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Multi-Criteria Decision Analysis Methods in Mobility Scenario Building and Non-Survey Methods in Freight Transportation Planning

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CONTENTS

ABSTRACT

One of the fundamental activities in transportation planning is forecasting. The present thesis has aimed to develop and test advanced methodologies in the areas of (i) **scenario building** and (ii) **freight transport demand modelling**.

Scenario building plays a key role in forecasting. In real world, numerous factors have an influence on the transport system. Factors fall into different domains, among the others demographics, economy, and energy. Factors can be characterised according to trend and impact on the transport system. The construction of scenarios is based on these factors. The selection of scenario variables from these factors has been the first aim of the research presented here. We have collected experts' judgements on the importance and trend uncertainty of factors by an online survey performed within the activities of the European project OPTIMISM of the Seventh Framework Programme. Then, the Multiple Criteria Decision Analysis (MCDA) methods ELECTRE I and II have been applied with the aim of selecting the most important and trend-uncertain factors. The combination of the expert-based online survey and the MCDA has allowed to identify the factors that can be selected as scenario variables. The product of this part of the research is relevant to planning studies, in particular those that are carried out at national and regional levels.

As to **freight transport demand modelling**, we have carried out, for a real case, a structured analysis of the production and consumption components of the economy of a region. The economy is of interest for the transport planner as it is the key determinant of freight transport demand. Due to the complexity of data and their linkages, as well as the difficulties of data gathering, methods of "non-survey" type are frequently used, thanks to their moderate requirement of data resources and "standardized" analysis process. We have applied Input-Output modelling, Location Quotients methods and a Bi-Proportional model to the case of the Lazio region. The activities have been performed within the PRMTL project (Piano Regionale Mobilità, Trasporti e Logistica della regione Lazio). Based on data provided by ISTAT, we have succeeded to draw a picture of the production and consumption levels of all the municipalities in the Lazio region, and of the trade flows of products among the twenty Italian regions. The analysis that has been performed provides the basis for the estimation of the impacts on freight traffic flows of changes in the economy, once the coupling of the data and modelling system developed with traffic data is accomplished (traffic data are available from the European project ETISplus - European Transport policy Information System).

1 MULTIPLE CRITERIA DECISION ANALYSIS METHODS IN BUILDING MOBILITY SCENARIOS

1.1 Introduction

The scenario building is a tool for transportation analysis and strategy making. It tends to present the effect of the potential variation of key-factors in the future and help the decision makers to gain a foresight containing several scenarios. Different from the methods that tend to offer a precise prediction basing on the current and historical data, the application of scenario building can underline the different key-factors of the transportation strategy planning and offer more options.

In our research of transportation planning, the "exploratory scenarios" approach is adopted. It builds realisable future scenarios of mobility basing on the past and present trends of the factors of passenger transport system. Although the scenarios seem trend-driven, there are still elements that can shape the future. This approach assumes that the human choices and actions can shape the future, and the uncertainty of various factors of the system may cause deviation. Therefore, the scenario building involves both rational analysis and subjective judgements basing on evidence/literature knowledge, expertise from experts and some creativity (Mietzner & Reger, 2005). To map in the scenario building a "possibility space" formed by the variation of key-factors, we should select two factors that have the most important impact and uncertain trend as the variables of scenarios, as shown in Figure 1-1.

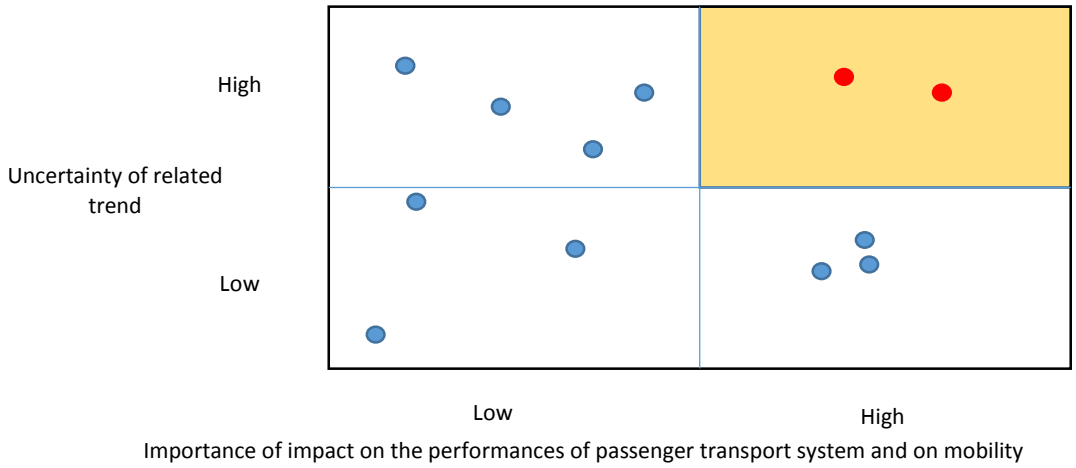

Figure 1-1 Selection of scenario variables

In the precedent research, we have identified a list of factors of the passenger transport system, and have carried out an online survey aiming to collect the experts' opinion about the factors in terms of their importance and the uncertainty of their trend. This paper focuses on the selection of two most important and uncertain factors as the scenario variables basing on the result of the online survey.

As an alternative to the traditional methods, the multi-criteria decision-analysis (MCDA) shows a great interest in such a selection process that concerns a decision-making in a multiple criteria

context. The decision/solution should fulfil a set of criteria or should achieve as many objectives as possible simultaneously. The process of MCDA could be defined as a process for choosing the best/most preferred solution by evaluating their performance in terms of criteria or their achievement with respect to the different objectives.

In this part, the section 2 presents briefly several wild-used MCDA methods, and provides a comparison from the point of view of one who would know some information about various MCDA methods before choosing the method to apply. The section 3 presents in detail the ELECTRE I and II methods. The section 4 presents the result of the online survey and the application of the ELECTRE I and II methods in the selection of variables of mobility scenarios. The section 5 summaries conclusion of the application of the ELECTRE methods in the selection of mobility scenario variables.

1.2 MCDA Methods

The MCDA is designed to structure and solve decisions and planning problems involving multiple criteria. Such criteria may be qualitative or quantitative with different measurement unit, even some of them might be in conflict with the others (Zionts, 1979). It is not possible to obtain a unique optimal solution to a multi-criteria problem without taking into account the information of the decision-maker (DM)'s preference.

Various MCDA methods are developed since 1950s when this area of study has initiated the recent cycle of development (Köksalan, et al., 2011). In this paper, we have reviewed several wildly used methods involving hierarchical, utility, outranking or geometric approaches.

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analysing complex decisions. The decision problem is firstly decomposed into a hierarchy of sub-problems which are easier to understand and can be analysed independently. One proceeds the evaluation of alternatives by comparing every pair of them with respect to their impact on a "father element" in the hierarchy (i.e. on the criteria); this process involves the human judgements - the decision maker's preference – as the essence for AHP (Saaty, 2008). In the fundamental scale for pairwise comparisons, numerical values are assigned to measure the strength of preference in a comparison. The DM should evaluate the performance difference between alternatives and assign to the comparison the corresponding value in the scale. Thusly, AHP allows the comparison between diverse even incommensurable elements, and can derive a numerical priority for each alternative on each criterion. The weight of criteria is also derived by the pairwise comparison of their importance to the DM in the matrix. Then the global priority of each decision alternative is calculated by adding up the products of multiplying the numerical priority and the weight of criteria respectively as the basis of the final choice.

The Multi-Attribute Utility Theory (MAUT) is a mathematically modelled technique for aiding the decision process under multiple criteria/objectives where it is difficult to compare these criteria/objectives quantitatively. It provides a framework in which multiple objectives and uncertainty can be combined in decision making (Kailiponi, 2010) (Keeney & Raiffa, 1993). For each of the criteria/objectives a single utility function (generally an exponential function) is established basing on the best/worst performance of alternatives and the DM's equivalence of

preference. This function connects the performance of one alternative in terms of a criterion/objective with the corresponding utility to the DM. Then the multi-utility function is to be built basing on the single utility functions, by using the additive model or the multiplicative model or both (Vincke, 1992) (Dyer, 2005) .

The ELECTRE (ELimination Et Choix Traduisant la REalté Elimination and choice expressing the reality) is a family of methods designed for problematic of choosing, ranking and sorting. The fundamental element is the outranking relation between two alternatives. The validation of such a relation between two alternatives requires supports from enough arguments (i.e. the comparison between the performances of two alternatives in terms of criteria) and no essential opposition from the other arguments. The ELECTRE methods include two steps: building the outranking relation and exploiting it with regard to the chosen statement of the problem (Vincke, 1992). The ELECTRE I and II methods concern problems involving only true criteria, meanwhile the ELECTRE III has introduced the pseudo-criteria. The true criteria are the criteria on which if alternative "*a*" has better performance than "*b*", no matter how minor is this advantage, "*a*" is preferred to "*b*" in terms of the criteria. Meanwhile, in order to consider the imprecision, uncertainty or indetermination, the pseudo criteria involve two thresholds (indifference threshold and preference threshold) to categorise the performance difference between alternatives into three states (indifference, weak preference and strong preference) (Roy, 1991) (Takeda, 2001) (Vincke, 1992). The ELECTRE IV method builds the outranking relation based upon the pseudo-criteria by counting the number of criteria in favour or in opposition, without weighting the criteria.

The Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) aims to build a valued outranking relation basing on the pairwise comparison of alternatives. Its principle is similar to that of ELECTRE III, but it involves concepts and parameters that have physical (or economic) interpretation and easily understandable by the DM (Vincke, 1992). The DM should define a preference function that reflects his preference basing on the performance difference between the alternatives in terms of a criterion. For each pair of alternatives, one multiplies the preference with the weight of the criterion; then all products in terms of all criteria are added up to derive the preference index of this pair of alternatives. The outranking index of one alternative is the quotient of the sum of its preference indices against all other alternatives divided by the number of other alternatives. At last, one obtains the ordering basing on that index, by considering different conditions (partial ordering in PROMETHEE I, complete ordering in PROMETHEE II) (Brans & Mareschal, 2005).

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. The DM weights the criteria. The performance of alternatives in terms of criteria should be normalised and multiplied by the weights of criteria respectively. The positive/negative ideal solution can be derived by selecting the best/worst value of all alternatives' performance on each of the criteria. The distance is then measured in Euclidean metric distance (Mela, et al., 2012) (Caterino, et al., 2009) (Opricovic & Tzeng, 2004).

The comparative analysis of these methods is summarised in Table 1-1.

Table 1-1 Comparative analysis of MCDA Methods

	AHP	MAUT	ELECTRE	PROMETHEE	TOPSIS
Core Process	1.Pairwise comparison matrices of: - alternatives on each criterion - criteria to weight them 2.Compute the priority of every alternative	1. Establish single utility function (maximal/minimal performance, equivalence of preference); 2. Build multiple utility function (additive, multiplicative, mix)	1. Define the weight of criteria 2. Pairwise comparison to compute concordance/discordance index 3. Check such indices with related threshold 4. Build outranking relations 5. Exploit outranking order	1. Define preference function and indifference / preference thresholds on each criterion 2. Compute the pairwise preference index by adding up the preference multiplied by the weight of criteria, on all criteria 3. Derive outranking index	1. Compute the normalised weighted performance of alternatives 2. Obtain the best / worst ideal alternative 3. Compute the geometric Euclidean distance between alternatives and the best/worst ideal ones. 4. Derive the closeness
Compensatory	Yes	Yes	No	No	Yes
Parameters required	Fundamental scale for pairwise comparison, Assignment of the value in the scale to the pairwise comparison	Equivalence level on each criterion	Weight of criteria, concordance and discordance thresholds	Weight of criteria, preference function, indifference and preference thresholds,	Weight of criteria
Numeric value of performance	No	Yes	Yes	Yes	Yes
Normalisation of data	No	No	ELECTRE I Yes	No	Yes
Final result	Global Hierarchy	Global ordering	ELECTRE I subset of alternatives ELETRE II, III, IV partial pre-order	PROMETHEE I partial ordering PROMETHEE II complete ordering	Global ordering

Compensatory

Generally, depend on whether the criteria are compensatory or not, these methods could be categorised into two groups. By saying "the criteria are compensatory", we mean that when evaluate the performance of one alternative in terms of different criteria, and the gain on one criterion can compensate the loss on another. The AHP, MAUT and TOPSIS proceed the selection by evaluating the global performance or utility of the alternatives, meanwhile ELECTRE and PROMETHEE separate the gain and the loss of the alternatives in performance with respect to criteria. Therefore, the AHP, MAUT and TOPSIS are compensatory, while the ELECTRE and PROMETHEE are not compensatory.

Parameters required

All these methods base on the DM's preference or the criteria's importance to him. The AHP requires the DM to establish at the very beginning the fundamental scale for the pairwise comparison to express his idea about the deviation between two elements (either criteria's importance or alternatives' performance), and to assign the corresponding value in the scale to the comparison. The MAUT requires the DM to set up the equivalence level in terms of each criterion at which the alternatives are indifferent to him. The methods of ELECTRE family need the DM to define the weight of criteria and the thresholds of concordance and discordance to express his limit with respect to the support for/opposition against the outranking relation statement between two alternatives. Other than the weight of criteria, the PROMETHEE demands

the DM to define, with respect to the deviation of the performance between two alternatives on one criterion, the minimal level of strong preference and maximal level of indifference, as well as the preference function between these two levels and the weight of criteria. The TOPSIS requires the DM to weight the criteria.

Necessity of numeric value of performance

The AHP valuates the alternatives basing on the fundamental scale for pairwise comparison and the human judgements; thusly it does not need numeric value. Meanwhile the MAUT requires the numeric performance value to establish the utility function, the ELECTRE and PROMETHEE build the outranking relation checking the deviation between alternatives' performances, and the TOPSIS uses the numeric value of performance to measure the geometric distance between alternatives.

Normalisation of data

The AHP valuates the alternative by the human judgement and the corresponding value in the fundamental scale, so it does not require the normalisation of data. The MAUT contains already the single utility building process in terms of each criterion; the utility range is between [0, 1]. Only the ELECTRE I involves an inter-criteria comparison of the deviation of alternatives' performance to compute the discordance index, it requires thusly the normalisation of data. In the PROMETHEE, instead, the outranking relation is established based on the preference function in terms of each criterion; consequently no normalisation of data is required. The TOPSIS involves the measurement of geometric distance between alternatives in the unique space, so the data should be normalised.

It cannot be told which method is better than others in the absolute sense. The selection of the MCDA method depends on the structure of the problematic and the particularity in each case. Here we have not summed the typical case in which one MCDA method is suitable, because the preference and the interpretation of the problematic vary case by case, and the computation of parameters/indicators is not difficult any more with the help of specified software.

1.3 ELECTRE I and II Methods

The ELECTRE methodology is designed to deal with cases of multi-criteria decision. According to (Figueira, et al., 2005), these cases may have at least one of the following characters:

1. The scale of evaluation is not suitable for the comparison of differences between the performances of actions.
2. The criteria are quite heterogeneous that make it difficult to aggregate all of them in a unique and common scale.
3. It is not acceptable to compensate the loss on a given criterion by a gain on another. Therefore, the use of non-compensatory aggregation procedures is required.
4. In case that the accumulation of several tiny differences of evaluation becomes significant, the discrimination thresholds (indifference and preference) are required to build "*a preference structure with a comprehensive intransitive indifference binary relation"*.

We have adopted the methods of ELECTRE I & II, because our problematic can be interpreted as "to select the subset of best alternatives" (ELECTRE I), or "to rank the alternatives and take the first two" (ELECTRE II). Furthermore, these two methods are suitable for cases if the simplicity is required and it is meaningful to consider a precise limit in terms of the support/opposition (Roy, 1991). The third point is in the selection of scenario variables, we considered the inter-criteria compensation as not appropriate, thusly the selection methods basing directly on the mean or other statistical indicators are out of consideration. At last, our criteria are true criteria: the factors are indifferent in terms of one criterion only when their performance is the same.

Basing on the pairwise comparison between alternatives, ELECTRE methods build the binary outranking relation "*S"* to model the preference between two alternatives. When the alternative "*a*" is at least as good as "*b*", it is marked as "*aSb*". The preference between two alternatives could be: the dominance, the indifference, and the incomparability. The following 4 cases resume the passible result:

- *aSb* and not *bSa*, i.e., *aPb* (*a* is strictly preferred to *b*, or *a* dominates *b*).
- *bSa* and not aSb, i.e., *bPa* (*b* is strictly preferred to *a*, or *a* is dominated by *b*).
- *aSb* and *bSa*, i.e., *aIb* (*a* is indifferent to *b*).
- Not *aSb* and not *bSa*, i.e., *aRb* (*a* is incomparable to *b*).

To note that ELECTRE does not follow the axiom of transitivity: among the alternatives *a*, *b*, *c*, it cannot get the statement "*aSc*" with already known statements "*aSb*" and "*bSc*"; the only way to judge the outranking relation between *a* and *c* is the comparison between them.

To proceed such comparisons, it requires a set of criteria on which all alternatives are evaluated; each criterion should be weighted, and the result of the evaluation should be quantitative.

ELECTRE methods introduce two important indices: Concordance and Discordance. The Concordance index represents how strongly the performances of alternatives on criteria support the outranking relation between two alternatives, and the Discordance index tells the opposition against to that relation. The principle is that the outranking relation between two alternatives will be confirmed if the support is strong (high score of concordance index) and the opposition is weak (low score of discordance index).

