distributed across the local territories. The distribution, under the assumptions described in the section 3.1, is based on the same variables used for the definition of regionalization coefficients.

Once the local value added per industry ($\bar{v}^{r}_{s}$), the local total final consumption expenditure of households ($\overline{F^{\circ}}^{r}_{FAM}$) and public administration ($\overline{F^{\circ}}^{r}_{PA}$), the local gross fixed capital formation ($\overline{F^{\circ}}^{r}_{INV}$) are obtained from the "Territorial economic accounts and aggregated" dataset, the calibration of the regionalized IO tables initiates basing on the balances represented by eq. (4-1) and (4-2). It is assumed that the domestic and foreign products have identical consumption tax rates and identical value added percentage. Firstly, the total local consumption of products and taxes as well as the production by the industry s (based on the eq. 4-2) are calculated as following:

$$\begin{aligned} \overline{Int^{\circ}}^{r}_{s,All} &= Int^{\circ r}_{s,All} \times v^{r}_{s} / \bar{v}^{r}_{s} \\ \bar{T}^{r}_{s,Use} &= T^{r}_{s,Use} \times v^{r}_{s} / \bar{v}^{r}_{s} \\ \overline{P^{\circ}}^{r}_{s} &= \overline{Int^{\circ}}^{r}_{s} + \bar{T}^{r}_{s,Use} + \bar{v}^{r}_{s} \end{aligned} \qquad (4\text{-}13)$$

For the production and consumption of each industry, and the expenditure of the three final consumptions (FAM, PA and INV), a matrix is built up, and the bi-proportional apportionment process is applied. As shown in the Table 4-6, each matrix consists of columns that represents every single NUTS 3 territory, and in the last column the correspondent total domestic production or consumption from the national IO table; different products are in rows, and in the last row the calibrated total production or consumption of that industry or final user in the local areas; the previously estimated values are in the cells. For consumptions, it is assumed that there is no preference between the domestic and foreign products.

Table 4-6 Structure of calibration matrix

Industry / final user s (*production: s= 1 to 63; consumption: s= 1 to 63, FAM, PA, INV*)	Local area *r* *r = 1 to 107*	Production / consumption of product at national level (national IO table)
Product m *m = 1 to 63*	$P^{\circ r}_{ms}$ or $Int^{\circ r}_{ms,All}$ or $F^{\circ r}_{ms,All}$	$P^{\circ N}_{ms}$ or $Int^{\circ N}_{ms,All}$ or $F^{\circ N}_{ms,All}$
Production / consumption by industry / final user *s*	$\overline{P^{\circ r}_{s}}$ or $\overline{Int^{\circ r}_{s,All}}$ or $\overline{F^{\circ r}_{s,All}}$	/

Source: author's elaboration

4.4 Estimation of local production-consumption flows

As presented in the section 3.2.1, the definition of technical coefficient depends on the meaning of the numerator. In our case, even though the list of products corresponds to the list of branches of economic activities, a product has more than one manufacturing industry, and an industry has more than one product. Therefore, the value of "the output of sector *m* consumed by sector *s* "is not equal to the value of "the product *m* consumed by sector *s*". We defined the technical coefficient as "the value of product *m* consumed by industry *s* to produce one monetary unit of sectoral output of *s*", taking account of the following reasons:

1. In the national IO tables used in the previous calculations, the production and intermediate uses are reported in the matrix with 63 products in rows and 63 branches of activity in columns; it is not feasible to trace the share of the output of a generic industry consumed by other industries.
2. Since the relation between the industries and the products is not unique and exclusive, in the national symmetrical table "product-product" one cannot identify the consumption of a generic industry that is the denominator of the technical coefficient.
3. Although with the national symmetrical table "industry-industry" one can locate the output of a sector consumed by another and calculate the national technical coefficients national and then estimate the local ones, it is still difficult to convert the "sectoral output" to "product" to calculate the flows of products.

The FLQ method is adopted for its better accuracy to estimate the local self-sufficiency coefficient. Flegg and Tohmo (2013) proposed a regression model to estimate δ based on regional size, import propensity and intermediate input mix. Giving the data constraint at the NUTS 3 level, the model calculations for this study were performed using a uniform $\delta = 0.3$ to ensure data consistency across the 107 territories. This value was selected based on the consensus in the literature available at the time of computation, which identified $\delta \approx 0.3$ as optimal in general for minimizing bias in multipliers (Flegg, et al., 1995) (Flegg & Webber, 1997) (Tohmo, 2004) (Bonfiglio & Chelli, 2008) (Flegg & Tohmo, 2013).

It is worth noting that subsequent to the completion of the model calculations, a very recent study specific to Italy (Socci, et al., 2025) has determined region-specific values of δ to correct data discrepancies with national accounts. Their results indicate that optimal δ values for Italian regions are concentrated in the 0.2-0.4 class though three regions had $\delta > 0.6$, with an average value of 0.35. This independent evidence provides post-doc validation that the uniform value of 0.3 adopted in this study falls within the robust range for the Italian context, despite the inherent sensitivity of the parameter to regional heterogeneity.

Originally, the FLQ measures the relative dimension of the supplier and consumer industry with the sectoral employment. In our case we use the coefficient of export $c_{x,m}^r$ that represents the local production capacity of the product *m*. The coefficient of local self-sufficiency q_{ms}^r is then calculated as:

$$q_{ms}^r = \begin{cases} 1, \ FLQ_{ms}^r \geq 1 \\ FLQ_{ms}^r, otherwise \end{cases} , \ \lambda^r = [log_2(1 + c_{oc}^r)]^{0.3}$$
$$FLQ_{ms}^r = \left(\frac{c_{x,m}^r}{c_s^r}\right) \cdot \lambda^r \ , \ s = 1 \ to \ 63, FAM, ISP, PA, INV, VAR \qquad (4\text{-}14)$$

In eq.(3-10) there are the sub-conditions *m=s* and *m≠s*. In out case, *m* stands for the product meanwhile *s* stands for the sector, as described in the point a) of the paragraph about the “Technical coefficients” in 3.2.1.1; when they have the same value, it only means that the product meets the corresponding (in classification) economic sector.

The intermediate and final consumptions of local products and non-local domestic products are calculated as in the following equation, and the structure of the local IO table has then became as shown in Table 4-7.

$$\begin{aligned} Int^{\circ r}{}_{ms,Loc} &= Int^{\circ r}{}_{ms,Dom} \cdot q_{ms}^r \\ Int^{\circ r}{}_{ms,XP} &= Int^{\circ r}{}_{ms,Dom} \cdot (1 - q_{ms}^r) \end{aligned} \ , s = 1 \ to \ 63$$
$$\begin{aligned} F^{\circ r}{}_{ms,Loc} &= F^{\circ r}{}_{ms,Dom} \cdot q_{ms}^r \\ F^{\circ r}{}_{ms,XP} &= F^{\circ r}{}_{ms,Dom} \cdot (1 - q_{ms}^r) \end{aligned} \ , s = FAM, ISP, PA, INV, VAR \qquad (4\text{-}15)$$

Table 4-7 Structure of local Input-Output table

Territory r	Million € basic prices current prices					
Product	Production / consumption	Industries s= 1 to 63	Total industries	Final users s=FAM,ISP,PA,INV, VAR	Total Final Users	Export abroad
m=1 to 63	Local production	$P^{\circ r}_{ms}$	$\sum$	/	/	/
	consumption of local products	$Int^{\circ r}_{ms,Loc}$	$\sum$	$F^{\circ r}_{ms,Loc}$	$\sum$	
	consumption of non-local domestic products	$Int^{\circ r}_{ms,XP}$	$\sum$	$F^{\circ r}_{ms,XP}$	$\sum$	
	consumption of foreign products	$Int^{\circ r}_{ms,For}$	$\sum$	$F^{\circ r}_{ms,For}$	$\sum$	$X^{\circ r}_{m,For.For}$
Taxes		$T^{r}_{Use,s}$	$\sum$	$T^{r}_{Use,s}$	$\sum$	$T^{r}_{Use,x}$
Value added		v^{r}_{s}	$\sum$	/	/	/

Source: author's elaboration

4.5 Conversion from basic prices to purchase prices

The local productions and consumptions estimated previously are at basic prices, while the gravity model requires input at purchase prices. The domestic and international imports / exports of Italian NUTS 3 territories will be calculated through a "account balancing" process, it is preferable to convert at this stage the so-far-obtained local IO table from basic prices to purchase prices.

Basing on the "uspa19" table and "uspb19" table, the consumption tax rate per product per user is defined as:

$$\tau_{Use,ms} = \begin{cases} \left(Int^{N}_{ms,All} - Int^{\circ N}_{ms,All}\right)/Int^{\circ N}_{ms,All} \ , \ s = 1 \ to \ 63 \\ \left(F^{N}_{ms,All} - F^{\circ N}_{ms,All}\right)/F^{\circ N}_{ms,All} \ , \ s = FAM, ISP, PA, INV, VAR \\ \left(X^{N}_{m,All.For} - X^{\circ N}_{m,All.For}\right)/X^{\circ N}_{m,All.For} \ , s = X \end{cases} \quad (4\text{-}16)$$

Assuming that the consumption tax rate is identical for both domestic and foreign products, one can calculate the tax on consumption of imported products *m*:

$$T^{N}_{Use,m,For} = \sum_{s=1}^{63} Int^{\circ N}_{ms,For} \times \tau_{Use,ms} + \sum_{s=final\ uses} F^{\circ N}_{ms,For} \times \tau_{Use,ms} + X^{\circ N}_{m,For.For} \times \tau_{Use,ms} \quad (4\text{-}17)$$

Basing on the eq. (4-1), for a product *m*, the sum of "commercial margin and transport" and the "taxes minus subsidies on products", of both domestic production and imports on the supply side equals to the sum of the tax on consumption of domestic and foreign product:

$$\Delta^{N}_{m,All} + T^{N}_{Sup,m,All} = T^{N}_{Use,m,Dom} + T^{N}_{Use,m,For} \quad (4\text{-}18)$$

With the eq. (4-3) and (4-17) one can calculate the sum of "commercial margin and transport" and the "taxes minus subsidies on products" of domestic production, denoted by $\Delta T^{N}_{Sup,m,Dom}$:

$$\Delta T^{N}_{Sup,m,Dom} = \Delta^{N}_{m,All} + T^{N}_{Sup,m,All} - T^{N}_{Use,m,For} \quad (4\text{-}19)$$

Then this value is distributed to each supplier industry *s* according to their share of the production of the product *m*:

$$\Delta T^{N}_{Sup,ms,Dom} = \Delta T^{N}_{Sup,m,Dom} \times (P^{\circ N}_{ms} / P^{\circ N}_{m}) \quad (4\text{-}20)$$

Like the consumption tax rate, the production tax rate per product *m* per industry *s* is defined as

$$\tau_{Sup,ms} = (P^{N}_{ms} - P^{\circ N}_{ms}) / P^{\circ N}_{ms} = \Delta T^{N}_{Sup,ms,Dom} / P^{\circ N}_{ms} \quad (4\text{-}21)$$

The local IO tables at basic prices are then converted to purchase prices by multiplying the production with $(1 + \tau_{\mathrm{Sup,ms}})$ and consumptions with $(1 + \tau_{\mathrm{Use},ms})$.

4.6 Estimation of domestic and international imports / exports of Italian NUTS 3 territories

As shown in Table 4-8, it needs to estimate the export abroad of local products $X^{r}_{m,Loc.For}$, the domestic export of local products $X^{r}_{m,Loc.XP}$ and the import of domestic products $I^{r}_{m,XP}$, all at purchase prices, by using the eq. (4-12) and (4-13).

In case where the local production is less than the estimated consumption of local products in the area, the shortfall will be compensated by the domestic import. This means the reduction of the estimated consumption of local products $(Int^{r}_{ms,Loc}, F^{r}_{ms,Loc})$ and increase of the estimated consumption of non-local domestic products $(Int^{r}_{ms,XP}, F^{r}_{ms,XP})$. It is assumed that the local consumption of each industry and final user vary at the same ratio.

Table 4-8 Data for estimation of imports and exports

Territory r	Million € basic prices current prices							
Product	Production / consumption	Industries s= 1 to 63	Final users s=FAM,ISP,PA,INV,VAR	Total	Export abroad (FOB)	Domestic export	Import from abroad (CIF)	Domestic import
m=1 to 63	Local production	P^r_{ms}	/	P^r_m	/	/	/	/
	consumption of local products	$Int^r_{ms,Loc}$	$F^r_{ms,Loc}$	$Int^r_{m,Loc} + F^r_{m,Loc}$	$X^r_{m,Loc.For}$	$X^r_{m,Loc.XP}$	/	$(I^r_{m,XP})$
	consumption of non-local domestic products	$Int^r_{ms,XP}$	$F^r_{ms,XP}$	$Int^r_{m,XP} + F^r_{m,XP}$	/	/	/	$I^r_{m,XP}$
	consumption of foreign products	$Int^r_{ms,For}$	$F^r_{ms,For}$	$Int^r_{m,For} + F^r_{m,For}$	$X^r_{m,For.For}$	/	∑Int+∑F	/

Source: author's elaboration

4.7 Harmonisation of international trade data of Italy with IO systems

The "UNCTAD International Trade and Transport" dataset provides for Italy, 125678 records of international imports, and 212654 records of international exports in 2019. In total 1214 physical commodities (HS 2017, 4 digits) from 206 countries have been imported to Italy, while 1220 physical commodities (HS 2017, 4 digits) have been exported from Italy to 164 countries.

These records are inprimis aggregated according to our zoning system. As result there are 35984 records of international imports, and 49400 records of international exports.

To ensure data consistency, the UNCTAD data must be aligned with the international import / export data in the national IO tables.

First, commodities are mapped from HS17-4 digits to CPA2.1 used in the IO tables (2 digits and 1 letter mixed) via the version 2017 of the Combine Nomenclature classification (CN 2017) (European Union, 2016). The CN system, based on the HS system managed by the World Customs Organisation (WCO), is the main classification of goods used by the European countries. In fact, the CN is an eight-digit coding system, comprising the HS codes with further EU subdivisions and legal notes specifically created to address the needs of the EU.

For simplification, the "classification – digits number" expression will hereafter denote the commodities at the level of the digits number of the classification, e.g., the "HS17-4" will stand for "commodities classified with 4 digits of HS 2017".

The identification of correspondence between HS17-4s and CPA2.1-2s is carried out at the most detailed level to reduce as much as possible the “one-multiple” and “multiple-multiple” cases. According to the correspondence tables published by Eurostat (European Union, 2023) (European Union, 2023), 5387 HS17-6s correspond to 9528 CN17-8s, and 9528 CN17-8s correspond to 1677 CPA 2.1-6s. First, for each HS17-6, we calculated the conversion ratio to CN17-8, namely “%HSCN”, as the reciprocal of the number[4] of the corresponding CN17-8s: e.g., if a HS17-6 corresponds to 3 CN17-8s, then its conversion ratio to each CN17-8 is 33.33%. We get a list with 9528 rows, each row contains the correspondence from one HS17-6 to one CN17-8, the conversion ratio %HSCN, the corresponding CPA2.1-6, as well as the corresponding HS17-4 and CPA2.1-IO. Then these 9528 correspondences are grouped into 1398 “HS17-4 to CPA2.1-IO” pairs with 1222 HS17-4 correspond to 30 CPA2.1-IO, aggregating the %HSCN. The conversion ratio, namely %HSCPA, for each HS17-4 to a CPA2.1-IO is then calculated as the share of their %HSCN in the sum of all %HSCN with the same HS17-4. For example, 0106 of HS corresponds to R01 of CPA with 12 as the sum of %HSCN, and to R03 with 1 as the sum of %HSCN, so the %HSCPA of 0106-R01 is 12/(12+1) = 92.31%, the %HSCPA of 0106-R03 is 1/(12+1) = 7.69%.

Then for each CPA2.1-IO, it is calculated alinement parameters that equal to the value of international import (CIF price in Italy) or export (FOB price in Italy) at purchase prices in the national IO tables divided, accordingly, by the sum of export value from all foreign areas to Italy (FOB price in origin + transport expenditure) or import value from Italy to all foreign areas (FOB price in Italy). It is assumed that the share of each foreign area in the import and export of Italy and the ratio of transport expenditure compared to the commodity cost at FOB price remain unvaried. Consequently, the import / export in terms of CPA2.1-IO of each foreign area with Italy is adjusted according to corresponding alinement parameter. Furthermore, these value variations have been brought to the records in terms of HS17-4, so that the value conversion errors in the commodity-freight conversion are minimized.