We should recall that the ELECTRE methods exhibit a high possibility of obtaining intransitive result and Condorcet Paradox because they do not need to fulfil the notion of transitivity (Figueira & Roy, 2009).

1.3.1 ELECTRE I

The ELECTRE I method is used in choice problematics in a multi-criteria decision-making process. It aims to figure out the subset of the best solution(s) in the concrete, multiple criteria, real-world problem (Figueira, et al., 2005). Among all the ELECTRE methods, ELECTRE I requires the less parameters and offers a simple and understandable solution to the decision maker.

The concordance index *C* indicates on how many criteria, represented by the weight of criteria,

the alternative "*a*" has a better performance than alternative "*b*". For every pair of factors, there is $C(aSb)+C(bSa)=1, a \neq b$.

The concordance index is defined as:

$$C(aSb)=\frac{\sum_j \omega_j}{\sum \omega},\ j: g_j(a) \geq g_j(b) \qquad (1\text{-}1)$$

$g_j(x)$: the evaluation of alternative *x* on criterion *j*;

ω_j : the weight of criterion *j* ,usually defined by the decision maker;

$\sum \omega$: the sum of the weights of all criteria; usually equals to 1.

As shown in the equation above, the concordance is indeed the sum of the weights associated to the criteria that are in favour of the statement "*aSb = a* is at least as good as *b*".

The discordance index, defined by eq.(1-2), indicates the strength of the opposition against the statement "*aSb*" in terms of the factors' performances on criteria. The calculation is independent of concordance. One pair of factors could have a high concordance value, but also a considerable discordance value.

$$D(aSb)=\begin{cases} 0, & if\ no\ g_j(b) > g_j(a) \\ \frac{1}{d}\max_k \{g_k(b)-g_k(a)\}, & k: g_k(a) < g_k(b) \end{cases} \qquad (1\text{-}2)$$

The dominator *d* is the maximal difference across alternatives between performance on the criteria *k* selected by the numerator (Roy, 1968)[1] (Botti & Peypoch, 2013).

To validate the statement "*aSb*", two conditions should be fulfilled:

- $C(aSb) \geq C^*$: the Concordance index *C(aSb)* should be greater than a given level *C** (concordance threshold) to ensure a sufficient majority of criteria supporting the outranking relation. The value of *C** could be defined by the decision maker, it usually falls within the range $\left[0.5,\ 1-\min_j \omega_j\right]$. The threshold of concordance shows the thought that only the considerably better performance could be taken into account. Any concordance index that falls under this threshold will be ignored.
- $D(aSb) \leq D^*$: the Discordance index *D(aSb)* should not surpass a given level *D** to

[1] The definition of the dominator d in the reference is "l'écart maximum qui existe entre les échelons extremes d'une meme échelle"

ensure that no result of the comparison in terms of criteria opposes the outranking relation too strongly. The value of *D** could also be defined by the decision maker.

This framework defines the binary relation between every two factors. In order to select the best compromise alternative(s) it involves the graph kernel concept (Figueira, et al., 2005) (Vincke, 1992). In this concept, all factors and their relation are converted into a graph where factors are represented as vertices, the statement "*aSb*" is represented as an arc from vertex *a* to vertex *b* (Roy, 1991). The exploitation of the outranking relation between factors aims to find out the kernel of the graph that has only arcs initiating towards outside the kernel but neither arcs entering nor arcs between factors inside, as defined by:

$$\begin{cases} \forall b \in A \setminus N,\ \exists a \in N:\ aSb \\ \forall a, c \in N:\ not\, aSc,\ nor\ cSa \end{cases} \qquad (1\text{-}3)$$

The factors in the subset *N* should be incomparable between each other, and they should not be outranked; the alternatives outside *N* are outranked by at least one alternative in *N*. Consequently, the alternatives in *N* could dominate (*P*) or be incomparable with the alternatives out *N*; the preference between the alternatives not in *N* could be any one of the cases listed above (dominate, dominated, indifferent and incomparable).

1.3.2 ELECTRE II

The ELECTRE II is designed for the ranking problematic (Figueira, et al., 2005) (Vincke, 1992). It also uses the concordance and discordance index to determine the outranking relation between two factors. Based on the ELECTRE I, it introduces a two-level outranking relation between actions: the strong outranking relation S^F and the weak outranking relation S^f.

First, according to the factors' performance in terms of a criterion *j*, noted as "$g_j(x)$", three sets are defined as:

$$J^+ = \left\{ j : g_j(a) > g_j(b) \right\},\ J^= = \left\{ j : g_j(a) = g_j(b) \right\},\ J^- = \left\{ j : g_j(a) < g_j(b) \right\}$$

The concordance index is defined as the same as in ELECTRE I (see eq.(1-1)). Meanwhile the discordance index in ELECTRE II refers to the deviation of factor's performance in terms of each criterion – that is to say, for every pair of factors, the value of discordance index varies, seen in

$$D_j(aSb) = g_j(b) - g_j(a),\ j \in J^- \qquad (1\text{-}4)$$

Since there are two levels of outranking relation, more thresholds in concordance and discordance are consequently introduced to distinguish the strength of the outranking relation. The number of thresholds introduced may vary, depending on the decision maker and analyst.

Roy et al (Figueira, et al., 2005) have defined the conditions to validate the outranking relation using two concordance thresholds ($C^+ > C^-$) and per criterion one discordance threshold:

$$aS^F b \ \textit{iff} \begin{cases} C(aSb) \geq C^+ \\ C(aSb) \geq C(bSa) \\ D_j(aSb) \leq D_j,\ j \in J^- \end{cases} \qquad aS^f b \ \textit{iff} \begin{cases} C(aSb) \geq C^- \\ C(aSb) \geq C(bSa) \\ D_j(aSb) \leq D_j,\ j \in J^- \end{cases} \qquad \textit{(1-5)}$$

Note that the second concordance condition is $C(aSb) \geq C(bSa)$; according to the definition of concordance (see (1-1)), it can be interpreted as $\sum_{j \in \{J^+, J^=\}} \omega_j \geq \sum_{j \in \{J^-, J^=\}} \omega_j \leftrightarrow \sum_{j \in J^+} \omega_j \geq \sum_{j \in J^-} \omega_j$ with $\sum \omega = 1$. This concordance condition is also found in (Duckstein & Gershon, 1983) (Armaghan & Renaud, 2012) (Norese, 2002).

According to (Vincke, 1992) the outranking condition are:

$$aS^F b \ \textit{iff} \begin{cases} C(aSb) \geq C^+ \\ \sum_{j \in J^+} \omega_j > \sum_{j \in J^-} \omega_j \\ D_j(aSb) \leq D_j,\ j \in J^- \end{cases} \qquad aS^f b \ \textit{iff} \begin{cases} C(aSb) \geq C^- \\ \sum_{j \in J^+} \omega_j > \sum_{j \in J^-} \omega_j \\ D_j(aSb) \leq D_j,\ j \in J^- \end{cases}$$

Comparing to the definition of (1-5) above mentioned, the second condition of concordance does not take into account the cases in which $\sum_{j \in J^+} \omega_j = \sum_{j \in J^-} \omega_j$. In our case, we have adopted the condition defined by (1-5).

As for the discordance threshold, the differences from that of ELECTRE I are:

1. It needs to be defined for each criterion, meanwhile in ELECTRE I there is only one threshold for all;
2. It becomes a threshold of maximal acceptable deviation between alternative *a* and *b* on a certain criterion. Meanwhile in ELECTRE I the discordance threshold is the maximal acceptable proportion with the maximal difference between alternative *a* and *b* as the numerator, and the maximal difference across all actions on that very criterion selected by the numerator as the denominator.

Different from the ELECTRE I, the exploitation process of ELECTRE II aims to build a partial pre-order of as many as possible alternatives. The exploitation process is:

1. Calculate the concordance and discordance index for every pair of alternatives.
2. Define the concordance thresholds and the discordance thresholds and establish the outranking relation between each pair of alternatives (S^F S^f or not).
3. Build the descending pre-order from the best alternative to the worst examining the number of alternatives by which one alternative is outranked: the less the better. As described by (Vincke, 1992) and (Norese, 2002) , the number of strong outranking relation S^F should be examined first to establish a rough descending ranking, then the weak outranking relation S^f would be checked out to precise the ranking in the part of the rough ranking where the alternatives have identical order.

4. Build the ascending pre-order from the worst alternative to the best by examining the number of alternatives that one alternative outranks: the more the better.
5. Build the so-called "partial pre-order" resulting from the intersection of the descending and ascending pre-orders (Figueira, et al., 2005) (Norese, 2002) (Wang & Triantaphyllou, 2008) (Armaghan & Renaud, 2012):
   - Alternative *a* outranks *b* if and only if *a* outranks *b* in both pre-orders, or in one pre-order a outranks *b* and in another they are in the same class;
   - Alternatives *a* and *b* are indifferent if and only if they are in the same class in both pre-orders.
   - Alternative *a* and *b* are incomparable if *a* outranks *b* in one pre-order and *b* outranks *a* in another.

The final step is the most problematic because in general the descending and ascending pre-order are not the same. It has been pointed out that the final partial pre-order can be obtained only by drawing in graph (Norese, 2002).

1.4 Online survey and Application of ELECTRE I&II

1.4.1 The Online Survey

In the research of transportation planning, the future mobility scenarios are to be built to assess the impacts of transport strategies on passenger transport system. According to the adopted "exploratory scenarios" approach, these future scenarios will base on the past and present trends of the factors of the passenger transport system; they will differ along 2 variables. Therefore, it leads to the identification of the variables of scenarios. We have carried out an online survey, collaborating with the EU project OPTIMISM, to investigate the experts' opinion with respect to the importance of the impact and the uncertainty of the related trend of various factors of passenger transport system.

The questionnaire contains 46 factors grouped in 10 topic areas. On each factor, the experts should choose one grade from "Not at all important/uncertain" to "extremely important / completely uncertain" respectively. At the end of each category, experts can also express their opinion on any factor not listed in the questionnaire and value its importance and uncertainty of the related trend.

In total, 131 experts have finished the questionnaire. To analyse the responses and perform calculations, we have assigned scores to the importance and uncertainty of the related trend according to the value showed in Table 1-2 (Delle Site, et al., 2013). The factors mentioned by experts at the end of each category are covered somehow by the 46 factors.

Table 1-2 Assignment of scores to the degrees of importance/uncertainty

Degree of importance	Degree of trend uncertainty	Score
Not at all important	Not at all uncertain	1
Slightly important	Slightly uncertain	2
Moderately important	Moderately uncertain	3
Very important	Very uncertain	4
Extremely important	Completely uncertain	5

The average value, as well as the standard deviation of the 131 experts' response in terms of importance/uncertainty of each factor are calculated, as listed in Table 1-3 (Delle Site, et al., 2013). For every factor, there are 4 parameters in terms of "importance of the factor in the passenger transport system" and "uncertainty of the related trend of the factor": the average value represents the general idea of these 131 experts in terms of the two criteria, while the standard deviation demonstrates how dispersed are the idea of these experts.

Table 1-3 Result of the online survey[2]

		Original dataset				**Standard score normalization**			
	max-min	1.36	0.47	1.55	0.55	3.76	4,77	5,13	5,17
	Average	3.77	0.91	2.76	0.98	0.00	0.00	0.00	0.00
	Standard deviation	0.36	0.10	0.30	0.11	1.00	1.00	1.00	1.00
Influential area	Factor	Av.im	Sd.im	Av.un	Sd.un	Av.im	Sd.im	Av.un	Sd.un
Demographics and social developments	Ageing society	3.96	0.83	1.60	0.77	0.52	-0.82	-3.82	-1.95
	Fertility (rate of birth affects population figures)	3.07	1.05	2.15	0.82	-1.94	1.42	-2.02	-1.50
	Migration (immigrants and emigrants affect population figures)	3.37	0.97	2.88	0.99	-1.11	0.63	0.41	0.04
	Level of income inequality	3.65	0.97	2.67	0.98	-0.34	0.60	-0.31	0.03
	Unemployment	3.66	0.91	2.91	1.07	-0.32	-0.06	0.48	0.82
	Flexibilisation of labour (varying working hours, teleworking, temporary vs. permanent employments, fulltime vs. part-time job)	3.85	0.91	2.81	1.00	0.22	0.02	0.16	0.15
	Changes in household structures (size and composition of households)	3.32	0.94	2.60	0.94	-1.25	0.28	-0.51	-0.38
Spatial structure	Urbanisation (rapid and massive growth of, as well as migration to, cities)	4,19	0.81	2.07	0.84	1.15	-1.01	-2.28	-1.29
	Urban sprawl (spreading of urban development into areas adjoining the city borders)	4,31	0.75	2.26	0.87	1.49	-1.60	-1.64	-1.06
	Growth of megacities (development of large metropolitan areas)	4,10	0.85	2.30	0.85	0.90	-0.57	-1.51	-1.22
Attitudes	Attitudes towards technology innovation (people willing to use innovative technologies)	3.63	0.91	2.65	0.95	-0.41	0.00	-0.37	-0.27
	Attitudes towards time and speed (more, or less, hectic life styles affect the required level of performance of transport systems, driving behaviour, etc.)	3.85	0.89	2.68	1.00	0.22	-0.19	-0.25	0.15
	Attitudes towards environmental concerns	3.82	0.94	2.77	1.00	0.12	0.33	0.02	0.22
Economy	GDP development	3.94	0.87	3.16	1.06	0.45	-0.42	1.31	0.78
	Geographic distribution of activities / trade (e.g. Relocation of production plants)	4,23	0.73	2.78	1.07	1.27	-1.82	0.05	0.86
	Share of service sector in GDP	3.50	0.85	2.54	0.89	-0.76	-0.60	-0.74	-0.88
	Share of e-commerce in total trade	3.27	0.92	2.87	0.98	-1.40	0.12	0.37	-0.01
Institutional and Political Factors	EU enlargement	3.06	1.04	2.87	1.09	-1.97	1.31	0.38	0.99
	Citizen participation in policy/decision making	3.27	1.16	2.94	1.03	-1.39	2.52	0.58	0.42
	Cohesion and structural policies developments (both at the EU and national level)	3.50	1.05	3.00	0.99	-0.77	1.40	0.80	0.11

[2] In the table, "Av" stands for "Average", "Sd" for "Standard Deviation", "im" for "Importance of the factor", "un" for "uncertainty of the related trend of the factor".

Table 1-3 Result of the online survey (continue)

Globalisation	Multipolarisation of the world (the existence of different poles with trade agreements)	3.50	0.93	2.78	1.06	-0.77	0.21	0.07	0.70
	Worldwide redistribution of income	3.63	1.01	3.09	1.13	-0.39	0.97	1.08	1.37
	Shortage of resources and energy, and risk of conflicts	4,30	0.91	2.66	1.32	1.45	-0.03	-0.31	3.21
Energy and Environment	Implementation of sustainable development principles	4,15	0.90	2.98	1.07	1.03	-0.10	0.75	0.83
	Share of renewable energy	3.89	1.00	2.92	1.00	0.33	0.89	0.52	0.22
	Demand for energy	4,21	0.82	2.37	1.07	1.19	-0.95	-1.27	0.79
	Energy prices	4,42	0.69	2.98	1.24	1.79	-2.24	0.75	2.38
ICT for Society and Economy	ICT R&D expenditures	3.50	1.03	2.84	0.82	-0.75	1.25	0.27	-1.47
	ICT Technological development and innovation	3.87	0.92	2.76	0.95	0.27	0.09	0.00	-0.24
	ICT The impact that these technologies may have on the way of life	3.98	0.83	2.98	0.97	0.58	-0.80	0.74	-0.12
	ICT Market uptake and diffusion of technologies	3.80	0.82	3.08	0.96	0.08	-0.89	1.06	-0.16
Vehicle Technologies	VT R&D expenditures	3.79	0.87	2.85	0.86	0.04	-0.39	0.30	-1.17
	VT Technological development and innovation	3.95	0.83	2.76	0.90	0.48	-0.80	0.00	-0.76
	VT The impact that these technologies may have on the way of life	3.87	0.90	2.96	0.98	0.26	-0.15	0.67	-0.05
	VT Market uptake and diffusion of technologies	3.91	0.85	3.06	0.85	0.39	-0.63	0.98	-1.21
Transport Policy and Planning	Implementation and governments' support of sustainable mobility policies	4,30	0.73	2.95	0.97	1.45	-1.83	0.62	-0.09
	Institutional structures (integration of spatial planning, urban planning, transport planning and economic policies, and coordination of plans at different institutional and geographical levels)	4,35	0.81	3.05	1.00	1.60	-1.00	0.95	0.17
	TEN-T (Trans-European Transport Network) policy	3.37	0.92	2.67	0.86	-1.11	0.09	-0.30	-1.09
	Opening of transport markets to competition	3.19	1.10	2.79	0.93	-1.60	1.92	0.09	-0.46
	Lack of financial resources for infrastructure investments	3.95	0.91	2.64	1.02	0.50	0.03	-0.39	0.38
	Innovative instruments for funding transport infrastructure and services (e.g. Public Private Partnerships, special purpose tax, value capture)	3.40	1.06	3.04	0.93	-1.02	1.52	0.93	-0.51
	Pricing (e.g. for parking and motorways) and charges (e.g. for congestion)	4,06	0.88	2.71	0.99	0.80	-0.33	-0.16	0.12
	Internalisation of externalities (e.g. carbon taxes)	4,10	0.88	3.11	1.13	0.91	-0.34	1.17	1.36
	Subsidies and incentives (e.g. vehicle scrapping schemes)	3.40	0.91	2.97	0.91	-1.03	-0.04	0.69	-0.69
	Enforcement of traffic law	3.38	1.03	2.51	0.91	-1.09	1.17	-0.82	-0.66
	New mobility concepts (e.g. car sharing)	3.74	0.99	2.91	1.11	-0.08	0.81	0.51	1.17

It is difficult to select the factors comparing in the statistic way their score of "importance of the factor" or "uncertainty of the related trend", since we consider the inter-criteria compensation as unsuitable. In the diagram, as shown in Figure 1-2, almost all factors are below the diagonal line that represents the same score of importance and trend uncertainty. The "Importance" and "Uncertainty" are the major criteria meanwhile the two "Standard deviation" are relatively less important. In the following data analysis, we have proceed the analysis in two conditions: one with only two major criteria, the other with all of four criteria.

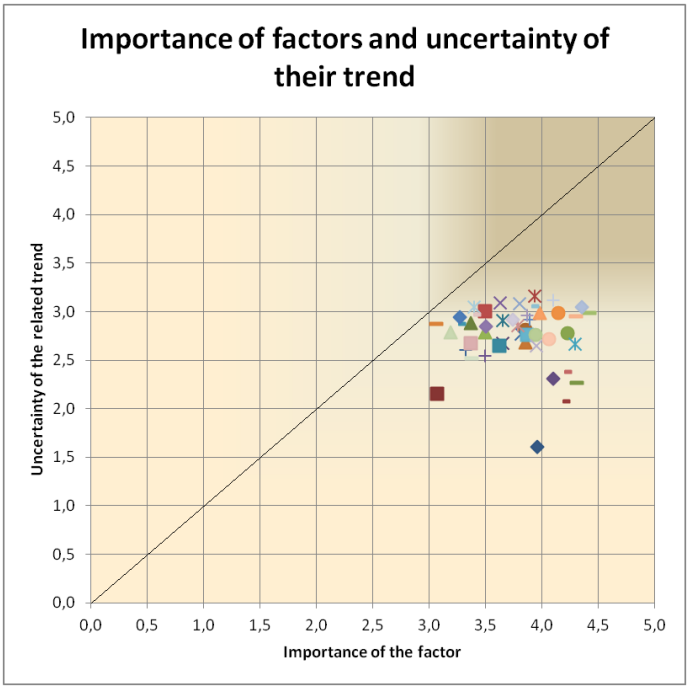

Figure 1-2 Importance of factors and uncertainty of their trend

1.4.2 Application of ELECTRE methods

In the application of ELECTRE I and II, the criteria of importance and uncertainty are ascending criteria, meaning "higher score is better than lower one"; the criteria of the standard deviations are descending criteria, meaning "lower score is better than higher one".

1.4.2.1 Definition of the weight for criteria

Both ELECTRE I and II need to assign to each criterion a weight in order to calculate the concordance index. J.Figueira and B.Roy have introduced a revised Simos' approach to define the weight of criteria (Figueira & Roy, 2002) :

1. Arrange the criteria from the least to the most important. If some criteria have the same importance, a sub-set of these criteria is established. In our research, we consider that the average value of factors' importance and related-trend uncertainty are more important than the standard deviation, that is *{Sd.im, Sd.un} < {Av.im, Av.un}.*
2. Put white card(s) between consecutive criteria to indicate the difference of their importance. More white cards between two criteria means a greater difference between the two criteria's importance. In our case, two white cards are inserted between the subsets of average value and of standard deviation.
3. Numerate the position of each criterion and the white cards. For those criteria with same importance, numerate them however with consecutive number. Then, the non-normalized weight of criteria is the number of their position. For those with the same importance, use the average value of their number.
4. Add up the position of criteria (excluding the position of white card). The normalized weight of each criterion is equal to their non-normalized weight divided by the

aforementioned sum.

Table 1-4 shows the procedure for defining the weight of criteria of the OPTIMISM dataset.

Table 1-4 Definition of criteria's weight

Subset with equal importance	Number of criteria	Position	Non-normalized weight	Normalized weight
{Sd.im, Sd.un}	2	1, 2	(1+2)/2=1.5	1.5/14=0.1
2 White cards	2	(3, 4)	…	
{Av.im, Av.un}	2	5, 6	(5+6)/2=5.5	5.5/14=0.4
Total	6	14		

Therefore, the weights of criteria are: $\{\omega_{av.im}, \omega_{sd.im}, \omega_{av.un}, \omega_{sd.un}\} = \{0.4, 0.1, 0.4, 0.1\}$

In case that only 2 criteria are considered (average importance and trend uncertainty), their weight is of 0.5: $\{\omega_{av.im}, \omega_{av.un}\} = \{0.5,\ 0.5\}$

Generally, ELECTRE II method is very robust (or insensitive) to the weight of criteria (Duckstein & Gershon, 1983).

1.4.2.2 Normalization of data

As shown in the Table 1-3, the importance and related-trend uncertainty of factors have the 1-to-5 scale; meanwhile the standard deviation does not have this scale. Before applying the ELECTRE methods, we have normalized the data using the standard-score normalisation rule defined by:

$$x^* = (x_j - \mu) / \sigma \qquad \mu : \text{mean} \quad \sigma : \text{standard deviation} \tag{1-6}$$

The data are normalised respectively in terms of average importance and its standard deviation, average uncertainty of related trend and its standard deviation, with the mean of 0, and the standard deviation of 1.414, as shown in Table 1-3.

We have adopted the standard-score normalization for the following motives:

1. The calculation of discordance index in ELECTRE I requires the homogeneity of the scales of criteria because it involves the inter-criteria comparison of the performance difference.
2. The normalized data as well as their subtraction follow a normal distribution, with respect to each criterion. This property is very useful for the definition of the discordance thresholds in ELECTRE II.

The normal distribution is illustrated in Figure 1-3.

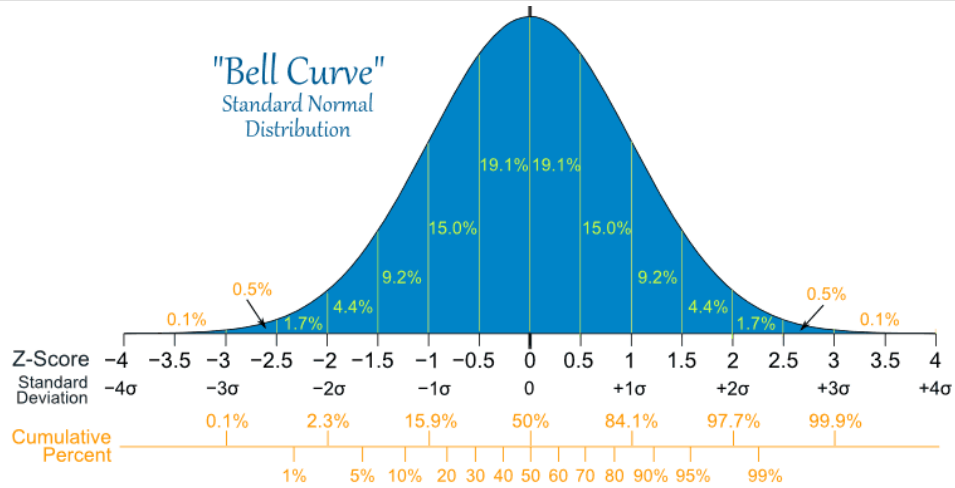

Figure 1-3 Normal Distribution

(Source: http://www.mathsisfun.com/data/images/normal-distrubution-large.gif)

1.4.2.3 Application of ELECTRE I

The exploitation of ELECTRE I, as defined in eq.(1-3), may lead to a subset that contains too many factors, or a unique kernel that contains all factors. In order to avoid this inconvenience we have modified the procedure of the exploitation. Instead of drawing the graph and looking into the arcs and vertices, we have examined the preference between every pair of factors: *aPb (a is preferred to b, or a dominates b), aIb (a is indifferent with b)* and *aRb (a and b are incomparable)*.

The rules of selection are:

1. factor *a* is better than *b* if *a* dominates more other factors and both *a* and *b* are dominated by the same number of other factors;
2. factor *a* is better than *b* if *a* is dominated by less other factors and both *a* and *b* dominate the same number of other factors;
3. the dominance over other factors weights more, i.e., *a* is better than *b* when, compared to *b*, *a* dominates *x* more factors but also dominated by *x* more factors.

Two Criteria Case

The weight of each criterion is 0.5. The concordance and discordance index of each pair of factors are calculated. For concordance indices, the mean is 0.51, standard deviation is 0.36; for discordance indices, the mean is 0.22, standard deviation is 0.23.

According to the definition of concordance index, the possible concordance values are {0, 0.5, 1} standing for the different combinations of the criteria on which one factor has better performance than another. The concordance threshold is then defined as 0.5 to ensure that the factor *a* should have better performance than *b* on at least one criterion. The discordance threshold is defined as the mean of all discordance indices, equal to 0.22. The result is shown in Table 1-5.

Table 1-5 Result: ELECTRE I, 2 Criteria

	Original Parameters				Tightened				Loosen			
Threshold of concordance	C*	0.50			C*	1			C*	0.5		
ELECTRE I Threshold of discordance	D*	0.22			D*	0.11			D*	0.33		
	im.		un.		im.		un.		im.		un.	
Weight of criterions	0,50		0,50		0,5		0,5		0,5		0,5	
Factor	Dominate	Indifferent	incomparable	Dominated by	Dominate	Indifferent	incomparable	Dominated by	Dominate	Indifferent	incomparable	Dominated by
Ageing society	0	0	19	26	0	0	32	13	0	0	15	30
Fertility	0	0	1	44	0	0	3	42	0	0	1	44
Migration	8	5	5	27	6	0	22	17	6	9	4	26
Level of income inequality	9	6	4	26	5	0	19	21	8	12	1	24
Unemployment	14	11	5	15	13	0	20	12	15	13	3	14
Flexibilisation of labour	20	10	3	12	10	0	25	10	18	16	1	10
Changes in household structures	1	6	2	36	1	0	11	33	1	6	2	36
Urbanisation	2	1	26	16	1	0	37	7	4	1	16	24
Urban sprawl	6	2	29	8	3	0	40	2	11	8	16	10
Growth of megacities	5	3	17	20	2	0	35	8	9	10	9	17
Attitudes towards technology innovation	8	5	4	28	4	0	17	24	6	11	1	27
Attitudes towards time and speed	18	6	3	18	7	0	24	14	16	14	0	15
Attitudes towards environmental concerns	19	10	3	13	7	0	26	12	13	18	0	14
GDP development	37	3	2	3	29	0	16	0	35	9	0	1
Geographic distribution of activities / trade	37	4	0	4	17	0	25	3	30	12	0	3
Share of service sector in GDP	4	4	2	35	2	0	16	27	2	11	1	31
Share of e-commerce in total trade	3	6	5	31	2	0	24	19	2	9	4	30
EU enlargement	1	3	6	35	0	0	26	19	1	8	4	32
Citizen participation in policy/decision making	6	5	5	29	4	0	27	14	4	10	5	26
Cohesion and structural policies developments	13	6	6	20	11	0	28	6	11	14	5	15
Multipolarisation of the world	6	8	5	26	4	0	23	18	4	13	3	25
Worldwide redistribution of income	18	10	8	9	16	0	27	2	17	16	4	8
Shortage of resources and energy, and risk of conflicts	33	3	5	4	10	0	32	3	28	14	0	3
Implementation of sustainable development principles	37	7	0	1	30	0	13	2	36	8	0	1
Share of renewable energy	27	6	2	10	20	0	17	8	28	9	0	8
Demand for energy	11	3	20	11	4	0	36	5	16	9	7	13
Energy prices	43	2	0	0	37	0	8	0	42	3	0	0
ICT R&D expenditures	8	8	5	24	7	0	23	15	7	14	4	20
ICT Technological development and innovation	20	11	3	11	8	0	27	10	17	18	0	10
ICT The impact that these technologies may have on the way of life	33	5	1	6	27	0	14	4	33	8	0	4
ICT Market uptake and diffusion of technologies	25	9	4	7	20	0	23	2	24	14	1	6
VT R&D expenditures	17	11	4	13	10	0	24	11	16	16	1	12
VT Technological development and innovation	23	12	1	9	8	0	30	7	19	19	0	7
VT The impact that these technologies may have on the way of life	25	7	3	10	20	0	18	7	27	11	0	7
VT Market uptake and diffusion of technologies	32	5	2	6	26	0	17	2	31	11	0	3

Table 1-5 Result: ELECTRE I, 2 Criteria (continue)

Implementation and governments' support of sustainable mobility policies	41	2	0	2	31	0	12	2	37	6	0	2
Institutional structures	43	2	0	0	39	0	6	0	41	4	0	0
TEN-T policy	3	7	4	31	2	0	15	28	2	8	2	33
Opening of transport markets to competition	1	4	5	35	1	0	21	23	1	7	3	34
Lack of financial resources for infrastructure investments	17	12	4	12	4	0	32	9	17	18	0	10
Innovative instruments for funding transport infrastructure and services	13	4	8	20	10	0	29	6	10	10	5	20
Pricing and charges	25	10	1	9	10	0	29	6	21	18	0	6
Internalisation of externalities	39	5	0	1	35	0	10	0	38	7	0	0
Subsidies and incentives	10	5	5	25	9	0	25	11	9	9	5	22
Enforcement of traffic law	1	3	3	38	1	0	12	32	1	7	1	36
New mobility concepts	18	9	4	14	14	0	20	11	18	12	2	13

The two selected factors are "Energy Prices" and "Institutional Structures". Each of them dominates other 43 factors and are indifferent with 2 factors:

- The "Energy Prices" is indifferent with "Implementation of sustainable developments principles" and "Institutional structure".
- The "Institutional structure" is indifferent with "Energy prices" and "Internalisation of externalities".

To investigate the sensitivity of the result, two sets of concordance/discordance threshold are applied: the tightened condition with *C*=1* and *D*=0.11*, and the loosen condition with *C*=0.5*, *D*=0.33*. In the tightened condition the concordance threshold rises to the level where the factor *a* should have better performance than *b* on both criteria, while the tolerance of discordance reduces to the half. In the loosen condition, the concordance threshold remains, and the tolerance of discordance augments to 150%.

When the thresholds become more rigid, it makes more difficult for one factor to outrank another, i.e. less "*xSy*" and more "*NOT xSy*" in the pairwise comparison. As consequence, the possibility of incomparability increases. When the thresholds are loosen, one factor outranks another more easily, so there are more "*xSy*". Consequently more indifferences appear. In both conditions, the result is robust enough as shown in Table 1-5.

Four Criteria Case

The weights of criteria are $\{\omega_{av.im}, \omega_{sd.im}, \omega_{av.un}, \omega_{sd.un}\} = \{0.4, 0.1, 0.4, 0.1\}$.

The possible values of the concordance index are $\{0,\ 0.1,\ 0.2,\ 0.4,\ 0.5,\ 0.6,\ 0.8,\ 0.9,\ 1\}$ according to the combination of criteria on which one factor has better performance than another. The concordance index has an average value of 0.51 and a standard deviation of 0.30. The discordance index has an average value of 0.30 and a standard deviation of 0.22.

Considering the symmetry of the 2 sets of criteria (importance and its standard deviation, related-trend uncertainty and its standard deviation), as well as $C(aSb) + C(bSa) = 1$, the concordance

threshold is defined as 0.6. This threshold means that for being considered, factor *a* should have better performance than *b* on at least 3 criteria of which one should be the criteria concerning the mean importance or related-trend uncertainty. The discordance threshold is defined as the mean of all discordance indices, equals 0.30. The result is listed in Table 1-6.