This adjustment procedure yields also the value at CIF price in destination area for the international export of Italy, using the same methodology (CIF = FOB + Transport Expenditure) of the dataset. For each CPA2.1-IO, a general (not destination-specific) conversion factor from FOB to CIF prices for the international exports is calculated as CIF value / FOB value. The international exports of Italian NUTS 3 territories are then converted from FOB price to CIF price.

[4] Someone may argue the precision of the conversion ratio defined basing on the number of correspondences, but it is still the best compromise facing to the actual data availability and the complexity of calculation.

Notably, values of gas / petroleum related liquid commodities (2709, 2710 and 2711 of HS17-4) are excluded, as these products fall outside the scope of the present study. In addition, this process does not involve international trade in services.

4.8 Conversion of exchanges in terms of commodities into freight load types

The domestic imports and exports between Italian NUTS 3 territories are in terms of products classified by CPA2.1, while the international imports and exports of Italy with foreign areas are in terms of products classified by HS17. They are to be converted into exchanges in terms of three freight load types: dry bulk, liquid bulk, general cargo.

In the previous section, the correspondence chain "HS 2017 – CN 2017 – CPA 2.1" is applied; it means the CN 2017 can serve as the starting point in this section. The SAMGODS model provides already the correspondence between the NST/R and freight types. The correspondence table "NST/R – CN2007 – CPA2008 – NST2007" (European Union, 2022) and "CN2007 – CN2017" (European Union, 2023) are used to build the correspondence between CN2017 and the freight types. The classifications in these two tables are all at the finest level of detail. The "NST/R – CN2007 – CPA2008 – NST2007" table lists the correspondences among 168 NST/R-3s, 9720 CN07-8s as well as 1741 CPA08-6s.

For simplification purposes, it is assumed that, for each CPA2.1-IO, the freight shares are identical in product for intermediate uses and final uses. This simplification could potentially mask heterogeneities in production structures and import propensities across commodity groups, as different sectors exhibit varying supply chain configurations and trade dependencies. However, given our focus on macro-level freight flow estimation rather than detailed sectoral analysis, this approximation is necessary for computational tractability and practical transport modelling and represents a reasonable trade-off between model complexity and practical applicability.

First, the freight types are added to the "NST/R-CN2007" table so that each of the 9720 CN07-8s and 1741 CPA08-6s is assigned a freight type. Compared to NST/R, the CN2007 offers significantly more detailed classification, thus the freight type of each CN07-8 / CPA08-6 is reviewed to match better the reality.

Since the correspondence between the CPA2.1 at 6 digits level and the CPA2008 at 6 digits level is quite straightforward, one can easily get the correspondence between the CPA2.1 used in the IO tables and the freight load types with their nominal conversion ratio, as shown in Table 4-9. The domestic imports and exports of Italian NUTS 3 territories, derived from the elaborations of IO tables, are then converted to exchanges in terms of three freight types.

Table 4-9 Nominal conversion ratio of products for domestic imports and exports

CPA2.1-IO	Product Name	Dry bulk	Liquid bulk	General Cargo	Services
R01	Products of agriculture, hunting and related services	73.41%	0.58%	23.12%	2.89%
R02	Products of forestry, logging and related services	46.67%	0.00%	40.00%	13.33%
R03	Fish and other fishing products; aquaculture products; support services to fishing	27.27%	0.00%	66.67%	6.06%
RB	Mining and quarrying	78.38%	5.41%	2.70%	13.51%
R10_12	Food products; Beverages; Tobacco products	7.82%	11.11%	65.84%	15.23%
R13_15	Textiles; Wearing apparel; Leather and related products	0.00%	0.59%	84.71%	14.71%
R16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	48.00%	0.00%	34.00%	18.00%
R17	Paper and paper products	7.27%	0.00%	80.00%	12.73%
R18	Printing and reproduction services of recorded media	0.00%	0.00%	6.25%	93.75%
R19	Coke and refined petroleum products	16.67%	75.00%	0.00%	8.33%
R20	Chemicals and chemical products	39.78%	17.74%	33.87%	8.60%
R21	Basic pharmaceutical products and pharmaceutical preparations	31.58%	15.79%	42.11%	10.53%
R22	Rubber and plastic products	2.04%	0.00%	83.67%	14.29%
R23	Other non-metallic mineral products	22.73%	0.00%	46.59%	30.68%
R24	Basic metals	5.88%	0.00%	78.15%	15.97%
R25	Fabricated metal products, except machinery and equipment	0.00%	0.00%	72.29%	27.71%
R26	Computer, electronic and optical products	0.00%	0.00%	88.55%	11.45%
R27	Electrical equipment	0.00%	0.00%	90.57%	9.43%
R28	Machinery and equipment n.e.c.	0.00%	0.00%	90.48%	9.52%
R29	Motor vehicles, trailers and semi-trailers	0.00%	0.00%	77.78%	22.22%
R30	Other transport equipment	0.00%	0.00%	81.03%	18.97%
R31_32	Furniture; Other manufactured goods	0.00%	0.00%	82.29%	17.71%
R33	Repair and installation services of machinery and equipment	0.00%	0.00%	0.00%	100.00%
RD	Electricity, gas, steam and air conditioning	0.00%	9.09%	0.00%	90.91%
R36	Natural water; water treatment and supply services	0.00%	0.00%	25.00%	75.00%
R37_39	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services	18.31%	1.41%	35.21%	45.07%
RF	Constructions and construction works	0.00%	0.00%	6.02%	93.98%
R45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	0.00%	0.00%	0.00%	100.00%
R46	Wholesale trade services, except of motor vehicles and motorcycles	0.00%	0.00%	0.00%	100.00%
R47	Retail trade services, except of motor vehicles and motorcycles	0.00%	0.00%	0.00%	100.00%
R49	Land transport services and transport services via pipelines	0.00%	0.00%	0.00%	100.00%
R50	Water transport services	0.00%	0.00%	0.00%	100.00%
R51	Air transport services	0.00%	0.00%	0.00%	100.00%
R52	Warehousing and support services for transportation	0.00%	0.00%	0.00%	100.00%
R53	Postal and courier services	0.00%	0.00%	0.00%	100.00%
RI	Accommodation and food services	0.00%	0.00%	0.00%	100.00%
R58	Publishing services	0.00%	0.00%	52.00%	48.00%
R59_60	Motion picture, video and television programme production services, sound recording and music publishing; Programming and broadcasting services	0.00%	0.00%	11.11%	88.89%
R61	Telecommunications services	0.00%	0.00%	0.00%	100.00%
R62_63	Computer programming, consultancy and related services; Information services	0.00%	0.00%	9.52%	90.48%

R64	Financial services, except insurance and pension funding	0.00%	0.00%	0.00%	100.00%
R65	Insurance, reinsurance and pension funding services, except compulsory social security	0.00%	0.00%	0.00%	100.00%
R66	Services auxiliary to financial services and insurance services	0.00%	0.00%	0.00%	100.00%
RL	Real estate services	0.00%	0.00%	0.00%	100.00%
R69_70	Legal and accounting services; Services of head offices; management consulting services	0.00%	0.00%	0.00%	100.00%
R71	Architectural and engineering services; technical testing and analysis services	0.00%	0.00%	3.33%	96.67%
R72	Scientific research and development services	0.00%	0.00%	0.00%	100.00%
R73	Advertising and market research services	0.00%	0.00%	0.00%	100.00%
R74_75	Other professional, scientific and technical services; Veterinary services	0.00%	0.00%	10.71%	89.29%
R77	Rental and leasing services	0.00%	0.00%	0.00%	100.00%
R78	Employment services	0.00%	0.00%	0.00%	100.00%
R79	Travel agency, tour operator and other reservation services and related services	0.00%	0.00%	0.00%	100.00%
R80_82	Security and investigation services; Services to buildings and landscape; Office administrative, office support and other business support services	0.00%	0.00%	0.00%	100.00%
R84	Public administration and defence services; compulsory social security services	0.00%	0.00%	0.00%	100.00%
RP	Education services	0.00%	0.00%	0.00%	100.00%
R86	Human health services	0.00%	0.00%	0.00%	100.00%
R87_88	Residential care services; Social work services without accommodation	0.00%	0.00%	0.00%	100.00%
R90_92	Creative, arts and entertainment services; Library, archive, museum and other cultural services; Gambling and betting services	0.00%	0.00%	13.64%	86.36%
R93	Sporting services and amusement and recreation services	0.00%	0.00%	0.00%	100.00%
R94	Services furnished by membership organisations	0.00%	0.00%	0.00%	100.00%
R95	Repair services of computers and personal and household goods	0.00%	0.00%	0.00%	100.00%
R96	Other personal services	0.00%	0.00%	4.76%	95.24%
RT	Services of households as employers; undifferentiated goods and services produced by households for own use	0.00%	0.00%	12.50%	87.50%

Source: author's elaboration

For each CN17-8, the conversion ratio to CN07-8, namely "%CN17CN07", is calculated like in the previous section. Then the conversion ratio to freight types, namely "%CN17Freight", is calculated based on the %CN17CN07, similar to the %HSCPA based on the %HSCN. At this point we have obtained, for each CN17-8 commodity, its share of each freight load type, represented by the ratio %CN17Freight. With the "HS2017-CN2017" correspondence table and the %HSCN calculated in the previous section, the actual conversion ratio of products classified by HS17 at 4 digits level is obtained, as in Table 4-10 (DB Dry Bulk, LB Liquid Bulk, GC General Cargo). The international imports and exports of Italy, derived from the UNCTAD dataset, are then converted to exchanges in terms of three freight types.