Table 1-6 Result: ELECTRE I, 4 Criteria

	Original Parameters				Tightened				Loosen			
Threshold of concordance	C*	0.60			C*	0.80			C*	0.50		
ELECTRE I Threshold of discordance	D*	0.30			D*	0.15			D*	0.45		
	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un
Weight of criterions	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10
Factor	Dominate	Indifferent	incomparable	Dominated by	Dominate	Indifferent	incomparable	Dominated by	Dominate	Indifferent	incomparable	Dominated by
Ageing society	0	0	42	3	0	0	43	2	1	0	36	8
Fertility	0	0	23	22	0	0	37	8	0	0	8	37
Migration	7	0	16	22	4	0	32	9	7	7	4	27
Level of income inequality	10	0	10	25	3	0	27	15	10	6	3	26
Unemployment	10	0	20	15	2	0	34	9	15	8	3	19
Flexibilisation of labour	14	0	18	13	6	0	32	7	16	10	2	17
Changes in household structures	3	0	10	32	0	0	25	20	3	3	3	36
Urbanisation	3	0	39	3	1	0	43	1	15	0	25	5
Urban sprawl	13	0	31	1	2	0	43	0	29	4	10	2
Growth of megacities	12	0	30	3	2	0	43	0	26	5	6	8
Attitudes towards technology innovation	11	0	11	23	3	0	28	14	11	5	3	26
Attitudes towards time and speed	14	0	14	17	3	0	31	11	16	9	1	19
Attitudes towards environmental concerns	10	0	17	18	3	0	32	10	13	8	1	23
GDP development	26	0	15	4	13	0	32	0	33	4	4	4
Geographic distribution of activities / trade	15	0	27	3	5	0	39	1	29	10	3	3
Share of service sector in GDP	11	0	17	17	2	0	36	7	12	2	3	28
Share of e-commerce in total trade	5	0	17	23	1	0	36	8	6	5	5	29
EU enlargement	0	0	8	37	0	0	28	17	0	1	3	41
Citizen participation in policy/decision making	2	0	13	30	0	0	34	11	3	1	4	37
Cohesion and structural policies developments	9	0	20	16	4	0	37	4	11	9	4	21
Multipolarisation of the world	3	0	16	26	0	0	31	14	6	5	3	31
Worldwide redistribution of income	6	0	17	22	1	0	42	2	13	0	8	24
Shortage of resources and energy, and risk of conflicts	0	0	33	12	0	0	42	3	2	1	22	20
Implementation of sustainable development principles	24	0	15	6	11	0	33	1	32	3	4	6
Share of renewable energy	19	0	15	11	8	0	31	6	23	4	2	16
Demand for energy	0	0	41	4	0	0	42	3	20	14	4	7
Energy prices	5	0	40	0	1	0	44	0	16	4	24	1
ICT R&D expenditures	10	0	29	6	3	0	40	2	11	13	8	13
ICT Technological development and innovation	17	0	17	11	6	0	35	4	19	9	2	15
ICT The impact that these technologies may have on the way of life	31	0	10	4	22	0	22	1	33	5	3	4
ICT Market uptake and diffusion of technologies	30	0	13	2	16	0	29	0	34	6	3	2

Table 1-6 Result: ELECTRE I, 4 Criteria (continue)

VT R&D expenditures	26	0	12	7	10	0	34	1	27	4	4	10
VT Technological development and innovation	29	0	13	3	8	0	35	2	29	6	2	8
VT The impact that these technologies may have on the way of life	24	0	12	9	15	0	27	3	25	6	3	11
VT Market uptake and diffusion of technologies	31	0	14	0	26	0	19	0	34	7	3	1
Implementation and governments' support of sustainable mobility policies	36	0	8	1	23	0	22	0	39	4	1	1
Institutional structures	39	0	6	0	25	0	20	0	42	3	0	0
TEN-T policy	8	0	17	20	2	0	39	4	8	3	5	29
Opening of transport markets to competition	1	0	21	23	0	0	30	15	1	6	4	34
Lack of financial resources for infrastructure investments	8	0	20	17	1	0	38	6	11	12	2	20
Innovative instruments for funding transport infrastructure and services	9	0	29	7	4	0	38	3	10	14	6	15
Pricing and charges	18	0	15	12	5	0	36	4	24	7	0	14
Internalisation of externalities	20	0	21	4	5	0	40	0	29	2	10	4
Subsidies and incentives	13	0	23	9	8	0	34	3	18	4	5	18
Enforcement of traffic law	4	0	10	31	0	0	30	15	4	3	3	35
New mobility concepts	9	0	15	21	2	0	33	10	13	4	4	24

The two best factors are “Implementation and governments’ support of sustainable mobility policies” and “Institutional structures”; only the latter dominates the former, and the latter is dominated by no other factors. They are the two factors that dominate the most of other ones. The “Vehicle technologies: market uptake and diffusion of technologies” is also worthy to be considered, because it dominates 31 other factors and is not dominated by any other factor. The “Energy prices” here dominates just 5 other factors and is incomparable with the other 40 factors because of its high standard deviation of the related-trend uncertainty.

The sensitivity is analysed by moving the concordance and discordance thresholds into tightened condition and loosen one (see Table 1-6). In tightened condition, the concordance threshold rises to 0.8 that stands for the weight of two criteria concerning the mean, at the same time the discordance threshold decreases to the half, equals 0.15. In the loosen condition, the concordance threshold is set to 0.5 stands for the weight of one mean-concerned criterion and one of the standard deviation; meanwhile the discordance threshold rises to 150%.

In tightened condition, since it is more difficult to appear “*xSy*”, the possibility of preference and indifference shifts to that of incomparability between two factors, for instance in this condition the “Institutional structures” no longer dominates “Implementation and governments’ support of sustainable mobility policies”. In the loosen condition, it is much easier to validate “*xSy*”, the possibility of incomparability thusly decreases. In this condition, “Institutional structures” dominates again the other one. The result is robust, as shown in Table 1-6.

1.4.2.4 Application of ELECTRE II

Different from ELECTRE I, this method aims to build a pre-order of factors. There should be at least 2 thresholds of concordance and 1 for discordance (Vincke, 1992) to generate the two-level

outranking relation; in the lecture (Norese, 2002) the application has been found. We can also increase the number of thresholds of concordance and discordance in order to obtain more severe pre-orders; for example, in some cases (Duckstein & Gershon, 1983) (Armaghan & Renaud, 2012), 3 thresholds of concordance and 2 of discordance are applied.

In our case, we have adopted a 3*2 thresholds system:

- 3 concordance thresholds $C^+ > C^0 > C^-$ for 4 levels of concordance (high $C \geq C^+$, average $C^+ > C \geq C^0$, low $C^0 > C \geq C^-$ and insufficient $C < C^-$)
- 2 discordance thresholds $D_j^- < D_j^+$ for three levels of discordance (low $D_j \leq D_j^-$, average $D_j^- < D_j \leq D_j^+$ and high $D_j > D_j^+$). Since we have normalised the data, a unique set of discordance thresholds is defined for all criteria.

The outranking relation is defined as follow and illustrated as Figure 1-4:

1. Factor *a* strongly outranks *b* if :

- The concordance is high and the discordance is average or low; or
- The concordance is average and the discordance is low

$$aS^F b \ \ iff \begin{cases} C(a,b) \geq C^+ \\ C(a,b) \geq C(b,a) \\ D_j(a,b) \leq D_j^+ \end{cases} \quad or \quad \begin{cases} C^+ > C(a,b) \geq C^0 \\ C(a,b) \geq C(b,a) \\ D_j(a,b) \leq D_j^- \end{cases}$$

2. Factor *a* weakly outranks *b* if :

- The concordance is average and the discordance is average; or
- The concordance is low and the discordance is average or low

$$aS^f b \ \ iff \begin{cases} C^+ > C(a,b) \geq C^0 \\ C(a,b) \geq C(b,a) \\ D_j^- < D_j(a,b) \leq D_j^+ \end{cases} \quad or \quad \begin{cases} C^0 > C(a,b) \geq C^- \\ C(a,b) \geq C(b,a) \\ D_j(a,b) \leq D_j^+ \end{cases}$$

3. Factor *a* does not outranks *b* if the concordance is insufficient or the discordance is high.

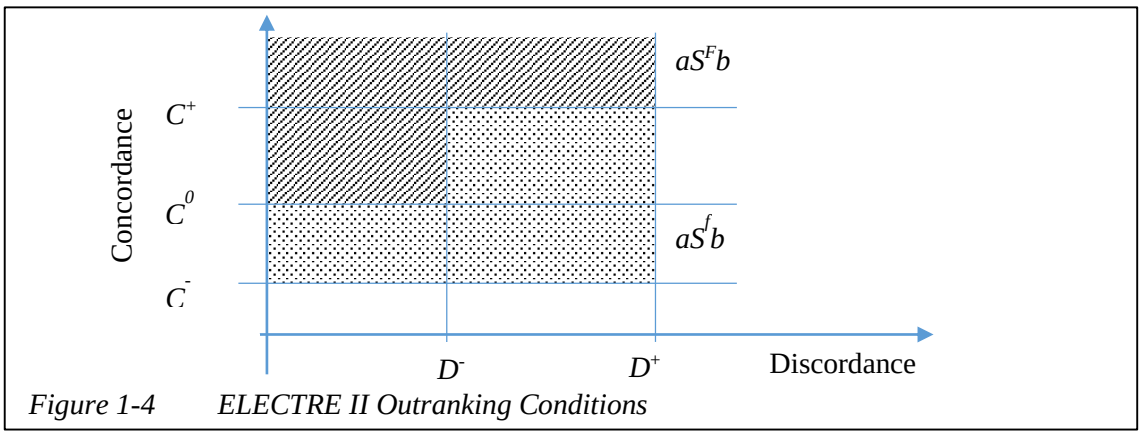

Figure 1-4 ELECTRE II Outranking Conditions

Having obtained the outranking relations between every pair of factors, the descending and ascending pre-order are to be built:

1. The descending pre-order ranks the factors from the best to the worst: one factor is better if it is outranked by less alternatives than another. The first step is to build a rough version basing on the strong outranking relation S^F, by ranking the factors according to the number (from the smallest to the biggest) of other factors by which that factor is outranked strongly. If there are factors with the same position, then rank them basing on the weak outranking relation S^f.
2. The ascending pre-order ranks the factors from the worst to the best: one factor is better if it outranks more alternatives than another. Firstly, the rough version is built based on the strong outranking relation S^F, by ranking the factors according to the number (from the biggest to the smallest) of other factors strongly outranked by that factor. Then refine the pre-order by ranking the factors with same position basing on the weak outranking relation S^f.

It should be highlighted that the most intuitive and possibly the only way to build the final pre-order is drawing the ordering in graph (Norese, 2002). Since the two aforementioned pre-orders are usually different, if we consider these two pre-orders equally important, then it is highly possible to obtain a final pre-order with numerous "incomparable" cases. Although many suggest to build the final pre-order with the intersection of the descending and ascending pre-order, like (Figueira, et al., 2005) and (Vincke, 1992), the incomparability between factors will gravely shorten the vertical length of the final pre-order. Instead, (Duckstein & Gershon, 1983) has simply used the average position of the action in two pre-orders as the final position.

Two Criteria Case

The weight of each criterion is 0.5. The mean of concordance indices is 0.51, and the standard deviation is 0.36. It should be recalled here that the concordance threshold usually surpasses 0.5 (Figueira, et al., 2005). The three concordance thresholds are then set as $C^- = 0.50, C^0 = 0.60, C^+ = 1.00$. However, the possible concordance values are $\{0,\ 0.5,\ 1\}$. Therefore, the C^0 could vary between 0.50 and 1.00.

The discordance in ELECTRE II is the performance difference in terms of criteria between factors. Since all our data are normalized by the standard-score normalization method, the discordance indices here thusly follow a normal distribution in terms of 4 criteria respectively.

In terms of each criterion, the discordance indices have the mean of 0 and standard deviation of 1.414. Basing on the property of the normal distribution, for each criterion the discordance thresholds are set as $D^- = 0, D^+ = 0.71$ in order to cover up to 69.1% of the whole discordance indices. The descending and ascending pre-order are presented in Table 1-7.

Table 1-7 Result: ELECTRE II, 2 Criteria

	Original Parameters				Strict				Loosen			
Threshold of concordance	C*	1.00	0.60	0.50	C*	1.00	0.60	0.50	C*	1.00	0.60	0.50
	D*.im		D*.un		D*.im		D*.un		D*.im		D*.un	
ELECTRE II Threshold of discordance: D+	0.71		0.71		0.00		0.00		1.41		1.41	
ELECTRE II Threshold of discordance: D-	0.00		0.00		-0.71		-0.71		0.71		0.71	
Weight of criterions	im.		un.		im.		un.		im.		un.	
	0,50		0,50		0,50		0,50		0,50		0,50	
Factor	Descending	Ascending			Descending	Ascending			Descending	Ascending		
Ageing society	45	31			44	31			45	31		
Fertility	45	46			44	46			45	46		
Migration	28	35			28	35			28	35		
Level of income inequality	29	39			29	39			29	39		
Unemployment	15	29			15	29			15	29		
Flexibilisation of labour	18	24			17	24			19	24		
Changes in household structures	41	45			40	45			42	45		
Urbanisation	43	19			40	18			43	19		
Urban sprawl	35	8			35	5			35	9		
Growth of megacities	38	22			36	21			36	22		
Attitudes towards technology innovation	33	41			30	41			33	41		
Attitudes towards time and speed	26	32			25	32			26	32		
Attitudes towards environmental concerns	25	29			25	29			25	30		
GDP development	6	4			6	1			6	4		
Geographic distribution of activities / trade	12	11			12	11			12	11		
Share of service sector in GDP	39	42			36	42			37	42		
Share of e-commerce in total trade	36	37			36	37			37	37		
EU enlargement	44	38			44	37			44	38		
Citizen participation in policy/decision making	32	33			30	32			34	33		
Cohesion and structural policies developments	16	17			16	15			16	16		
Multipolarisation of the world	31	36			30	36			31	36		
Worldwide redistribution of income	13	10			13	5			13	10		
Shortage of resources and energy, and risk of conflicts	19	11			17	11			17	12		
Implementation of sustainable development principles	5	6			5	5			5	5		
Share of renewable energy	9	21			9	21			11	21		
Demand for energy	34	14			30	14			32	14		
Energy prices	2	1			2	1			2	1		
ICT R&D expenditures	27	34			25	34			27	34		
ICT Technological development and innovation	24	24			23	24			24	25		
ICT The impact that these technologies may have on the way of life	7	13			7	13			7	13		
ICT Market uptake and diffusion of technologies	9	9			9	5			9	8		
VT R&D expenditures	19	27			17	26			20	27		
VT Technological development and innovation	23	20			23	18			23	20		
VT The impact that these technologies may have on the way of life	9	18			9	18			10	18		

Table 1-7 Result: ELECTRE II, 2 Criteria (continue)

VT Market uptake and diffusion of technologies	8	7			8	5			8	7		
Implementation and governments' support of sustainable mobility policies	4	5			4	5			4	5		
Institutional structures	1	2			1	1			1	1		
TEN-T policy	37	43			36	43			39	43		
Opening of transport markets to competition	40	40			40	40			40	40		
Lack of financial resources for infrastructure investments	30	23			30	23			30	23		
Innovative instruments for funding transport infrastructure and services	21	16			17	15			21	17		
Pricing and charges	17	15			17	15			18	15		
Internalisation of externalities	3	3			3	1			3	3		
Subsidies and incentives	22	28			22	26			22	28		
Enforcement of traffic law	42	44			40	44			41	44		
New mobility concepts	14	26			14	26			14	26		

The result shows that in both descending and ascending pre-order "Institutional structures" and "Energy prices" occupy the first two positions, with a switch of position between them. Consequently, in the final pre-order they are tied for the first place, with the incomparability between them.

In the sensitivity analysis, only the discordance thresholds vary (see Table 1-7). In the tightened condition, the discordance thresholds decrease by $\sigma/2 = 0.71$ to $D^- = -0.71, D^+ = 0$ in order to cover only at most 50% of the discordance indices. In the loosen condition the thresholds rise by $\sigma/2$ to $D^- = 0.71, D^+ = 1.41$ so that up to 84.1% of the discordance index can be considered as "non-veto". In both conditions, "Institutional structures" and "Energy prices" stay at the head of the ordering. The descending and ascending pre-order do not present significant variance.

Four Criteria Case

The weights of criteria are $\{\omega_{av.im}, \omega_{sd.im}, \omega_{av.un}, \omega_{sd.un}\} = \{0.4, 0.1, 0.4, 0.1\}$.

The possible values of a concordance index are $\{0,\ 0.1,\ 0.2,\ 0.4,\ 0.5,\ 0.6,\ 0.8,\ 0.9,\ 1\}$ according to the combination of criteria on which one factor has better performance than another. The mean concordance is 0.51 and the standard deviation is 0.30. We have set the concordance thresholds as: $C^- = 0.5,\ C^0 = 0.6,\ C^+ = 0.8$.

The discordance indices follow a normal distribution in terms of each criterion respectively with the mean of 0 and standard deviation of 1.414. The thresholds are $D^- = 0,\ D^+ = 0.71$ so that up to 69.1% of all discordance indices are "non-veto". The result is represented in Table 1-8.

Table 1-8 Result: ELECTRE II, 4 Criteria

	Original Parameters				Strict				Loosen			
Threshold of concordance	C*	0.80	0.60	0.50	C*	0.90	0.80	0.60	C*	0.80	0.60	0.50
	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un
ELECTRE II Threshold of discordance: D+	0.71	0.71	0.71	0.71	0.00	0.00	0.00	0.00	1.41	1.41	1.41	1.41
ELECTRE II Threshold of discordance: D-	0.00	0.00	0.00	0.00	-0.71	-0.71	-0.71	-0.71	0.71	0.71	0.71	0.71
Weight of criterions	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un	im	Sd.im	un	Sd.un
	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10
Factor	Descending	Ascending			Descending	Ascending			Descending	Ascending		
Ageing society	40	10			25	1			43	10		
Fertility	40	31			25	1			43	34		
Migration	18	34			15	38			25	37		
Level of income inequality	23	41			25	42			29	39		
Unemployment	27	35			15	41			21	29		
Flexibilisation of labour	14	32			11	31			15	28		
Changes in household structures	38	46			25	34			39	45		
Urbanisation	32	10			25	1			40	7		
Urban sprawl	28	1			25	1			31	4		
Growth of megacities	32	6			25	1			32	9		
Attitudes towards technology innovation	24	40			25	29			28	38		
Attitudes towards time and speed	20	38			25	34			18	31		
Attitudes towards environmental concerns	20	36			25	38			20	33		
GDP development	7	6			10	1			8	11		
Geographic distribution of activities / trade	17	10			25	16			16	8		
Share of service sector in GDP	28	28			15	16			33	32		
Share of e-commerce in total trade	31	33			25	38			35	39		
EU enlargement	40	45			25	46			43	46		
Citizen participation in policy/decision making	40	39			25	45			37	41		
Cohesion and structural policies developments	24	27			15	24			22	26		
Multipolarisation of the world	36	43			25	42			34	44		
Worldwide redistribution of income	34	19			25	24			27	27		
Shortage of resources and energy, and risk of conflicts	40	21			25	29			43	21		
Implementation of sustainable development principles	9	15			11	16			10	15		
Share of renewable energy	11	29			15	31			11	25		
Demand for energy	40	20			25	24			42	16		
Energy prices	34	1			15	1			36	1		
ICT R&D expenditures	22	16			15	1			19	17		
ICT Technological development and innovation	13	26			15	16			14	24		
ICT The impact that these technologies may have on the way of life	4	14			3	1			4	12		
ICT Market uptake and diffusion of technologies	5	6			6	1			5	6		
VT R&D expenditures	8	13			7	16			7	20		
VT Technological development and innovation	12	17			9	1			6	12		
VT The impact that these technologies may have on the way of life	6	21			5	24			9	23		

Table 1-8 Result: ELECTRE II, 4 Criteria (continue)

VT Market uptake and diffusion of technologies	1	1			1	1			3	3		
Implementation and governments' support of sustainable mobility policies	3	1			2	1			2	4		
Institutional structures	2	1			4	1			1	1		
TEN-T policy	26	25			15	24			26	35		
Opening of transport markets to competition	39	44			25	34			40	41		
Lack of financial resources for infrastructure investments	36	30			25	31			30	30		
Innovative instruments for funding transport infrastructure and services	19	24			11	16			23	19		
Pricing and charges	15	18			11	16			13	22		
Internalisation of externalities	16	9			15	1			12	12		
Subsidies and incentives	10	21			7	16			17	18		
Enforcement of traffic law	40	42			25	34			38	43		
New mobility concepts	30	36			25	42			24	36		

In descending pre-order, “Institutional structures”, “Vehicle Technologies: Market uptake and diffusion of technologies” and “Implementation and governments’ support of sustainable mobility policies” occupy the first three positions. In ascending pre-order, they are tied for the first position. Therefore, in the final pre-order they are the first three factors.