Table 4-10 Actual conversion ratio of products for international imports and exports derived from UNCTAD dataset

HS17-4	***DB***	***LB***	***GC***
0101	100%		
0102	100%		
0103	100%		
0104	100%		
0105	100%		

0106	100%		
0201			100%
0202			100%
0203			100%
0204			100%
0205			100%
0206			100%
0207			100%
0208			100%
0209		100%	
0210			100%
0301			100%
0302			100%
0303			100%
0304			100%
0305			100%
0306			100%
0307			100%
0308			100%
0401			100%
0402			100%
0403			100%
0404			100%
0405			100%
0406			100%
0407			100%
0408			100%
0409			100%
0410			100%
0501			100%
0502			100%
0504			100%
0505			100%
0506			100%
0507			100%
0508			100%
0510			100%
0511			100%
0601	17%		83%
0602			100%
0603			100%
0604			100%
0701	100%		
0702	100%		
0703	100%		
0704	100%		
0705	100%		
0706	100%		
0707	100%		
0708	100%		
0709	93%		7%
0710	100%		
0711	100%		
0712	100%		
0713	75%		25%
0714	50%		50%
0801	100%		
0802	100%		
0803	100%		
0804	100%		
0805	100%		
0806	100%		
0807	100%		
0808	100%		

0809	100%		
0810	100%		
0811			100%
0812			100%
0813	100%		
0814			100%
0901			100%
0902			100%
0903			100%
0904			100%
0905			100%
0906			100%
0907			100%
0908			100%
0909			100%
0910			100%
1001	100%		
1002	100%		
1003	100%		
1004	100%		
1005	100%		
1006	100%		
1007	100%		
1008	100%		
1101			100%
1102			100%
1103			100%
1104			100%
1105			100%
1106			100%
1107			100%
1108	100%		
1109	100%		
1201	100%		
1202	100%		
1203	100%		
1204	100%		
1205	100%		
1206	100%		
1207	100%		
1208	100%		
1209	100%		
1210	100%		
1211	100%		
1212	100%		
1213	100%		
1214	100%		
1301			100%
1302			100%
1401			100%
1404			100%
1501			100%
1502			100%
1503		100%	
1504		100%	
1505		100%	
1506		100%	
1507		100%	
1508		100%	
1509		100%	
1510		100%	
1511		100%	
1512		100%	
1513		100%	

1514		100%	
1515		100%	
1516	10%	90%	
1517		38%	63%
1518	17%	83%	
1520		100%	
1521		100%	
1522		100%	
1601			100%
1602			100%
1603			100%
1604			100%
1605			100%
1701	40%		60%
1702			100%
1703			100%
1704			100%
1801			100%
1802			100%
1803			100%
1804			100%
1805			100%
1806			100%
1901			100%
1902			100%
1903			100%
1904			100%
1905			100%
2001			100%
2002			100%
2003			100%
2004			100%
2005			100%
2006			100%
2007			100%
2008			100%
2009			100%
2101			100%
2102			100%
2103			100%
2104			100%
2105			100%
2106			100%
2201			100%
2202			100%
2203			100%
2204			100%
2205			100%
2206			100%
2207			100%
2208			100%
2209			100%
2301			100%
2302			100%
2303			100%
2304			100%
2305			100%
2306			100%
2307			100%
2308			100%
2309			100%
2401			100%
2402			100%
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2501	100%		
2502	100%		
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2509	100%		
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2511	100%		
2512	100%		
2513	100%		
2514	100%		
2515	100%		
2516	100%		
2517	100%		
2518	100%		
2519	100%		
2520	100%		
2521	100%		
2522	100%		
2523	100%		
2524	100%		
2525	100%		
2526	100%		
2528	100%		
2529	100%		
2530	100%		
2601	100%		
2602	100%		
2603	100%		
2604	100%		
2605	100%		
2606	100%		
2607	100%		
2608	100%		
2609	100%		
2610	100%		
2611	100%		
2612	100%		
2613	100%		
2614	100%		
2615	100%		
2616	100%		
2617	100%		
2618	100%		
2619	100%		
2620	100%		
2621	100%		
2701	100%		
2702	100%		
2703	100%		
2704	100%		
2705		100%	
2706		100%	
2707		100%	
2708		100%	
2709		100%	
2710		100%	
2711		100%	
2712		100%	
2713		100%	
2714	100%		

2715		100%	
2716			100%
2801	33%	67%	
2802	100%		
2803	100%		
2804	55%	45%	
2805	90%	10%	
2806		100%	
2807		100%	
2808		100%	
2809	50%	50%	
2810	100%		
2811	21%	79%	
2812	11%	89%	
2813	50%	50%	
2814		100%	
2815	63%	38%	
2816	100%		
2817	100%		
2818	100%		
2819	100%		
2820	100%		
2821	100%		
2822	100%		
2823	100%		
2824	100%		
2825	100%		
2826	100%		
2827	100%		
2828	100%		
2829	100%		
2830	100%		
2831	100%		
2832	100%		
2833	100%		
2834	100%		
2835	100%		
2836	100%		
2837	100%		
2839	100%		
2840	100%		
2841	100%		
2842	100%		
2843	100%		
2844	85%		15%
2845	100%		
2846	100%		
2847	100%		
2849	100%		
2850	100%		
2852	100%		
2853		100%	
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2937	100%		
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2940	100%		
2941	100%		
2942	100%		
3001			100%
3002			100%
3003			100%
3004			100%
3005			100%
3006			100%
3101	100%		
3102	100%		
3103	100%		
3104	100%		
3105	100%		
3201	100%		
3202	100%		
3203	100%		
3204	100%		
3205	100%		
3206	100%		
3207	100%		
3208	100%		
3209	100%		
3210	100%		
3211	100%		
3212	100%		
3213	100%		
3214	100%		
3215	100%		
3301		100%	
3302		100%	
3303		100%	
3304			100%
3305			100%
3306			100%
3307			100%
3401			100%

3402		100%
3403		100%
3404		100%
3405		100%
3406		100%
3407		100%
3501		100%
3502		100%
3503		100%
3504		100%
3505		100%
3506		100%
3507		100%
3601		100%
3602		100%
3603		100%
3604		100%
3605		100%
3606		100%
3701		100%
3702		100%
3703		100%
3704		100%
3705		100%
3706		100%
3707		100%
3801		100%
3802		100%
3803		100%
3804		100%
3805		100%
3806		100%
3807		100%
3808		100%
3809		100%
3810		100%
3811		100%
3812		100%
3813		100%
3814		100%
3815		100%
3816		100%
3817		100%
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3819		100%
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3826		100%
3901	100%	
3902	100%	
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3909	100%	
3910	100%	
3911	100%	
3912	100%	
3913	100%	
3914	100%	
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3916	100%	
3917		100%
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3919		100%
3920		100%
3921		100%
3922		100%
3923		100%
3924		100%
3925		100%
3926		100%
4001		100%
4002		100%
4003		100%
4004		100%
4005		100%
4006		100%
4007		100%
4008		100%
4009		100%
4010		100%
4011		100%
4012		100%
4013		100%
4014		100%
4015		100%
4016		100%
4017		100%
4101		100%
4102		100%
4103		100%
4104		100%
4105		100%
4106		100%
4107		100%
4112		100%
4113		100%
4114		100%
4115		100%
4201		100%
4202		100%
4203		100%
4205		100%
4206		100%
4301		100%
4302		100%
4303		100%
4304		100%
4401	100%	
4402	100%	
4403	100%	
4404	100%	
4405	100%	
4406	100%	
4407	100%	
4408	100%	
4409	100%	
4410	100%	
4411	100%	
4412	100%	
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4415		100%
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4501	100%	
4502	100%	
4503		100%
4504		100%
4601		100%
4602		100%
4701	100%	
4702	100%	
4703	100%	
4704	100%	
4705	100%	
4706	100%	
4707	100%	
4801		100%
4802		100%
4803		100%
4804		100%
4805		100%
4806		100%
4807		100%
4808		100%
4809		100%
4810		100%
4811		100%
4812		100%
4813		100%
4814		100%
4816		100%
4817		100%
4818		100%
4819		100%
4820		100%
4821		100%
4822		100%
4823		100%
4901		100%
4902		100%
4903		100%
4904		100%
4905		100%
4906		100%
4907		100%
4908		100%
4909		100%
4910		100%
4911		100%
5001		100%
5002		100%
5003		100%
5004		100%
5005		100%
5006		100%
5007		100%
5101		100%
5102		100%
5103		100%