The sensitivity analysis is carried out by tightening or loosening the thresholds of concordance and discordance (see Table 1-8). In the tightened condition, the concordance thresholds rise to $C^- = 0.6,\ C^0 = 0.8, C^+ = 0.9$, meanwhile the discordance thresholds fall by $\sigma/2$ to $D^- = -0.71, D^+ = 0$. The $C^+ = 0.9$ represents the better performance of one factor compared to another on the combination of two “mean” criteria and one “standard deviation” criterion. In the loosen condition, the concordance thresholds remain because they should surpass 0.5, and the discordance thresholds rise by $\sigma/2$ to $D^- = 0.71,\ D^+ = 1.41$.

This analysis shows a change of positions following the variation of the thresholds of concordance and discordance. When the thresholds are tightened, it is more difficult for one factor to outrank another, i.e. less “*xSy*”; while the descending and ascending pre-order are built by counting this outranking relation. As consequence, the final pre-order becomes a partial ordering with more cases of incomparability. However, the “Institutional structures” and “Vehicle technologies: market uptake and diffusion of technologies” stay at the forward positions, together with “Implementation and governments’ support of sustainable mobility policies”.

1.5 Conclusion

By applying the ELECTRE I and II methods, we have selected the scenario variables from the factors of the passenger transport system. If we take into account only the mean importance and mean related-trend uncertainty, the two scenario variables selected by both methods are “Energy prices” and “Institutional structures”. When we consider all of four criteria concerning both the “mean” and the “standard deviation”, there are three scenario variable candidates: “Institutional structures”, “Implementation and governments’ support of sustainable mobility policies” and “Vehicle technologies market uptake and diffusion of technologies”. In both methods, these three

factors stand in the first three positions. The result is robust.

Each MCDA method has its property and advantage. We cannot tell which method is better than others in the absolute sense. The selection of the MCDA method depends on the structure of the problematic and the particularity in each case. Besides, the preference and the interpretation of the problematic vary case by case, and the computation of parameters/indicators is not an obstacle any more with the help of specified software. In the case of OPTIMISM data analysis, it is not suitable to compensate the weak performance on one criterion by the strong performance on another. The ELECTRE I and II methods have fulfilled this requirement with the simplicity and easily understandable process. Although we have modified or simplified the exploitation process in our application, both methods have provided a reasoning mechanism to select and rank the best factors with respect to the criteria.

2 NON-SURVEY METHODS IN FREIGHT TRANSPORT AND LOGISTICS PLANNING

2.1 Introduction

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 focused on the first two steps, and the goal was to determine trade flows between regions and provide a first representation of the production/consumption of goods in the Lazio region in terms of monetary value of the products. It concerns to create the OD matrices of products trade flows at the regional level and the Input-Output tables (I-O tables) at the regional, provincial and municipal level.

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.

When it comes to planning the freight transport, the modelling concerns some system aspects different from the passenger transport, among which the following are evident:

1. The considerable complexity of goods types made by the cargo, and consequently the diversity of the organization of transport (e.g. from bulk shipments of large quantities to deliveries of packages to more stops);
2. 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);
3. The diversity of the role of decision-makers whose decisions affect the freight transport system (e.g. putting, broker/logistics operators, carrier, driver);
4. The diversity of the decisions in the field of transport (e.g. shipment dimensions, mode/service, type of vehicle, planning/timetable, route);
5. The considerable difficulty in collecting and processing the relative data, especially

those disaggregated, because of the lack of the information standard between the various parties concerned, and also in part due to 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: they are usually based on statistics data. This brings another advantage: the economic-sociological linkages between data that are especially due to the second and third point listed above are then simplified in the analysis. Considering the data availability, we focus on the methods based on the Input-Output model. The Input-Output model (I-O model), one of the basic tools of economy analysis, allows us to build a quantitative representation of the flows of goods based on statistical data; in fact, this model is wildly adopted by the statistics institute of different countries to descript the economy at national level. Taking the study area as a whole, this basic I-O model can capture the economic impacts of a sector's changes in the system. However, it fails to investigate the inter-regional effects when the study area has economic interchanges with other areas. For example, the automobile industry in region A uses the tyres produced in region B; and the tyre industry in region B uses rubber imported from region A. An order from abroad will increase the production of the automobile industry in region A, but the basic I-O model will fail to capture the production augmentation of the rubber industry in region A.

To overcome such shortage of the basic I-O model, the Inter-regional Input-Output (IRIO) model, the Multi-Regional Input-Output (MRIO) model are often used to perform the analysis of inter-regional economy (Isard, et al., 1998) (Hewings & Jensen, 1986) (Cascetta, et al., 1996) (Kim, 1974) (Round, 1978) (Oosterhaven & Stelder, 2007) (Murray & Lenzen, 2013). 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 in order to simplify the model and reduce the data requirement. These two models can handle inter-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 concerned information that is used to estimate the trade coefficients usually comes from origin-to-destination commodity shipment information; the commodity shipment information and the data in the I-O models should be uniform somehow (e.g. the categorisation of industries and products, the value unit, etc).

Another wildly used tool for modelling the distribution of trade flows is the gravity model (Miller & Blair, 2009) (Flegg & Webber, 1997). The basic idea of this model is to consider the study areas as masses, and the distribution of trade flows between regions follow the effect of the "gravity" of the masses. Such "gravity" is usually valuated through various aspects of the regional economy such as the GDP (total or by sector), the distance between regions (e.g. the distance between the regional capital cities), the employment (total or by economic sector) and/or population, etc. There are numerous gravity models to perform the inter-regional economy

analysis. It needs also to estimate several parameters of the model. To analyse the I-O data already available from the national institute of statistics with gravity model, the uniformity of data (especially the categorisation of economic activities and products) should be guaranteed, and the intra-regional / inter-regional trade flows should be divided first.

It should be noted that the complexity of modelling using IRIO, MRIO and the gravity model arises significantly when the number of regions increases, and the amount of data required becomes enormous. Therefore, considering the data availability, the basic input-output model (to analyse the economy of the study areas), location quotients methods (to allocate the intra-regional/inter-regional production/consumption) and bi-proportional apportionment (to estimate the distribution of trade flows) are adopted in this research thanks to their simplicity and moderate data requirement.

Once modelled the economy, one can establish a linkage between the economy model and the observed traffic data estimating a set of conversion parameters. It allows to forecast the impacts of economic changes on traffic.

After the brief introduction in the first section, the "non-survey" methodology for modelling the generation/attraction of goods trade flows and the distribution are presented in the second section. The third section focuses on the application of the "non-survey" methodologies in the context of the update of the Regional Plan of Mobility and Transport Logistics of Lazio (PRMTL). The data analysis of the results is presented in the fourth section. The linkage between the above-mentioned economic model and traffic data is introduced in the fifth section. The conclusion is presented in the end.

2.2 Non-survey Methodology

2.2.1 Input-Output model

The I-O 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 I-O 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 2-1 shows schematically the structure of a generic I-O 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 2-1 National I-O table

		Intermediate Use €				Final Use€		
		…	Sector j	…	Total intermediate	Households e government	Export	Total final
…		…	…	…	…	…	…	…
		…	…	…	…	…	…	…
Sector i	Production	…	${}^{D}Int_{ij}$	…	$\sum_j {}^{D}Int_{ij}$	${}^{D}F_i$	${}^{D}X_i$	${}^{D}F_i + {}^{D}X_i$
	Import	…	${}^{I}Int_{ij}$	…	$\sum_j {}^{I}Int_{ij}$	${}^{I}F_i$	${}^{I}X_i$	${}^{I}F_i + {}^{I}X_i$
…		…	…	…	…	…	…	…
		…	…	…	…	…	…	…
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 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 I-O table, for a generic economic sector *j* in column, the monetary value of its consumption of goods/services as sectorial input is represented in this column. In the "Final use" part, the numbers of the columns are the monetary values of the goods/services consumed by households and the public sector, and those for export. These goods/services are provided as output from 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 sectorial output. These goods/services are consumed as input by the 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 sectorial production for intermediate uses ($\sum_j {}^{D}Int_{ij}$) and that for final uses (${}^{D}F_i + {}^{D}X_i$); the sum of these two elements ($\sum_j {}^{D}Int_{ij} + {}^{D}F_i + {}^{D}X_i$) represents the domestic production of sector *i*. It shows also the same values in respect of sectorial imports for intermediate uses ($\sum_j {}^{I}Int_{ij}$) and final uses (${}^{I}F_i + {}^{I}X_i$).

The domestic consumption of the total sectorial production will be equal to the sum of the values for intermediate and final uses, supplied by both domestic production and import ($\sum_j ({}^{D}Int_{ij} + {}^{I}Int_{ij}) + {}^{D}F_i + {}^{I}F_i$). The export is excluded from this amount.

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/service, and one product/service is supplied by more than one sector. The modelling of freight transport and logistics focus one the products with physical entity that are transported, so it is necessary to distinguish the supply/use of services from that of products. The I-O table in terms of "sectors x sectors" does not allow such a distinction. On the other hand, statistical institutes normally publish the national I-O tables while it is rare to find such tables for regions/provinces/municipalities; consequently, the sectorial

employment is necessary as the measure to divide to local level the production and consumption at national scale. In this respect, we have considered the national I-O table in terms of "commodities x sectors" of "supply" and "use", whose structure are shown schematically by Table 2-2 and Table 2-3.

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

Supply	Domestic production €				Import €			
	…	Sector s	…	Total	…	Sector s	…	Total
…	…	…	…	…	…	…	…	…
Commodity m	…	P_{ms}	…	$\sum_s P_{ms}$	…	I_{ms}	…	$\sum_s I_{ms}$
…	…	…	…	…	…	…	…	…
Total	…	$\sum_m P_{ms}$	…	$\sum_s \sum_m P_{ms}$	…	$\sum_m I_{ms}$	…	$\sum_s \sum_m I_{ms}$

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

Use		Intermediate use €				Final use €		
		…	Sector s	…	Total intermediate	Household e government	Export	Total final
…		…	…	…	…	…	…	…
		…	…	…	…	…	…	…
Commodity m	Domestic production	…	${}^{D}Int_{ms}$	…	$\sum_s {}^{D}Int_{ms}$	${}^{D}F_m$	${}^{D}X_m$	${}^{D}F_m + {}^{D}X_m$
	Import	…	${}^{I}Int_{ms}$	…	$\sum_s {}^{I}Int_{ms}$	${}^{I}F_m$	${}^{I}X_m$	${}^{I}F_m + {}^{I}X_m$
…		…	…	…	…	…	…	…
		…	…	…	…	…	…	…
Total		…		…				

Different from the Table 2-1, the rows represent goods supplied/consumed; while in columns remain economic sectors and final consumers. In the following sections, the left superscript "*D*" indicating "domestic product" is omitted in order to simplify the writing.

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

1. The relationship between the sectorial supply (production, import) in an area and the national one is identical to the ratio of the sectorial employment in this area to that of national territory; if a sector produce more than one product/service, this assumption applies to each of them;

$$\frac{Local\ sectorial\ supply\ of\ product/service}{National\ sectorial\ supply\ of\ product/service} = \frac{Local\ sectorial\ employment}{National\ sectorial\ employment}$$

2. The relationship between the sectorial consumption for reproduction (intermediate uses) in an area and the national one is identical to the ratio of the sectorial employment in this area to that of national territory; if a sector consume more than one product/service as input, this assumption applies to each of them;

$$\frac{Local\ sectorial\ intermediate\ use\ of\ product/service}{National\ sectorial\ intermediate\ use\ of\ product/service} = \frac{Local\ sectorial\ employment}{National\ sectorial\ employment}$$

3. The relationship between the households/public sector's consumption a product/service in an area and the national one is identical to the ratio of the local population to the national population;

$$\frac{Local\ final\ use\ (fam., public) of\ product/service}{National\ final\ use\ (fam., public) of\ product/service} = \frac{Local\ population}{National\ population}$$

4. The relationship between the exports of a product/service to abroad at local and national level is identical to the ratio of the total production of such goods in that area to the national one.

$$\frac{Local\ export\ of\ product\ to\ abroad}{National\ export\ of\ product\ to\ abroad} = \frac{Total\ local\ production\ of\ product}{Total\ national\ production\ of\ product}$$

With these assumptions, we have allocated the supply and use of products/services to the local level (productions, uses and export to abroad). Note that these uses relate to the products / services from all over the country.

2.2.2 Allocation of intra-regional and inter-regional flows using Location Quotients methods

2.2.2.1 Preliminary estimation with Location Quotients methods

Taking into account the resources imported from other regions and from abroad, there is the balance between the supply and use in the regional account:

$$P_m^R + I_m^{R.reg} + I_m^{R.est} = Int_m^R + F_m^R + X_m^{R.reg} + X_m^{R.est} + {}^I Int_m^R + {}^I F_m^R \qquad (2\text{-}1)$$

Where:

P_m^R : value of regional production of product/service *m* in the region *R*;

$I_m^{R.reg}, I_m^{R.est}$: value of regional imports of product/service *m* from other regions and from abroad;

$Int_m^R, {}^I Int_m^R$: value of product/service *m*, domestically produced and imported from abroad, used by the productive activities as intermediate input in the region *R*;

$F_m^R, {}^I F_m^R$: value of product/service *m*, domestically produced and imported from abroad, used by households and public sectors in the region *R*;

$X_m^{R.reg}, X_m^{R.est}$: the value of domestic product/service *m* exported to other regions and abroad from the region *R*.

To determine the goods sent from the production areas and received in destination areas, we need to identify the import from other regions ($I_m^{R.reg}$) and export to other regions ($X_m^{R.reg}$).

We distinguish intra-regional and inter-regional flows. The intra-regional flows come from regional productions, and finish in the regional intermediate/final uses as well as export to other regions and abroad. The inter-regional flows initiate from imports from other regions, and devote only to regional intermediate/final uses under the assumption that the region exports to abroad only the goods it produces. The import from abroad and its use are independent of these two streams. These conditions are expressed in the eq.(2-2).

$$\begin{aligned} &Int_m^R = Int^{\circ R}_m + Int'^R_m, \quad F_m^R = F^{\circ R}_m + F'^R_m \\ &P_m^R = Int^{\circ R}_m + F^{\circ R}_m + X_m^{R.est} + X_m^{R.reg} \\ &I_m^{R.reg} = Int'^R_m + F'^R_m \\ &I_m^{R.est} = {}^I Int_m^R + {}^I F_m^R \end{aligned} \qquad (2\text{-}2)$$

Where:

$Int^{\circ R}_m, F^{\circ R}_m$: total regional intermediate, final uses of product/service *m* locally supplied in the region *R*;

Int'^R_m, F'^R_m : total regional intermediate, final uses of product/service *m* in the region *R* imported from other regions;

With the assumptions described in the previous section we can obtain the regional production (P_m^R), import from abroad ($I_m^{R.est}$), intermediate and final uses of domestic products/services (Int_m^R, F_m^R) and imported ones (${}^I Int_m^R, {}^I F_m^R$), as well as export to abroad ($X_m^{R.est}$). With eq. (2-2) one can obtain the import from other regions ($I_m^{R.reg}$) and export to other regions ($X_m^{R.reg}$) after having identified the origin of the goods/services consumed in the region ($Int^{\circ R}_m, Int'^R_m$ and $F^{\circ R}_m, F'^R_m$).

Flows of 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

The technical coefficient is defined as the eq. (2-3):

$$a_{ms} = Int_{ms} / P_s \qquad (2\text{-}3)$$

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

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

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/service *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 / service *m*".

In this introductive section of the methodology, the relationship between product/service 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/service *m* from the region *R* that is used by the sector *s* in the same region to produce one monetary unit of sectorial output, as in eq. (10)

$$t_{ms}^{R} = Int^{\circ R}_{ms} / P_{s}^{R} \qquad (2\text{-}4)$$

3. Coefficient of inter-regional import

The inter-regional coefficient import w_{ms}^{R} indicates the value of the product/service *m* imported from other regions and consumed by the sector *s* in the region *R* to produce one monetary unit of sectorial output. Evidently, there is a relationship 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}, as in eq. (2-5):

$$w_{ms}^{R} = Int'^{R}_{ms} / P_{s}^{R} = a_{ms}^{R} - t_{ms}^{R} \qquad (2\text{-}5)$$

It is assumed that the production technologies are identical on the national and regional level. Furthermore, it is assumed that one relationship exist between the national technical coefficient and the coefficient of intra-regional input as in eq (2-6):

$$t_{ms}^{R} = a_{ms}^{N} \cdot q_{ms}^{R}, \quad a_{ms}^{R} = a_{ms}^{N} \qquad (2\text{-}6)$$

q_{ms}^{R} is the degree of self-sufficiency that indicates in the region *R* the share of the intermediate demand of sector *s* for the product/service *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.(2-3), (2-4), (2-5) and (2-6), we have:

$$w_{ms}^{R} = a_{ms}^{N}(1-q_{ms}^{R}) \tag{2-7}$$

and

$$\begin{aligned} Int^{\circ R}_{ms} &= P_s^R \cdot t_{ms}^R = P_s^R \cdot a_{ms}^R \cdot q_{ms}^R = Int_{ms}^R \cdot q_{ms}^R \\ Int'^{R}_{ms} &= Int_{ms}^R \cdot (1-q_{ms}^R) \end{aligned} \tag{2-8}$$

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).

1. Simple Location Quotient (SLQ)

   With the SLQ, the q_{ms}^{R} is estimated as in eq. (2-9):

$$q_{ms}^{R} = q_{m}^{R} = \begin{cases} 1, & SLQ_m \geq 1 \\ SLQ_m^R, & otherwise \end{cases}, \quad SLQ_m^R = \frac{E_m^R / E_m^N}{E^R / E^N} \tag{2-9}$$

   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 takes into account the relative size of sector *m* in region *R* (E_m^R / E_m^N) that provides the product/service *m* as well as the relative size of the region (E^R / E^N). When q_{ms}^{R} is less than 1, it means that the employment of the region *R* is less concentrated in the sector *m* compared to the national average; as the consequence, the region would be less specialized in producing the product/service *m*, thus it would be less likely that the region 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/service *m*.

2. Cross-Industry Location Quotient (CILQ)

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

$$q_{ms}^{R} = \begin{cases} 1, & CILQ_{ms} \geq 1 \\ CILQ_{ms}^R, & otherwise \end{cases}, \quad CILQ_{ms}^R = \frac{SLQ_m}{SLQ_s} = \frac{E_m^R / E_m^N}{E_s^R / E_s^N} \tag{2-10}$$

   The CILQ considers the relative size of both the sector *m* (E_m^R / E_m^N) that provides

the product/service *m* and the sector *s* (E_s^R / E_s^N) that uses the product/service *m*. The relative size of the region *R* is not recognized because 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.

3. 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):

$$
\begin{aligned}
q_{ms}^R &= \begin{cases} 1, & FLQ_{ms}^R \geq 1 \\ FLQ_{ms}^R, & \text{otherwise} \end{cases} \\
FLQ_{ms}^R &= \begin{cases} CILQ_{ms}^R \cdot \lambda^*, & for\ m \neq s \\ SLQ_{ms}^R \cdot \lambda^*, & for\ m = s \end{cases} \\
\lambda^* &= \left[\log_2 (1 + E^R / E^N) \right]^\delta
\end{aligned}
\qquad (2\text{-}11)
$$

The FLQ has incorporated the CILQ, so it recognize 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 I-O table (Bonfiglio & Chelli, 2008) (Tohmo, 2004) (Flegg & Webber, 1997) (Flegg & Tohmo, 2013). 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).

Flows of final uses

For final uses, few examples in the literature deal with identifying the origin of the goods/services consumed by final use. One example is that (Isard, et al., 1998) has dealt with this topic with the LQ methods.

Other than the intermediate use, final uses do not reproduce any goods/services; the quantity of products/services consumed by households and the government in the region *R* is obtained by dividing the corresponding national data according to the ratio of population. There is not the coefficient similar to the technical coefficient to link the regional production to the final uses. Nevertheless, the coefficient of intra-regional input for final uses k_m^R is defined as the share of the demand of households and government for the product/service *m* satisfied by the local production in the region *R*; therefore it is similar to the q_{ms}^R for flows of intermediate uses:

$$k_m^R = F^{\circ R}_m / F_m^R \qquad (2\text{-}12)$$

The coefficient k_m^R is to be estimated by LQ methods.

2.2.2.2 Adjustment of the preliminary estimation and model calibration

The eq.(2-2) implies that the regional uses of the product/service *m* should not exceed the regional available resources, i.e.:

$$P_m^R - X_m^{R.est} \geq Int^{\circ R}_m + F^{\circ R}_m \qquad (2\text{-}13)$$

The estimate of the intermediate and final uses of locally supplied products/services will be approved only if it meets that restriction, and the export to other regions is equal to the left over regional resource:

$$\begin{aligned} X_m^{R.reg} &= (P_m^R - X_m^{R.est}) - (\hat{I}nt^{\circ R}_m + \hat{F}^{\circ R}_m) \\ I_m^{R.reg} &= \hat{I}nt'^R_m + \hat{F}'^R_m \end{aligned} \qquad (2\text{-}14)$$

In case the estimate does not meet the restriction, it will be necessary to calibrate the estimate by reducing the estimated intermediate and final uses of locally supplied products/services, and move this part supply into the inter-regional import:

$$\begin{aligned} X_m^{R.reg} &= 0 \\ I_m^{R.reg} &= (\hat{I}nt'^R_m + \hat{F}'^R_m) + \left[(\hat{I}nt^{\circ R}_m + \hat{F}^{\circ R}_m) - (P_m^R - X_m^{R.est}) \right] \end{aligned} \qquad (2\text{-}15)$$

This calibration ensures that the regional account achieves the equilibrium between the supply and use relative to local goods/services.

Having derived the regional account, this allocation model could be calibrated using the regional statistics data (if available).

2.2.3 Distribution of trade flows of goods between regions using bi-proportional apportionment

The trade flows of goods concern only product that has the physical entity and can be transported, therefore in this section only the products are taken into account. In the previous section, in a generic region *R*, the total export to other regions and the total import from other regions are estimated for each product. It is needed to distribute these values to every pair of regions to modelling the trade flows. In other words, for each product *m*, there is a matrix with the origin regions in rows and the destination regions in columns; the total import of the regions ($I_m^{D.reg}$) are

listed in the last row and the total export ($X_m^{O.reg}$) in the last column[3]. The objective is to estimate the values in the cells that indicate the trade flows from origin to destination region (sc_m^{OD}) fulfilling the restriction of total values in rows and in columns, as shown in the Table 2-4.

Table 2-4 Matrix of trade flows

Product m		Destination			Total export
		Region 1	…	Region *D*	
Origin	Region 1	sc_m^{11}	…	sc_m^{1D}	$X_m^{1.reg}$
	…	…	…	…	…
	Region *O*	sc_m^{O1}	…	sc_m^{OD}	$X_m^{O.reg}$
Total import		$I_m^{1.reg}$	…	$I_m^{D.reg}$	

Several methods are available for this purpose among which the gravity model is widely used. In case the data availability is strictly limited, one could consider the bi-proportional apportionment method to gain the first estimate of the trade flows. This adjustment method is also known as "iterative proportional fitting". (Lahr & Mesnard, 2004) has provided an overview of this method and discussed its application in the field of economic research. The founder of the I-O model for economy analysis Leontief has applied this balancing method to identify the changes in the I-O tables of a given nation with only the margin variation known (Leontief, 1941).

In the matrix of Table 2-4 there are only inter-regional flows to be distributed, and the flows in the same region are excluded. There are two ways to build the initial matrix:

- For the generic product *m*, the share of the origin region *O*'s export to the destination region *D* in the total import of the region *D* is equal to the ratio of the region *O*'s export to the total export from all regions except region *D*:

$$sc_m^{OD} = I_m^{DO} = I_m^D \cdot \frac{X_m^{O.reg}}{\sum_O X_m^{O.reg} - X_m^{D.reg}}, \quad sc_m^{DD} = 0 \qquad (2\text{-}16)$$

- For the generic product *m*, the share of the destination region *D*'s import from the origin region *O* in the total export of the region *O* is equal to the ratio of the region *D*'s import to the total import to all regions except region *O*:

$$sc_m^{OD} = X_m^{OD} = X_m^O \cdot \frac{I_m^{D.reg}}{\sum_D I_m^{D.reg} - I_m^{O.reg}}, \quad sc_m^{OO} = 0 \qquad (2\text{-}17)$$

It should be emphasized that the bi-proportional apportionment method estimates the trade flows on the very restrictive assumption that the inter-regional imports/exports are relative only to the

[3] To distinguish the region of origin and destination, the right superscript "*R*" of $I_m^{R.reg}, X_m^{R.reg}$ is substituted by "*O*" to indicate the origin region and by "*D*" to indicate the destination region.

production/consumption in the regions, without considering other factors such as, for example, the distance, the transport cost, etc.

Therefore, the cells that indicate the origin and destination within the same region are assigned as zero. In the denominator of eq. (2-16) the total export of the region *D* itself to other regions is excluded; this is because the region *D*'s export cannot take share in its import; otherwise it becomes the intra-regional flow. For the same reason the denominator of eq.(2-17) has excluded the total import of the region *O* from other regions. This constraint leads obviously to the fact that, in the initial matrix, the sum of the columns or rows is not equal to the already-known value of "Total import" or "Total export" ($\sum_O sc_m^{OD} \neq I_m^{D.reg}$, $\sum_D sc_m^{OD} \neq X_m^{O.reg}$).

The bi-proportional apportionment is an iterative procedure that allows minimizing the deviations presented in the initial matrix. One iteration consists of "Row scaling" and "Column scaling":

1) Row scaling: reduce/increase the value of each cell according to the ratio of the sum of all cells in the row to the corresponding value of "total export":

$$^{1}sc_m^{OD} = {}^{0}sc_m^{OD} \cdot \frac{X_m^{O.reg}}{\sum_D {}^{0}sc_m^{OD}} \qquad (2\text{-}18)$$

2) Column scaling: reduce/increase the value of each cell obtained in "row scaling" according to the ratio of the sum of all cells in the column to the corresponding value of "total import":

$$^{2}sc_m^{OD} = {}^{1}sc_m^{OD} \cdot \frac{I_m^{D.reg}}{\sum_O {}^{1}sc_m^{OD}} \qquad (2\text{-}19)$$

The order of "Row scaling" and "Column scaling" can be inverse. The iteration stops when the value in the cells meet the constraint posed by the margins (the row and column sums). The trade flows distribution could be calibrated with regional exchange data (if available).

2.3 Application

2.3.1 Data

As described in the section of methodology, the necessary data are:

- National input-output data;
- Employment of the economic sectors, represented by the number of employee;
- Population on different geographic level.

2.3.1.1 National Input-Output tables

The national I-O tables (or tables of supply and use) of Italy updated to 2010 (Istituto Nazionale di Statistica, 2013) is published in the Data Warehouse of the Italian National Institute of Statistics

(ISTAT). The I-O 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 I-O tables adopt the classification of NACE Rev.2 (2008) (Eurostat, 2008) for economic activities and CPA 2008 (Eurostat, 2008) 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/services and the corresponding economic sectors of the NACE classification. The NACE Rev. 2 classifies economic sectors in 88 divisions belonging to 21 sections, and the CPA in 2008 ranks products in 88 divisions correspondingly, as in Appendix 1.

In the national I-O 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/services are correspondingly regrouped into 6. They correspond exactly to the terms of NACE Rev.2 and use the same index code. In this study, for the calculation it is assigned to each products/services and their corresponding economic sectors a sequence number, noted as *m* and *s*, as in Table 2-5. However, since it deals with the statistic data of Italy, the terms are maintained in Italian.

Table 2-5 Activities and products/services in the national I-O tables of Italy

Seq. No.	Activities (NACE Rev.2)		Products/services (CPA 2008)	
	Note 1. "V" indicate "Activity", "R" indicate "Product/service"; 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	Produzioni vegetali e animali, caccia e servizi connessi	R01	Prodotti dell'agricoltura e della caccia e relativi servizi
2	V02	Silvicoltura e utilizzo di aree forestali	R02	Prodotti della silvicoltura, delle operazioni di taglio e trasporto dei tronchi e servizi connessi
3	V03	Pesca e acquicoltura	R03	Pesci ed altri prodotti della pesca; prodotti dell'acquacoltura; servizi di supporto per la pesca
4	VB	Attività estrattiva	RB	Prodotti delle miniere e delle cave
5	V10_12	Industrie alimentari, delle bevande e del tabacco	R10_12	Prodotti alimentari, bevande e prodotti a base di tabacco
6	V13_15	Industrie tessili, confezione di articoli di abbigliamento e di articoli in pelle e simili	R13_15	Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti
7	V16	Industria del legno e dei prodotti in legno e sughero, esclusi i mobili; fabbricazione di articoli in paglia e materiali da intreccio	R16	Legno e prodotti in legno e sughero (esclusi i mobili); articoli di paglia e materiali da intreccio
8	V17	Fabbricazione di carta e di prodotti di carta	R17	Carta e prodotti di carta
9	V18	Stampa e riproduzione su supporti registrati	R18	Servizi di stampa e di registrazione
10	V19	Fabbricazione di coke e prodotti derivanti dalla raffinazione del petrolio	R19	Coke e prodotti petroliferi raffinati

Table 2-5 Activities and products/services in the national I-O tables of Italy (continue)

11	V20	Fabbricazione di prodotti chimici	R20	Prodotti chimici
12	V21	Fabbricazione di prodotti farmaceutici di base e di preparati farmaceutici	R21	Prodotti farmaceutici di base e preparati farmaceutici
13	V22	Fabbricazione di articoli in gomma e materie plastiche	R22	Articoli in gomma e in materie plastiche
14	V23	Fabbricazione di altri prodotti della lavorazione di minerali non metalliferi	R23	Altri prodotti della lavorazione di minerali non metalliferi
15	V24	Attività metallurgiche	R24	Metalli
16	V25	Fabbricazione di prodotti in metallo, esclusi macchinari e attrezzature	R25	Prodotti in metallo, esclusi macchine e impianti
17	V26	Fabbricazione di computer e prodotti di elettronica e ottica	R26	Prodotti informatici, elettronici ed ottici
18	V27	Fabbricazione di apparecchiature elettriche	R27	Apparecchiature elettriche
19	V28	Fabbricazione di macchinari e apparecchiature n.c.a.	R28	Macchine ed apparecchi meccanici n.c.a[4].
20	V29	Fabbricazione di autoveicoli, rimorchi e semirimorchi	R29	Autoveicoli, rimorchi e semirimorchi
21	V30	Fabbricazione di altri mezzi di trasporto	R30	Altri mezzi di trasporto
22	V31_32	Fabbricazione di mobili; altre industrie manifatturiere	R31_32	Mobilio; altri manufatti
23	V33	Riparazione e installazione di macchine e apparecchiature	R33	Servizi di riparazione e installazione di macchinari e apparecchi
24	VD	Fornitura di energia elettrica, gas, vapore e aria condizionata	RD	Energia elettrica, gas, vapore e aria condizionata
25	V36	Raccolta, trattamento e fornitura di acqua	R36	Acqua naturale; servizi di trattamento delle acque e di produzione e distribuzione d'acqua
26	V37_39	Gestione delle reti fognarie; attività di raccolta, trattamento e smaltimento dei rifiuti; recupero dei materiali; attività di risanamento e altri servizi di gestione dei rifiuti	R37_39	Servizi di smaltimento delle acque di scarico; fanghi di depurazione; servizi di raccolta, trattamento e smaltimento dei rifiuti; servizi di recupero dei materiali; servizi di decontaminazione ed altri servizi di trattamento dei rifiuti
27	VF	Costruzioni	RF	Lavori di costruzione ed opere di edilizia civile
28	V45	Commercio all'ingrosso e al dettaglio e riparazione di autoveicoli e motocicli	R45	Servizi di vendita all'ingrosso e al dettaglio e di riparazione di autoveicoli e motocicli
29	V46	Commercio all'ingrosso, escluso quello di autoveicoli e di motocicli	R46	Servizi di vendita all'ingrosso, escluso quello di autoveicoli e di motocicli
30	V47	Commercio al dettaglio, escluso quello di autoveicoli e di motocicli	R47	Servizi di vendita al dettaglio, escluso quello di autoveicoli e di motocicli
31	V49	Trasporto terrestre e trasporto mediante condotte	R49	Servizi di trasporto terrestre e di trasporto mediante condotte
32	V50	Trasporti marittimi e per vie d'acqua	R50	Servizi di trasporto marittimo e per vie d'acqua
33	V51	Trasporto aereo	R51	Servizi di trasporto aereo
34	V52	Magazzinaggio e attività di supporto ai trasporti	R52	Servizi di magazzinaggio e di supporto per i trasporti
35	V53	Servizi postali e attività di corriere	R53	Servizi postali e di corriere

[4] n.c.a.: non classificati altrove, not elsewhere classified .