5104	100%
5105	100%
5106	100%
5107	100%
5108	100%
5109	100%
5110	100%
5111	100%
5112	100%
5113	100%
5201	100%
5202	100%
5203	100%
5204	100%
5205	100%
5206	100%
5207	100%
5208	100%
5209	100%
5210	100%
5211	100%
5212	100%
5301	100%
5302	100%
5303	100%
5305	100%
5306	100%
5307	100%
5308	100%
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9207	100%	9601	100%	9703	100%
9208	100%	9602	100%	9704	100%
9209	100%	9603	100%	9705	100%
9301	100%	9604	100%	9706	100%
9302	100%	9605	100%		

Source: author's elaboration

Basing on the result of the conversion of the physical products imports and exports data (derived from UNCTAD dataset) and the correspondence chain "HS2017-CN2017-CPA2.1" as well as the conversion ratios, we have calculated the share of each freight type in each CPA2.1 product of import and of export, separately. The international trade in services recorded in the IO tables is not involved, like in the previous data harmonization step. This approach essentially assumed that in the international imports and exports of Italy, all CPA2.1 products which have corresponding trade value in the UNCTAD dataset were only traded in physical form. The result is shown in Table 4-11. The international imports and exports of Italian NUTS 3 territories that are derived from the IO tables are then converted to exchanges in terms of three freight types. It is necessary to carry out the conversion in this way to maintain the consistency with the elaborations based on the UNCTAD dataset.

Table 4-11 Actual conversion ratio for international trade of Italian NUTS 3 territories

CPA 2.1-IO	***International Import***			***International Export***		
	Dry Bulk	***Liquid Bulk***	***General Cargo***	***Dry Bulk***	***Liquid Bulk***	***General Cargo***
R01	77.24%	0.07%	22.69%	78.02%	0.02%	21.96%
R02	88.09%	0.00%	11.91%	48.41%	0.00%	51.59%
R03	1.32%	0.00%	98.68%	0.94%	0.00%	99.06%
RB	6.27%	92.31%	1.42%	82.24%	11.93%	5.82%
R10_12	5.03%	10.82%	84.15%	3.34%	5.11%	91.56%
R13_15	0.00%	0.01%	99.99%	0.00%	0.00%	100.00%
R16	68.22%	0.00%	31.78%	53.71%	0.00%	46.29%
R17	17.39%	0.00%	82.61%	0.60%	0.00%	99.40%
R18	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R19	0.91%	99.09%	0.00%	1.09%	98.91%	0.00%
R20	51.16%	19.89%	28.95%	42.06%	14.41%	43.53%
R21	6.84%	0.95%	92.21%	4.94%	1.78%	93.28%

R22	1.55%	0.00%	98.45%	1.04%	0.00%	98.96%
R23	19.74%	0.08%	80.18%	22.45%	0.15%	77.41%
R24	1.53%	0.00%	98.47%	0.28%	0.00%	99.72%
R25	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R26	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R27	0.04%	0.00%	99.96%	0.02%	0.00%	99.98%
R28	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R29	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R30	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R31_32	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R33	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RD	0.00%	0.18%	99.82%	0.00%	0.41%	99.59%
R36	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R37_39	32.99%	48.92%	18.09%	20.26%	74.41%	5.33%
RF	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R45	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R46	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R47	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R49	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R50	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R51	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R52	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R53	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RI	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R58	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R59_60	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R61	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R62_63	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R64	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R65	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R66	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R69_70	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R71	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
R72	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R73	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R74_75	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R77	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R78	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R79	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R80_82	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R84	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R86	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R87_88	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R90_92	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
R93	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R94	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R95	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
R96	0.00%	0.00%	100.00%	0.00%	0.00%	100.00%
RT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: author's elaboration

The global balancing condition is observed for each freight type:

- the total domestic exports of all Italian NUTS 3 territories equal to the total domestic imports of all Italian NUTS 3 territories.
- the total international exports of all Italian NUTS 3 territories equal to the total imports of all foreign areas from Italy.
- the total international imports of all NUTS 3 territories equal to the total exports of all foreign areas to Italy.

This study has reconstructed, for each of the 107 Italian territories at NUTS 3 level, the table of the local production and use of local / non-local-domestic / foreign products; the structure of the table is shown in Table 4-5. Furthermore, for each of the 107 Italian NUTS 3 territories, it has provided the value at purchase prices of domestic and international imports / exports (both at CIF prices), and for each of the 68 foreign countries / areas the value at CIF prices of international trade with Italy. All these exchange values are then used as input to the structural gravity model.

4.9 Data of the Metropolitan City of Rome

Once built all the local IO tables, for illustrative purposes some data analyses of the Metropolitan City of Rome have been proceeded to derive information on the characteristics of production and consumption. They have identified, in terms of monetary value, the principal goods produced by the NUTS 3 area, those consumed for intermediate use, and those consumed by final users. Notably, the gas and petroleum related products are included.

In this section, the value of exports is not included in the final uses.

In total, the production of the Metropolitan City of Rome has provided physical products and services worth more than 280 billion euro in 2019, yet only about 111 billion are consumed locally within the area. As illustrated in Figure 4-1, the economy of the Metropolitan City of Rome demonstrated significant interdependence with external territories, importing products and services worthy more than 117 billion euro from other Italian territories and approximately 40 billion euro from international sources. This substantial import dependency reveals Rome's position as a consumption hub rather than a self-sufficient production centre.

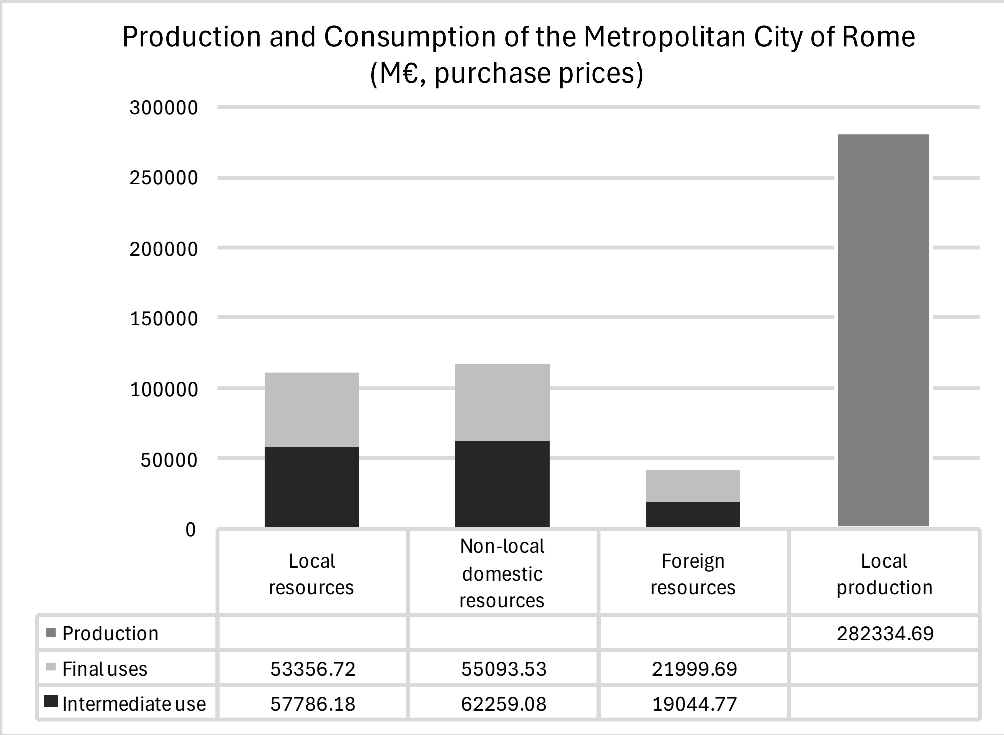

Figure 4-1 Production and consumption of the Metropolitan City of Rome
Source: author's elaboration

Considering the local production and consumption, the first 15 products with highest value of production plus consumption are listed in descending order in Table 4-12. The "x" in the cell indicates that the product is one of the major products of the production / consumption in column. It reveals important structural patterns in Rome's economy that functions primarily as a service-oriented economy. The Metropolitan City of Rome demonstrates comparative advantage in service sectors, particularly real estate, construction, public administration, and business services.

Table 4-12 Products with major production and/or consumption in the Metropolitan City of Rome

Product	***Production***	***Intermediate use***			***Final use***		
		Local Resources	Non-local domestic resources	Foreign resources	Local Resources	non-local domestic resources	Foreign resources
Real estate services	x	x	x		x	x	
Constructions and construction works	x	x	x		x	x	
Public administration and defence services; compulsory social security services	x				x	x	
Electricity, gas, steam and air conditioning	x	x	x				
Legal and accounting services; Services of head offices; management consulting services	x	x	x				
Accommodation and food services	x				x	x	
Human health services	x				x		

Computer programming, consultancy and related services; Information services	x	x			x		
Warehousing and support services for transportation	x	x		x			
Security and investigation services; Services to buildings and landscape; Office administrative, office support and other business support services	x	x					
Food products; Beverages; Tobacco products			x	x	x	x	x
Coke and refined petroleum products			x	x		x	
Textiles; Wearing apparel; Leather and related products						x	x
Land transport services and transport services via pipelines		x	x				
Financial services, except insurance and pension funding		x	x				

Source: author's elaboration

Regarding the local production, as detailed in Table 4-13, the productive structure is dominated by service sectors, with most of the top 10 products / services in terms of value all being service-oriented and collectively accounting for more than 50% of the total local production value. Real estate services alone represent 8.16% of total production, followed by public administration (6.20%), utilities including electricity and gas (5.24%), and healthcare services (5.23%).

Table 4-13 Main productions of the Metropolitan City of Rome

Name	***Value****	***%***
Real estate services	23035.99	8.16%
Public administration and defence services; compulsory social security services	17500.21	6.20%
Electricity, gas, steam and air conditioning	14805.09	5.24%
Human health services	14772.53	5.23%
Legal and accounting services; Services of head offices; management consulting services	14098.69	4.99%
Constructions and construction works	13994.55	4.96%
Accommodation and food services	12671.64	4.49%
Computer programming, consultancy and related services; Information services	12261.02	4.34%
Warehousing and support services for transportation	11999.29	4.25%
Security and investigation services; Services to buildings and landscape; Office administrative, office support and other business support services	11475.12	4.06%
Other 52 products and services	135720.57	48.07%
**Value in Million Euro at purchase prices*		

Source: author's elaboration

Table 4-14 provides valuable insights into Rome's supply chain dependencies for business inputs. The intermediate consumption analysis reveals a dual pattern: local industries primarily consume locally produced services such as business consulting, security services and IT services, while relying significantly on other domestic and foreign resources for physical products. Notably, "Food products, beverages, tobacco products" and "Coke and refined petroleum products" rank among the top 10 non-local domestic and international inputs, indicating critical dependencies on external supply chains for these essential commodities. International imports show even stronger concentration in physical products, with mining products, petroleum derivatives, pharmaceuticals and electronics comprising major import categories. This pattern creates distinct freight flow profiles across different geographical scales: service-oriented intra-metropolitan movements, mixed freight for domestic flows, and predominantly high-value physical goods for international freight.

Table 4-14 Main intermediate uses in the Metropolitan City of Rome

Resources	*Name*	*Value**	*%*
Local resources	Legal and accounting services; Services of head offices; management consulting services	5413.90	9.37%
	Electricity, gas, steam and air conditioning	4710.56	8.15%
	Security and investigation services; Services to buildings and landscape; Office administrative, office support and other business support services	4449.49	7.70%
	Warehousing and support services for transportation	3650.72	6.32%
	Financial services, except insurance and pension funding	3088.58	5.34%
	Computer programming, consultancy and related services; Information services	3016.42	5.22%
	Land transport services and transport services via pipelines	2926.26	5.06%
	Real estate services	2681.50	4.64%
	Telecommunications services	2006.76	3.47%
	Constructions and construction works	1969.39	3.41%
	Other 51	23872.60	41.31%
Non-local domestic resources	Real estate services	3878.63	6.23%
	Electricity, gas, steam and air conditioning	3792.03	6.09%
	Legal and accounting services; Services of head offices; management consulting services	3222.76	5.18%
	Architectural and engineering services; technical testing and analysis services	2414.13	3.88%
	Food products; Beverages; Tobacco products	2344.52	3.77%
	Land transport services and transport services via pipelines	2196.29	3.53%
	Constructions and construction works	2093.77	3.36%
	Coke and refined petroleum products	2052.33	3.30%
	Financial services, except insurance and pension funding	1917.82	3.08%
	Services auxiliary to financial services and insurance services	1826.66	2.93%
	Other 51	36520.15	58.66%
Foreign resources	Mining and quarrying	2225.57	11.69%
	Coke and refined petroleum products	1387.17	7.28%
	Basic pharmaceutical products and pharmaceutical preparations	1191.45	6.26%
	Computer, electronic and optical products	1172.19	6.15%
	Chemicals and chemical products	1083.51	5.69%
	Rental and leasing services	794.64	4.17%
	Food products; Beverages; Tobacco products	656.79	3.45%
	Machinery and equipment n.e.c.	632.62	3.32%
	Warehousing and support services for transportation	548.83	2.88%
	Furniture; Other manufactured goods	526.20	2.76%
	Other 49	8825.79	46.34%
**Value in Million Euro at purchase prices*			

Source: author's elaboration

Table 4-15 demonstrates that Rome residents primarily consume locally-produced services related to daily life, such as health, education, public administration, entertainment and insurance, while depending on external sources for physical goods. The significant imports of fuel, textiles, machineries, furniture and appliance for housing from both national and international sources highlight Rome's role as a major consumption centre.

Table 4-15 Main final uses (without export abroad) in the Metropolitan City of Rome

Resources	Name	Value*	%
Local resources	Real estate services	7062.56	13.24%
	Human health services	6436.53	12.06%
	Constructions and construction works	4796.99	8.99%
	Accommodation and food services	4730.34	8.87%
	Education services	3556.10	6.66%
	Public administration and defence services; compulsory social security services	3049.66	5.72%
	Computer programming, consultancy and related services; Information services	1815.17	3.40%
	Creative, arts and entertainment services; Library, archive, museum and other cultural services; Gambling and betting services	1799.76	3.37%
	Food products; Beverages; Tobacco products	1750.86	3.28%
	Insurance, reinsurance and pension funding services, except compulsory social security	1669.13	3.13%
	Other 49	16689.62	31.28%
Non-local domestic resources	Real estate services	8254.72	14.98%
	Food products; Beverages; Tobacco products	7788.27	14.14%
	Constructions and construction works	5933.69	10.77%
	Accommodation and food services	4534.49	8.23%
	Public administration and defence services; compulsory social security services	2944.72	5.34%
	Coke and refined petroleum products	2856.82	5.19%
	Products of agriculture, hunting and related services	2501.74	4.54%
	Textiles; Wearing apparel; Leather and related products	2165.42	3.93%
	Machinery and equipment n.e.c.	1721.32	3.12%
	Furniture; Other manufactured goods	1653.48	3.00%
	Other 45	14738.85	26.75%
Foreign resources	Textiles; Wearing apparel; Leather and related products	3696.32	16.80%
	Motor vehicles, trailers and semi-trailers	3302.17	15.01%
	Computer, electronic and optical products	2614.62	11.88%
	Food products; Beverages; Tobacco products	2362.78	10.74%
	Furniture; Other manufactured goods	1431.23	6.51%
	Machinery and equipment n.e.c.	1179.13	5.36%
	Basic pharmaceutical products and pharmaceutical preparations	1035.53	4.71%
	Mining and quarrying	982.47	4.47%
	Electrical equipment	826.87	3.76%
	Products of agriculture, hunting and related services	750.23	3.41%
	Other 23	3818.33	17.36%

**Value in Million Euro at purchase prices*

Source: author's elaboration

This service-intensive economic structure has important implications for freight transport planning, as these sectors generate different freight profiles compared to manufacturing economies. While service sectors typically generate less volume-intensive freight flows, they often require higher-value, time-sensitive deliveries with specific handling requirements.