Table 2-5 Activities and products/services in the national I-O tables of Italy (continue)

36	VI	Servizi di alloggio; attività di servizi di ristorazione	RI	Servizi di alloggio e di ristorazione
37	V58	Attività editoriali	R58	Servizi di editoria
38	V59_60	Attività di produzione cinematografica, di video e di programmi televisivi, di registrazioni musicali e sonore; attività di programmazione e trasmissione	R59_60	Servizi di produzione di pellicole cinematografiche, di video e di programmi televisivi; edizione di registrazioni sonore e edizioni musicali; servizi di programmazione e di emissione radiofonica e televisiva
39	V61	Telecomunicazioni	R61	Servizi di telecomunicazione
40	V62_63	Programmazione, consulenza informatica e attività connesse; attività dei servizi d'informazione	R62_63	Programmazione informatica, consulenze e servizi connessi; servizi d'informazione
41	V64	Prestazione di servizi finanziari (ad esclusione di assicurazioni e fondi pensione)	R64	Servizi finanziari (escluse le assicurazioni e i fondi pensione)
42	V65	Assicurazioni, riassicurazioni e fondi pensione, escluse le assicurazioni sociali obbligatorie	R65	Servizi connessi alle assicurazioni, alle riassicurazioni e ai fondi pensione, escluse le assicurazioni sociali obbligatorie
43	V66	Attività ausiliarie dei servizi finanziari e delle attività assicurative	R66	Servizi ausiliari dei servizi finanziari e dei servizi assicurativi
44	VL	Attività immobiliari	RL	Servizi immobiliari
45	V69_70	Attività legali e contabilità; attività di sedi centrali; consulenza gestionale	R69_70	Servizi legali e contabilità; servizi di sedi sociali; servizi di consulenza in materia amministrativo-gestionale
46	V71	Attività degli studi di architettura e d'ingegneria; collaudi e analisi tecniche	R71	Servizi in materia di architettura e di ingegneria; servizi di sperimentazione e di analisi tecnica
47	V72	Ricerca scientifica e sviluppo	R72	Servizi di ricerca e sviluppo scientifici
48	V73	Pubblicità e ricerche di mercato	R73	Servizi di pubblicità e studi di mercato
49	V74_75	Altre attività professionali, scientifiche e tecniche; servizi veterinari	R74_75	Altri servizi professionali, scientifici e tecnici; servizi veterinari
50	V77	Attività di noleggio e leasing	R77	Servizi di locazione e leasing
51	V78	Attività di ricerca, selezione, fornitura di personale	R78	Servizi del lavoro
52	V79	Attività dei servizi delle agenzie di viaggio, dei tour operator e servizi di prenotazione e attività correlate	R79	Servizi delle agenzie di viaggio, degli operatori turistici ed altri servizi di prenotazione e servizi connessi
53	V80_82	Servizi di investigazione e vigilanza; attività di servizi per edifici e per paesaggio; attività amministrative e di supporto per le funzioni d'ufficio e altri servizi di supporto alle imprese	R80_82	Servizi investigativi e di vigilanza; servizi di manutenzione degli edifici e del paesaggio; servizi amministrativi e di sostegno per le funzioni d'ufficio ed altri servizi di sostegno alle imprese
54	VO	Amministrazione pubblica e difesa; assicurazione sociale obbligatoria	R84	Servizi di pubblica amministrazione e difesa; servizi di assicurazione sociale obbligatoria
55	VP	Istruzione	RP	Servizi di istruzione
56	V86	Attività dei servizi sanitari	R86	Servizi sanitari
57	V87_88	Assistenza sociale	R87_88	Servizi di assistenza residenziale; servizi di assistenza sociale non residenziale
58	V90_92	Attività creative, artistiche e d'intrattenimento; attività di biblioteche, archivi, musei e altre attività culturali; attività riguardanti scommesse e case da gioco	R90_92	Servizi creativi, artistici e d'intrattenimento; servizi di biblioteche, archivi, musei ed altri servizi culturali; servizi riguardanti il gioco d'azzardo

Table 2-5 Activities and products/services in the national I-O tables of Italy (continue)

59	V93	Attività sportive, di intrattenimento e di divertimento	R93	Servizi sportivi e di intrattenimento e divertimento
60	V94	Attività di organizzazioni associative	R94	Servizi forniti da organizzazioni associative
61	V95	Riparazione di computer e di beni per uso personale e per la casa	R95	Servizi di riparazione di elaboratori elettronici e di beni per uso personale e domestico
62	V96	Altre attività di servizi personali	R96	Altri servizi personali
63	VT	Attività di famiglie e convivenze come datori di lavoro per personale domestico; produzione di beni e di servizi indifferenziati per uso proprio da parte di famiglie e convivenze	RT	Servizi di datore di lavoro svolti da famiglie e convivenze; produzione di beni e servizi per uso proprio da parte di famiglie e convivenze

The national I-O tables of Italy are constructed on the basis of two evaluation criteria[5]:

- Base price: 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 price: the price actually paid by the purchaser for the good or service produced.

The I-O tables meet two fundamental balances:

1. Balance of supplies and uses by product/service at purchase prices on a national scale, i.e. for a generic product/service "*m*", the value of all uses at purchase prices in the table of uses is equal to the value of the total supply at purchase prices:

$$ {}_{b}P_m^{IT} + I_m^{IT.est} + \Delta_m^{IT} + T_m^{IT} = {}_{a}^{D,I}Int_m^{IT} + {}_{a}^{D,I}F_m^{IT} + X_m^{IT.est} \qquad (2\text{-}20) $$

Where:

${}_{b}P_m^{IT}$: value of domestic production of product/service *m* at basic prices;

$I_m^{IT.est}$: value of import from abroad at price cif (cost insurance freight)[6];

Δ_m^{IT} : margins of trade and transport;

T_m^{IT} : taxes minus the subsidies to the product;

${}_{a}^{D,I}Int_m^{IT}$, ${}_{a}^{D,I}F_m^{IT}$: value of consumptions by intermediate and final uses at purchase price; the products/services consumed come from both domestic production and import;

[5] This is because while the basic statistics on businesses allow estimating the output at basic prices, demand (consumption, investment and exports) is estimated in terms of purchase prices.

[6] The piece includes the value of services of transportation and insurance to the frontier of the importer.

$X_m^{IT.est}$: value of export to abroad at price fob (free on board)[7].

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

$$ {}_bP_s^{IT} = {}_a^{D,I}Int_s^{IT} + v_s^{IT} \qquad (2\text{-}21) $$

Where:

${}_bP_s^{IT}$: value of the domestic production of sector *s* at basic prices;

${}_a^{D,I}Int_s^{IT}$: value of the products/services (domestic and imported) consumed as input by sector *s* at purchase price;

v_s^{IT} : value added at basic prices.

In the national I-O tables, the value of the margins of trade / transport and that of taxes minus subsidies are recorded by product. It is therefore difficult to distribute such values on each of the economic activities. Accordingly, by subtracting these two values from eq.(2-20), for a generic product/service "*m*" the balance of supply and consumption is at basic prices, as in the eq.(2-22):

$$ {}_bP_m^{IT} + I_m^{IT.est} = {}_b^{D,I}Int_m^{IT} + {}_b^{D,I}F_m^{IT} + X_m^{IT.est} \qquad (2\text{-}22) $$

where ${}_b^{D,I}Int_m^{IT}$, ${}_b^{D,I}F_m^{IT}$ are the values of product/service *m* (domestic and imported) consumed by intermediate and final uses at basic prices.

For this reason, in the entire set of tables of supply and use updated to 2010, the following tables at current prices[8] are considered:

- The table of supply "Sup11" of "SUPPLY_63B.xls" which brings all the resource of domestic production and import classified by product and by industry. It is built at basic prices and includes transformation to the purchase prices of the totals. Imports are valued at price "cost insurance freight" (CIF), which includes the value of the services of transport and insurance to the frontier of the importer.
- The table of use "Uspb11" of "USEPB_63B.xls" that shows the value at basic prices of consumptions of goods and services by product and by type of use (intermediate or final). Exports are valued at the price "free on board" (fob), the price recorded at the customs frontier of the exporter. The products/services consumed come both from domestic

[7] The price indicates the value recorded at the customs frontier.

[8] The current price in the market in the period in which the assessment is carried out.

production and import.

- The table of use for imports "Imprt11" of "IMPORT_63B.xls" that shows the value of consumption of goods and services by product and by type of use (intermediate or final) of imports. The value of the total consumption for the product equals to the value of the import in the table "Sup10."

Imports, in the national table of supply "Sup11" are recorded by product/service, not by industry; while the consumption of them is recorded aside in the national table of use "Imprt11" by product and by industry/activity. Therefore, we focus on the balance between domestic production and consumption of domestic products, removing the imports and their consumption by changing the balance of eq.(2-22) as:

$$ {}_{b}P_{m}^{IT} = {}_{b}^{D,I}Int_{m}^{IT} + {}_{b}^{D,I}F_{m}^{IT} + X_{m}^{IT.est} - {}_{b}^{I}Int_{m}^{IT} - {}_{b}^{I}F_{m}^{IT} \qquad (2\text{-}23) $$

Where:

${}_{b}^{I}Int_{m}^{IT}$: value at basic prices of generic product/service *m* imported from abroad and consumed by intermediate uses;

${}_{b}^{I}F_{m}^{IT}$: value at basic prices of generic product/service *m* imported from abroad and consumed by final uses.

To simplify the writing, the left subscript "*b*" that indicate "at basic prices" in the equations is omitted.

Table 2-6 shows schematically the structure of the supply table "Sup11." In this table, the number in a cell indicates the value (in millions of euros) of the product/service (e.g., $P_{1,1}^{IT}$) which is identified by the row (e.g., product/service 1), provided by the economic activity which is identified by the column (e.g., Activities 1), or coming from the import (e.g., I_1^{IT}).

Table 2-6 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)
	Activity 1	…	Activity 63	Total production					
Product/service 1	$P_{1,1}^{IT}$		$P_{1,63}^{IT}$	$\sum_{s=1}^{63} P_{1s}^{IT}$	I_1^{IT}	$\sum_{s=1}^{63} P_{1s}^{IT} + I_1^{IT}$	Δ_1	T_1	Σ
…									
Product/service 63									
Total	$\sum_{m=1}^{63} P_{m1}^{IT}$								

For a generic product/service *m*, the value of the total supply at basic prices is derived from the aggregation of the productions of the activities that produce the product/service and import (e.g., the total supply of the product/service 1 at basic prices is $\sum_{s=1}^{63} P_{1s}^{IT} + I_1^{IT}$). By adding the value of trade and transport margins, and taxes minus subsidies by product, we derive the total supply

at purchasers' prices (e.g., the total supply of the product/service 1 at purchase prices is $\sum_{s=1}^{63} P_{1s}^{IT} + I_1^{IT} + \Delta_1 + T_1$).

For a generic activity *s*, its total supply results from the aggregation of the value of its various products (e.g., the total supply of activity 1 at basic prices is $\sum_{m=1}^{63} P_{m1}^{IT}$).

Table 2-7 shows schematically the structure of the table of use "Uspb11". The table of use for imports "Imprt11" has the same structure, except the last 3 rows "Total intermediate/final use (purchase prices)", "Value added (basic prices)" and "Production (basic prices)."

Table 2-7 Table of use at basic prices

Use (millions of €)	Intermediate uses				Final uses					Total uses
	Activity 1	...	Activity 63	Total intermediate uses	Use 1	...	Use 6	Export (fob)	Total final uses	
Product/service 1	${}^{D,I}Int_{1,1}^{IT}$		${}^{D,I}Int_{1,63}^{IT}$	$\sum_{s=1}^{63} {}^{D,I}Int_{1s}^{IT}$	${}^{D,I}F_{1,1}^{IT}$		${}^{D,I}F_{1,6}^{IT}$	X_1^{IT}	$\sum_{u=1}^{6} {}^{D,I}F_{1u}^{IT} + X_1^{IT}$	$\sum$
...										
Product/service 63										
Total intermediate/final uses (basic prices)	$\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT}$									
Total intermediate/final uses (purchase prices)	$\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT} + z_1$									
Value added (basic prices)	v_1									
Production (basic prices)	$\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT} + z_1 + v_1$									

The columns of the table of uses are organized into two parts. In the part of "intermediate Uses", the number in a cell represents the value of the product/service, which is identified by the row, used as input by the economic activity which is identified by the column. In the part of "Final uses", the number in a cell represents the value of the product/service consumed without further processing. As the intermediate uses aim at further productions, therefore, for each activity, the total value of intermediate inputs equals to the cost of production and there is an value added generated during production.

For example, for a generic product/service *m*, ${}^{D,I}Int_{m1}^{IT}$ represents the value of the amount used by the activity 1. The total value of intermediate uses at basic prices is $\sum_{s=1}^{63} {}^{D,I}Int_{ms}^{IT}$. In the part of the "final uses", ${}^{D,I}F_{m1}^{IT}$ indicates the value of the product/service *m* consumed by the final use 1, and X_m^{IT} represents the value of the amount exported; both are at basic prices. The total final uses is $\sum_{u=1}^{6} {}^{D,I}F_{mu}^{IT} + X_m^{IT}$. Total uses at basic prices is the sum of intermediate and final uses $\sum_{s=1}^{63} {}^{D,I}Int_{ms}^{IT} + \sum_{u=1}^{6} {}^{D,I}F_{mu}^{IT} + X_m^{IT}$.

For activity 1, the value at basic prices of all products/services used as input is $\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT}$. This value is converted to the purchase price as $\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT} + z_1$, where z_1 is the reassigned value of trade and transportation margin, taxes minus subsidies to the activity 1. With the value added v_1 the sum $\sum_{m=1}^{63} {}^{D,I}Int_{m1}^{IT} + z_1 + v_1$ is equal to the production value of activity 1 at basic prices.

The condition $\{m \in N, s \in N, u \in N, m \leq 63, s \leq 63, u \leq 6\}$ is valid for all equations hereinafter.

2.3.1.2 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. These data are collected in the Census of Industry and Services in 2011 (Istituto Nazionale di Statistica, 2013) (hereinafter referred as "the Census") on the national, regional, provincial and municipal level. The data of the region of Lazio concern the 5 provinces and 378 municipalities.

The Census has collected data on the number of employees in local units of active enterprises and effective personnel in service in local units of active public institutions in the Italian territory. The Census 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 in the Census:

- attività di famiglie e convivenze come datori di lavoro per personale domestico (section T, division 97) (Activities of households as employers of domestic personnel);
- produzione di beni e servizi indifferenziati per uso proprio da parte di famiglie e convivenze (section T, division 98) (Undifferentiated goods - and services-producing activities of private households for own use);
- organizzazioni ed organismi extraterritoriali (section U).

Furthermore, the data of the following activities are detailed only until the provincial level:

- amministrazione pubblica e difesa, assicurazione sociale obbligatoria (section O, division 84) (Public administration and defence; compulsory social security);
- attività di organizzazioni associative (section S, division 94) (Activities of membership organisations).

The population data of Italy in 2011 (Istituto Nazionale di Statistica, 2014) has been used. Such data concerns the total residential population of Italy, 20 Italian regions, 5 provinces in Lazio as well as the region's 378 municipalities.

2.3.2 Division of the national I-O tables to local level

2.3.2.1 Definition of coefficients

Since the ATECO 2007 is the Italian national version of NACE Rev.2 that aims to classify the economic activities, one can calculate the coefficients with the employee numbers gathered in the Census for distributing the national I-O tables, except the following cases:

- To estimate the employee number of the activity of division 84 and 94 (ATECO 2007) at municipal level, it is assumed that, for the generic municipality "*a*" in the province "*x*", the municipal employee number of each activity is proportional to the population : $E_{84}^{a} = E_{84}^{x} * Pop^{a} / Pop^{x}$ where *E* is the employee number.
- The activity of section U (NACE Rev.2, ATECO2007) is omitted in the distribution because it is not included in the national I-O table and its employee number is not gathered in the Census.
- The activities of section T (NACE Rev.2, including division 97 and 98) don't consume any other product/service as input, the value of their production consists in the value added; their unique product is totally consumed by the families. Therefore, it is assumed that their employee number at local level is of the same proportion with the population when compared to the corresponding nationwide data: $E_{T}^{a} = E_{T}^{IT} * Pop^{a} / Pop^{IT}$.

It was then necessary to determine for each geographic area the following coefficients:

- 63 coefficients of employment for 63 economic activities "c_s"

For each of the 63 branches of activities, the employment coefficients were calculated for 20 Italian regions, 5 provinces in Lazio as well as the region's 378 municipalities. Each coefficient was calculated by dividing the number of employees of a specific activity of the geographical unit (municipality, province, and region) by the corresponding number at the national level; for example, the employment coefficient of sector *s* of the region *R* was calculated using the equation:

$$c_s^R = E_s^R / E_s^{IT} \qquad (2\text{-}24)$$

- 63 coefficients of division for 63 products/services "r_m"

The coefficient of division, which aims to measure the relative dimension of the total production of a generic product/service *m* in one area (e.g., region *R*), was calculated as:

$$r_m^R = P_m^R / P_m^{IT} \qquad (2\text{-}25)$$

- a coefficient of population "c_{pop}"

The coefficient of population of geographical units was calculated by dividing the total number

of inhabitants in the geographical unit by the number of all inhabitants in Italy:

$$c_{pop}^{R} = Pop^{R} \big/ Pop^{IT} \tag{2-26}$$

2.3.2.2 Division of national I-O tables data

To simplify the reading, the equations in this section are for division at the regional level. For the division at provincial and municipal level, it needs only to change the coefficient to the one of the corresponding geographic unit.

The value of a generic product/service *m* supplied by 63 branches of activities in the region *R* was calculated as:

$$P_{m}^{R} = \sum_{s=1}^{63} P_{ms}^{R} = \sum_{s=1}^{63} P_{ms}^{IT} \cdot c_{s}^{R} \tag{2-27}$$

In other words, the total amount of a generic product/service *m* produced in the region *R* is equal to the sum of the 63 sectors' production of *m* in the region. For the generic sector *s*, the proportion of its production of *m* in region *R* to its total production of *m* at national level is equal to the coefficient of sectorial employment in that region.