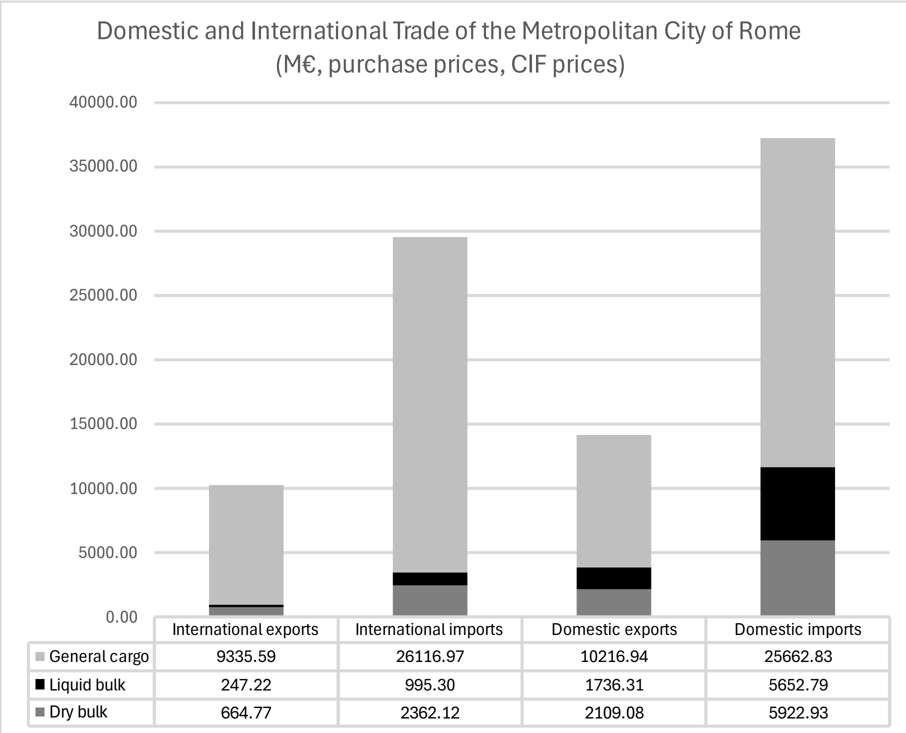

Figure 4-2 Domestic and international trade of the Metropolitan City of Rome
Source: author's elaboration

Regarding inter-territorial trade patterns, Figure 4-2 demonstrates that general cargo constitutes the predominant freight category in the exchange flows of the Metropolitan City of Rome, which aligns with economic theory as general cargo typically embodies higher value-added processes compared to bulk commodities. This distribution reflects Rome's economic specialization in manufactured goods, pharmaceuticals, electronics, and other high-value products that characterize the metropolitan economy's competitive advantage. The data explicitly excludes petroleum and gas-related products from these trade statistics, as these commodities fall outside the current research framework.

The analysis of freight types in Table 4-16 and Table 4-17 reveals important commodity-specific trade patterns. Chemical products, pharmaceutical products, and food products dominate international imports and exports by each freight type of the Metropolitan City of Rome. Besides, the international imports and exports of general cargo feature high-value manufactured goods, such as electronics and transport equipment.

It should be noted that, although certain product is named by "service", in the classification system it includes also the material with which the service works.

Table 4-16 Main physical products per freight type exported abroad from the Metropolitan City of Rome

Freight	*Product*	*Value**	*%*
Dry bulk	Chemicals and chemical products	402.51	60.55%
	Basic pharmaceutical products and pharmaceutical preparations	77.82	11.71%
	Mining and quarrying	72.81	10.95%

	Other non-metallic mineral products	47.63	7.16%
	Food products; Beverages; Tobacco products	27.42	4.12%
	Other 9	36.60	5.51%
Liquid bulk	Chemicals and chemical products	137.94	55.80%
	Food products; Beverages; Tobacco products	41.95	16.97%
	Basic pharmaceutical products and pharmaceutical preparations	28.02	11.33%
	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services	24.36	9.85%
	Mining and quarrying	10.56	4.27%
	Other 5	4.39	1.78%
General cargo	Basic pharmaceutical products and pharmaceutical preparations	1469.33	15.74%
	Computer, electronic and optical products	1183.39	12.68%
	Other transport equipment	765.56	8.20%
	Food products; Beverages; Tobacco products	752.20	8.06%
	Machinery and equipment n.e.c.	693.87	7.43%
	Other 23	4471.25	47.89%
*Value in Million Euro at CIF prices, purchase prices			

Source: author's elaboration

Table 4-17 Main physical products per freight type imported from abroad in the Metropolitan City of Rome

Freight	***Product***	***Value****	***%***
Dry bulk	Chemicals and chemical products	910.68	38.55%
	Products of agriculture, hunting and related services	804.21	34.05%
	Basic pharmaceutical products and pharmaceutical preparations	173.07	7.33%
	Food products; Beverages; Tobacco products	152.25	6.45%
	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	150.26	6.36%
	Other 10	171.64	7.27%
Liquid bulk	Chemicals and chemical products	354.07	35.57%
	Food products; Beverages; Tobacco products	327.28	32.88%
	Mining and quarrying	227.98	22.91%
	Coke and refined petroleum products	38.00	3.82%
	Basic pharmaceutical products and pharmaceutical preparations	24.15	2.43%
	Other 5	23.81	2.39%
General cargo	Textiles; Wearing apparel; Leather and related products	3921.35	15.01%
	Computer, electronic and optical products	3809.47	14.59%
	Motor vehicles, trailers and semi-trailers	3532.58	13.53%
	Food products; Beverages; Tobacco products	2545.13	9.75%
	Basic pharmaceutical products and pharmaceutical preparations	2334.85	8.94%
	Other 23	9973.61	38.19%
**Value in Million Euro at CIF prices, purchase prices*			

Source: author's elaboration

Errore. L'autoriferimento non è valido per un segnalibro. and Table 4-19 show patterns of the domestic trade of Rome. Food and pharmaceutical products and their related products such as agricultural and hunting products and chemical products dominate the trade of Rome with other Italian NUTS 3 territories. The waste services rank in top 5 dry bulk products both in the domestic imports and exports of Rome. This means that Rome not only processes waste from other territories but also sends its waste out for processing.

Table 4-18 Main physical products per freight type exported from the Metropolitan City of Rome to other Italian NUTS 3 territories

Freight	Product	Value*	%
Dry bulk	Mining and quarrying	638.67	30.28%
	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services	461.76	21.89%
	Basic pharmaceutical products and pharmaceutical preparations	336.85	15.97%
	Chemicals and chemical products	246.75	11.70%
	Food products; Beverages; Tobacco products	190.98	9.06%
	Other 7	234.08	11.10%
Liquid bulk	Electricity, gas, steam and air conditioning	917.12	52.82%
	Food products; Beverages; Tobacco products	271.39	15.63%
	Coke and refined petroleum products	187.16	10.78%
	Basic pharmaceutical products and pharmaceutical preparations	168.43	9.70%
	Chemicals and chemical products	110.04	6.34%
	Other 3	82.18	4.73%
General cargo	Food products; Beverages; Tobacco products	1608.24	15.74%
	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services	887.99	8.69%
	Creative, arts and entertainment services; Library, archive, museum and other cultural services; Gambling and betting services	887.43	8.69%
	Publishing services	735.16	7.20%
	Computer programming, consultancy and related services; Information services	644.64	6.31%
	Other 25	5453.47	53.38%
**Value in Million Euro at purchase prices*			

Source: author's elaboration

Table 4-19 Main physical products per freight type imported in the Metropolitan City of Rome from other Italian NUTS 3 territories

Freight	Product	Value*	%
Dry bulk	Products of agriculture, hunting and related services	2168.87	36.62%
	Coke and refined petroleum products	818.19	13.81%
	Food products; Beverages; Tobacco products	792.28	13.38%
	Chemicals and chemical products	460.76	7.78%
	Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services	388.21	6.55%
	Other 9	1294.63	21.86%
Liquid bulk	Coke and refined petroleum products	3681.86	65.13%
	Food products; Beverages; Tobacco products	1125.86	19.92%
	Electricity, gas, steam and air conditioning	421.66	7.46%
	Chemicals and chemical products	205.47	3.63%
	Basic pharmaceutical products and pharmaceutical preparations	135.64	2.40%
	Other 4	82.28	1.46%
General cargo	Food products; Beverages; Tobacco products	6671.79	26.00%
	Textiles; Wearing apparel; Leather and related products	2166.29	8.44%
	Machinery and equipment n.e.c.	2116.06	8.25%

	Furniture; Other manufactured goods	1978.82	7.71%
	Fabricated metal products, except machinery and equipment	1685.01	6.57%
	Other 27	11044.87	43.04%
**Value in Million Euro at purchase prices*			

Source: author's elaboration

The Metropolitan City of Rome is an example of a specialised service-oriented economy with complex dependencies for physical goods. The metropolitan area generates significant economic output through knowledge-intensive sectors while importing essential physical products. This economic configuration creates both advantages in productivity and vulnerabilities through supply chain dependencies, particularly for critical commodities like energy, food, and pharmaceuticals. Rome's competitive strengths in pharmaceutical production, digital services, and specialized business services represent strategic advantages.

4.10 Exploratory Validation and Plausibility Checks

While the proposed methodology guarantees accounting consistency between local and national Input-Output tables by construction, empirical validation against independent trade or freight flow data remains an important step for assessing external credibility (de Jong, et al., 2013) (Tavasszy & de Jong, 2014). However, it is important to clarify the conceptual scope of the outputs generated in this study and the appropriate stage for validation within the freight modelling chain.

4.10.1 Conceptual Distinction: Production-Consumption Flows vs. Transport OD Flows

The outputs of this research represent Production-Consumption (P-C) flows: the monetary value of goods produced in one territory and consumed (as intermediate or final use) in another, regardless of the physical transport path. These represent economic origin-destination relationships. By contrast, observed freight statistics, such as those published by ISTAT[5], represent Transport Origin-Destination (OD) flows: the physical tonnage or tonne-kilometres of goods moving between locations after accounting for modal choice, consolidation, trans-shipment, empty runs, and network assignment.

This study addresses the Generation/Attraction step in the classic 4-step freight demand modelling framework. Validation against transport statistics would be conceptually appropriate only after the subsequent steps—Distribution (gravity model), Modal/Chain Choice, and Network Assignment—have been completed, as these steps transform

[5] https://esploradati.istat.it/databrowser/

economic P-C flows into physical transport OD flows. Direct comparison at the P-C stage would therefore conflate modelling stages and could lead to misleading conclusions about the accuracy of the economic regionalization.

4.10.2 Data Constraints at NUTS 3 Level

A further practical constraint is the scarcity of disaggregated trade data at the NUTS 3 and 2 level in Italy, particularly when calibration is required across 63 CPA product/service categories. While aggregate freight statistics by mode and broad commodity group are available nationally, their spatial and product disaggregation is insufficient to enable product-by-product, territory-by-territory validation of the estimated P-C matrices. This data limitation is, in fact, one of the primary motivations for adopting the non-survey methodology presented here.

4.10.3 Internal Consistency Checks

In light of these conceptual and data constraints, several exploratory checks were performed to assess the plausibility of the results:

- Accounting Balances: The model enforces three fundamental balancing conditions: (a) for each product and territory, total supply equals total use; (b) the sum of domestic exports across Italian NUTS 3 territories equals the sum of domestic imports; (c) the sum of international exports equals the sum of imports reported by foreign partners (after harmonisation via UNCTAD data). These constraints eliminate structural imbalances that often plague purely survey-based or gravity-only approaches.
- Face Validity through Economic Patterns: The results for the Metropolitan City of Rome (Section 3.9) illustrate face validity. The estimated production structure—dominated by services such as real estate, public administration, and business consulting—aligns with Rome's known economic profile as a service-oriented capital area. Similarly, import dependency for physical goods (e.g., food products, petroleum derivatives, machinery) is consistent with the metropolitan area's role as a consumption hub.
- Sensitivity to Key Parameters: A limited sensitivity analysis on the FLQ parameter δ (re-estimating with $\delta = 0.25$ and $\delta = 0.35$) yielded variations in total inter-regional trade estimates of less than ±8% at the national aggregate level, suggesting that aggregate patterns are relatively stable within the empirically supported range of δ values (Bonfiglio & Chelli, 2008).

These exploratory checks, while not a substitute for validation against independent freight flow data at the transport OD stage, provide initial evidence that the model outputs are economically plausible and internally coherent.

5 CONCLUSION

The analysis of economy is necessary for freight transport and logistics planning; such analysis needs usually a large dimension and detailed dataset that are often unavailable at NUTS 3 levels. In the freight transport field, the persistent heterogeneity of data sources, inconsistency in reporting standards, and practical difficulties in data collection present significant methodological challenges. The non-survey methods with relatively lower data requirement offer a viable pathway to overcome these persistent problems while maintaining analytical rigor. Based on the data published by national institute of statistics and implementing Flegg's Location Quotients, this study has drawn a comprehensive picture of the economic conditions for each of the 107 NUTS 3 territories in Italy. Furthermore, it has systematically provided the monetary values of imports and exports between each Italian NUTS 3 zones and with 68 foreign zones, gathering input data for the structural gravity model to estimate the spatial distribution of trade flows.

In contrast to the survey-based methods that often suffer from sampling biases and response fatigue, this top-down methodology guarantees by nature the accounting balances between the national and estimated local Input-Output tables, preserving macroeconomic consistency while delivering subnational detail. In the context of the scientific debate on regional modelling, this study demonstrates the feasibility of using non-survey techniques for comprehensive national coverage at the NUTS 3 level, challenging the assumption that such detail requires survey-based data. A key original contribution of this research is the strategic integration of non-survey regionalization techniques with spatial interaction modelling. By employing FLQ to estimate intra-regional self-sufficiency prior to the gravity model, the framework overcomes the lack of calibrated Origin-Destination data at the NUTS 3 level that is a common barrier in freight transport planning. This sequential approach combines the accounting consistency of Input-Output analysis with the spatial sensitivity of gravity models, offering a robust solution for disaggregated freight demand estimation where survey data is prohibitive.

The modular structure of this approach allows researchers to easily modify the parameters and algorithms at each computational step without disrupting the entire framework. Specifically, the integration of freight-type conversion before distribution modelling represents a novel methodological adaptation that aligns economic accounts with physical transport requirements, reducing complexity while maintaining accuracy. Although some may question certain technical aspects in this methodology, such as the conversion between different product classification systems, the conversion approach implemented in this project is carefully derived from balancing model complexity and practical accuracy based on available data constraints; when more detailed data becomes accessible, we can seamlessly replace specific conversion rules with enhanced ones without having to reconstruct the entire methodology. Another example is the optimal value of δ in the application of Flegg's Location Quotients: future iterations could benefit from region-specific calibration of δ when new empirical evidence emerges, such as the specific study of regional trade pattern in Italy mentioned in section 4.4. For simplification purpose in this project, the imports and exports are estimated assuming direct flows without intermediate transitions via other local areas. However, the estimation process is inherently flexible and can integrate specialized models that specifically address multistage trade dynamics.

By establishing a replicable framework grounded in official statistics rather than costly primary data collection, this research contributes to more evidence-based freight mobility planning across Italy's diverse local economies. Ultimately, this approach provides transport policymakers with a dynamic analytical tool capable of evaluating how economic shifts or policy interventions might reshape the freight transport demand, thereby supporting more efficient freight transport management and policy making.

Finally, it is important to acknowledge a limitation regarding empirical validation. As emphasized in the freight modelling literature (Tavasszy & de Jong, 2014) (de Jong, et al., 2013), non-survey models benefit greatly from comparison with independent traffic or trade statistics. In this study, two factors limited a comprehensive external validation at the Production-Consumption flow stage: (1) the conceptual distinction between economic P-C flows (estimated here) and physical transport OD flows (captured by observed freight statistics), which implies that validation against transport data would be appropriate only after the Distribution, Modal Choice, and Assignment steps of the freight modelling chain; and (2) the scarcity of publicly available, disaggregated trade data at the NUTS 3 level across 63 CPA product categories. The exploratory checks presented in Section 3.10 offer initial plausibility evidence, but future research should prioritize the integration of this framework into a complete 4-step freight demand model, enabling validation at the transport OD stage against ISTAT freight statistics or emerging data sources such as mobile phone data for freight vehicle tracking, customs microdata, or harmonized European freight statistics.

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