As seen previously, the table of use "Uspb11" shows the value of the products/services consumed in 2011; these products/services are coming from both domestic production and import. The list of posts for imports "Imprt11" just about the uses of the products / services imported. So consumption data of domestic production at national level are calculated by subtracting the values in the table "Imprt11" from corresponding values in the table "Uspb11":

$$\begin{aligned} Int_{ms}^{IT} &= {}^{D,I}Int_{ms}^{IT} - {}^{I}Int_{ms}^{IT} \\ F_{mu}^{IT} &= {}^{D,I}F_{mu}^{IT} - {}^{I}F_{mu}^{IT} \end{aligned} \tag{2-28}$$

As for the intermediate uses of domestic products/services (same for the products/services imported), the total value of the generic product/service *m* used as intermediate input by 63 sectors in the region *R* is calculated as:

$$Int_{m}^{R} = \sum_{s=1}^{63} Int_{ms}^{R} = \sum_{s=1}^{63} Int_{ms}^{IT} c_{s}^{R} \tag{2-29}$$

The total value of a generic product/service *m* consumed as input by 63 sectors in the region *R* is derived from the aggregation of each sector's consumption of *m* in the region. For a generic sector *s*, the proportion of its consumption of *m* in the region to that at national level is equal to the coefficient of the sectorial employment in the region.

Besides export, the table of use distinguishes the following 6 final uses:

1) Spesa per consumi finali delle famiglie (Final consumption expenditure of households);
2) Spesa per consumi finali delle istituzioni sociali senza scopo di lucro al servizio delle famiglie (ISP) (Final consumption expenditure of non-profit social institutions serving

households);

3) Spesa per consumi finali delle amministrazioni pubbliche (AA. PP.) (Final consumption expenditure of general government);
4) Investimenti fissi lordi (Gross fixed capital formation,GFCF);
5) Oggetti di valore (Valuables);
6) Variazione di scorte (Variation of stocks).

As for the final use 1), 2), 3) and 5), it is assumed that the consumption is proportional to the population. Thusly the value of a generic domestic product *m* (same for imported *m*) used for these four usages in the region *R* is given by the eq. (2-30):

$$F_{mu}^{R} = F_{mu}^{IT} \cdot c_{pop}^{R}, \quad u = 1,2,3,5 \tag{2-30}$$

For the final use 4), 6) and export, the regional consumption of a generic product/service *m* is assumed to be of the same proportion with the total regional production of *m* comparing to nationwide data:

$$\begin{aligned} F_{mu}^{R} &= F_{mu}^{IT} \cdot r_{m}^{R}, \quad u = 4,6 \\ X_{m}^{R.est} &= X_{m}^{IT.est} \cdot r_{m}^{R} \end{aligned} \tag{2-31}$$

The result of the national data division, for each of the 20 Italian regions and for the 5 provinces, 387 municipalities in Lazio, consists of:

- The local production of 63 products/services from 63 economic sectors;
- The local consumption of 63 products/services produced in Italy in 63 economic sectors and 6 final uses, as well as the export to abroad;
- The local consumption of 63 products/services imported from abroad in 63 economic sectors and 6 final uses.

All productions and consumptions are at basic prices (export is at fob price); the structure is shown in Table 2-8.

Table 2-8 Structure of the result of national data division

Province / municipality		Million € basic prices current prices																	
			Use of domestic products									Use of foreign products							
n.	Product	Local production	Intermediate	Household	ISP	AA.PP.	GFCF	Valuables	Stocks	Export to abroad	Total	Intermediate	Household	ISP	AA.PP.	GFCF	Valuables	Stocks	Export to abroad	Total

2.3.3 Allocation of intra-regional and inter-regional flows of Italian regions

To model the trade flows between the 20 Italian regions, it is needed to identify, at regional level, the origin area from which come the products/services, basing on the regional account balance showed in eq.(2-1) and the conditions in eq.(2-2).

2.3.3.1 Definition of coefficients

1) National and regional technical coefficient

As presented in the section 2.2.2.1, the definition of technical coefficient depends on the meaning of the numerator. In our case, despite the list of products/services corresponds to the list of branches of economic activities, a product/service has more than one manufacturing sector, and a sector has more than one product/service. Therefore, the value of "the output of sector *m* consumed by sector *s* "is not equal to the value of "the product/service *m* consumed by sector *s*". We defined the technical coefficient as "the value of product/service *m* consumed by sector *s* to produce one monetary unit of sectorial output of *s*", taking account of the following reasons:

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

In the calculation of national technical coefficients, the denominators are assigned the values of the total supply of each sector in the national table of supply at basic prices of 2011 "sup11" of "SUPPLY_63B.xls". Since the table of supply has indicated only the total value of import by the product, but not by sector, the so-defined denominators do not include the import. Consequently, the numerator Int_{ms} refers only to the uses of domestic products/services, as in eq.(2-28).

The national technical coefficient a_{ms}^{IT} is calculated as:

$$a_{ms}^{IT} = Int_{ms}^{IT} / P_s^{IT} = Int_{ms}^{IT} \Big/ \sum_{m=1}^{63} P_{ms}^{IT} \qquad (2\text{-}32)$$

As for the regional technical coefficient a_{ms}^{R}, by definition it could be calculated as:

$$a_{ms}^{R} = Int_{ms}^{R} / P_s^{R} \qquad (2\text{-}33)$$

where the total production of sector *s* in the region *R* can be derived by:

$$P_s^R = \sum_{m=1}^{63} P_{ms}^{IT} \cdot c_s^R = P_s^{IT} \cdot c_s^R \qquad (2\text{-}34)$$

With the eq.(2-29), (2-33) and (2-34), one can get:

$$a_{ms}^{R} = \frac{Int_{ms}^{R}}{P_{s}^{R}} = \frac{Int_{ms}^{IT} \cdot c_{s}^{R}}{P_{s}^{IT} \cdot c_{s}^{R}} = \frac{Int_{ms}^{IT}}{P_{s}^{IT}} = a_{ms}^{IT} \qquad (2\text{-}35)$$

It shows that the technical coefficients are equal at both local and national level, as mentioned in the eq.(2-6) in the section 2.2.2.1.

2) Coefficient of intra-regional input for final uses

For each of the 6 final uses (see page 50), the coefficient of intra-regional input for final use k_{mu}^{R} is defined as:

$$k_{mu}^{R} = F^{\circ R}_{mu} / F_{mu}^{R}, \quad u = 1, 2, 3, 4, 5, 6 \qquad (2\text{-}36)$$

3) Coefficient of FLQ

The FLQ is adopted for its better performance on accuracy. Comparing to other two LQ methods, its application requires additionally the assignment of the parameter δ. Various studies have investigated the impact of the value of δ on the result obtained (Tohmo, 2004) (Flegg & Tohmo, 2013) (Bonfiglio & Chelli, 2008) (Flegg, et al., 1995) (Flegg & Webber, 1997); $\delta = 0.3$ is suggested.

By definition, the FLQ involves the sectorial employment to measure the relative dimension of the supplies of the product/service *m* and the output of the sector *s* that uses *m*. In our case, however, the measurement based on sectorial employment does not match precisely the relative dimension of the regional production of the product/service. Therefore we have decided to calculate the FLQ with the production data: $SLQ_{m}^{R} = \frac{P_{m}^{R} / P^{R}}{P_{m}^{IT} / P^{IT}}$, $SLQ_{s}^{R} = \frac{P_{s}^{R} / P^{R}}{P_{s}^{IT} / P^{IT}}$, $\lambda^{R} = \left[\log_{2}(1 + P^{R} / P^{IT}) \right]^{0.3}$.

When applying the FLQ in the field of final uses, the product/service is consumed by the whole population so $SLQ_{u}^{R} = 1$, while the total regional production of the product/service is measured by the same methods as for intermediate uses.

2.3.3.2 Allocation of the flows and calibration of the estimation

For the flows of intermediate uses, with the eq.(2-8) and (2-11) as well as the modification above, one can get:

$$\begin{aligned} &\hat{I}nt^{\circ R}_{ms} = Int_{ms}^{R} \cdot q_{ms}^{R}, \quad \hat{I}nt'^{R}_{ms} = Int_{ms}^{R} \cdot (1 - q_{ms}^{R}), \\ &q_{ms}^{R} = \begin{cases} 1, & FLQ_{ms}^{R} \geq 1 \\ FLQ_{ms}^{R}, & \text{otherwise} \end{cases}, \quad \lambda^{R} = \left[\log_{2}(1 + P^{R} / P^{IT}) \right]^{0.3} \\ &FLQ_{ms}^{R} = CILQ_{ms}^{R} \cdot \lambda^{R} = \frac{SLQ_{m}^{R}}{SLQ_{s}^{R}} \cdot \lambda^{R} = (\frac{P_{m}^{R} / P_{m}^{IT}}{P_{s}^{R} / P_{s}^{IT}}) \cdot \lambda^{R}, \end{aligned} \qquad (2\text{-}37)$$

In eq.(2-37) the sub-conditions $m=s$ and $m\neq s$. In fact, m stands for the product/service meanwhile s stands for the sector; when they have the same value, it only significates that the product/service meets the corresponding (in classification) economic sector.

For the flows of final uses, with eq.(2-11) and (2-36) as well as the modification above, one obtains:

$$\begin{aligned}
&\hat{F}^{\circ R}_{mu} = F^{R}_{mu} \cdot k^{R}_{mu}, \quad \hat{F}^{'R}_{mu} = F^{R}_{mu} \cdot (1-k^{R}_{mu}) \\
&k^{R}_{mu} = \begin{cases} 1, & FLQ^{R}_{mu} \geq 1 \\ FLQ^{R}_{mu}, & \text{otherwise} \end{cases}, \quad \lambda^{R} = \left[\log_2 (1+ P^{R} \big/ P^{IT}) \right]^{0.3} \\
&FLQ^{R}_{mu} = SLQ^{R}_{m} \cdot \lambda^{R} = (\frac{P^{R}_{m} \big/ P^{R}}{P^{IT}_{m} \big/ P^{IT}}) \cdot \lambda^{R},
\end{aligned} \tag{2-38}$$

To check whether the estimated flows satisfy the constraint, a checking parameter is introduced, defined as:

$$g^{R}_{m} = \left(P^{R}_{m} - X^{R.est}_{m} \right) \Big/ \left(\sum_{s=1}^{63} \hat{Int}^{\circ R}_{ms} + \sum_{u=1}^{6} \hat{F}^{\circ R}_{mu} \right) \tag{2-39}$$

The adjusted flows are:

$$\begin{aligned}
&Int^{\circ R}_{ms} = \begin{cases} \hat{Int}^{R}_{ms}, & g^{R}_{m} \geq 1 \\ \hat{Int}^{R}_{ms} \cdot g^{R}_{m}, & g^{R}_{m} < 1 \end{cases}, \quad Int^{'R}_{ms} = Int^{R}_{ms} - Int^{\circ R}_{ms} \\
&F^{\circ R}_{mu} = \begin{cases} \hat{F}^{R}_{mu}, & g^{R}_{m} \geq 1 \\ \hat{F}^{R}_{mu} \cdot g^{R}_{m}, & g^{R}_{m} < 1 \end{cases}, \quad F^{'R}_{mu} = F^{R}_{mu} - F^{\circ R}_{mu}
\end{aligned} \tag{2-40}$$

The inter-regional flows are then calculated as:

$$\begin{aligned}
&I^{R.reg}_{m} = \sum_{s=1}^{63} Int^{'R}_{ms} + \sum_{u=1}^{6} F^{'R}_{mu} \\
&X^{R.reg}_{m} = \left(P^{R}_{m} - X^{R.est}_{m} \right) - \left(\sum_{s=1}^{63} Int^{\circ R}_{ms} + \sum_{u=1}^{6} F^{\circ R}_{mu} \right)
\end{aligned} \tag{2-41}$$

The regional account, whose structure is shown in Table 2-9, then consists of four parts:

- The regional production per product/service;
- The regional consumption of local products/services;
- The regional consumption of domestic products/services imported from other regions;
- The regional consumption of products/services imported from abroad.

The balance is between the first two parts.

Table 2-9 Regional account structure

Region		Million € basic prices current prices												Million € basic prices current prices														
			Use of domestic products																			Use of foreign products							
			Use of regional products											Use of inter-regionally imported products														
n.	Product	Local production	intermediate	Household	ISP	AA.PP.	GFCF	Valuables	Stocks	Export to	Total in the region (1)	Inter-regional Export (2)	Total (3) = (1)+(2)	Intermediate	Household	ISP	AA.PP.	GFCF	Valuables	Stocks	Total (4)	Total use of domestic products (5)=(3)+(4)	Intermediate	Household	ISP	AA.PP.	GFCF	Valuables	Stocks	Export	Total

To provide a clear and comprehensible representation of the regional economy, in this account table, the local production and intermediate uses are in aggregate according to the product/service.

2.3.4 Distribution of trade flows between 20 Italian regions

In the trade flows distribution, among the 63 products/services listed in the I-O tables only 21 products with physical entity are taken into account. They are listed in Table 2-10.

Table 2-10 Products studied in the distribution of trade flows

Seq. No.	Products (CPA 2008)	
	Note	1. "R" indicate "Product" or "service" according to the nature of the commodity; 2. The number refers to the corresponding division of the classification (e.g. 10_12 indicates the division 10, 11 e 12) while the letter indicates the corresponding section (e.g. B indicates section B).
1	R01	Prodotti dell'agricoltura e della caccia e relativi servizi
2	R02	Prodotti della silvicoltura, delle operazioni di taglio e trasporto dei tronchi e servizi connessi
3	R03	Pesci ed altri prodotti della pesca; prodotti dell'acquacoltura; servizi di supporto per la pesca
4	RB	Prodotti delle miniere e delle cave
5	R10_12	Prodotti alimentari, bevande e prodotti a base di tabacco
6	R13_15	Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti
7	R16	Legno e prodotti in legno e sughero (esclusi i mobili); articoli di paglia e materiali da intreccio
8	R17	Carta e prodotti di carta
10	R19	Coke e prodotti petroliferi raffinati
11	R20	Prodotti chimici
12	R21	Prodotti farmaceutici di base e preparati farmaceutici
13	R22	Articoli in gomma e in materie plastiche
14	R23	Altri prodotti della lavorazione di minerali non metalliferi
15	R24	Metalli
16	R25	Prodotti in metallo, esclusi macchine e impianti
17	R26	Prodotti informatici, elettronici ed ottici
18	R27	Apparecchiature elettriche
19	R28	Macchine ed apparecchi meccanici n.c.a.
20	R29	Autoveicoli, rimorchi e semirimorchi
21	R30	Altri mezzi di trasporto
22	R31_32	Mobilio; altri manufatti

For each product, two initial trade flows matrices have been built using the eq.(2-16) and (2-17). For each of the two initial matrices, the total deviation in absolute value between the sum of each

column/row and the already known total import/export value, shown in the eq.(2-42), is used as the indicator of iteration.

$$d_m = \sum_D \left| \sum_O sc_m^{OD} - I_m^{D.reg} \right| + \sum_O \left| \sum_D sc_m^{OD} - X_m^{O.reg} \right| \qquad (2\text{-}42)$$

The bi-proportional apportionment, as shown in eq.(2-18) and (2-19), is then applied to both initial matrices with the threshold as $d_m \leq 10^{-4}$ or d_m becomes stable in case it cannot fall below 10^{-4}. The threshold of 10^{-4} is defined considering the deviation between the total supply and total use of each product presented in the national I-O tables. The trade flows matrix of each product is obtained by taking the average value of the two final matrices.

2.4 Data analysis of Lazio region

This study has reconstructed:

- For the 5 provinces and 378 municipalities in Lazio, the table of the supply and use of domestic / imported products; the structure of the table is shown in Table 2-8. In the table the local production and intermediate inputs are aggregated to the product.
- For the Lazio and the other 19 regions, the account of the 21 regional products (i.e., excluding services) whose structure is shown in Table 2-9, and the matrices of trade flows for 21 products whose structure is illustrated in Table 2-4.

The database with the results of calculations is contained in the Excel file listed in Appendix 3.

Once built all the I-O tables related Lazio, some data analysis have been proceeded to derive information on the characteristics of production and consumption in the region. These analyses have identified, in terms of monetary value, the principal goods produced by the region, those consumed for intermediate use, and those consumed by households and for exchange. The end uses for other expenditures (those of ISPs and AA.PP, for GFCF, for valuables and for variations in stocks) were not considered because of their lower value.

Production in the Lazio region

As regards the regional production, the principal products of Lazio are refined petroleum products, alimentary products and beverages, basic pharmaceutical products and pharmaceutical preparations, metal products and chemical products; the production of these five products account for more than 50% of the total production of the 22 products, as shown in Table 2-11.

Table 2-11 Principal products of Lazio

Product	Value (M€, basic prices)	% of all products
Coke e prodotti petroliferi raffinati	7474,14	16,40%
Prodotti alimentari, bevande e prodotti a base di tabacco	6076,09	13,33%
Prodotti farmaceutici di base e preparati farmaceutici	4898,25	10,75%
Prodotti in metallo, esclusi macchine e impianti	2981,45	6,54%
Prodotti chimici	2880,93	6,32%
Altri 16 prodotti		46,65%

Comparing the values for the various provinces, it is also noticeable that the province of Rome is the largest producer of all five products. This is because the province of Rome has the largest number of employees in the majority of economic activities.

The Figure 2-1 presents how the production of these products are distributed in the provinces of Lazio region. The greater part of the production is concentrated in the province of Rome, followed by the province of Latina. Table 2-12 shows, for each of these five products, the first five municipalities in Lazio with the largest production in terms of monetary value.

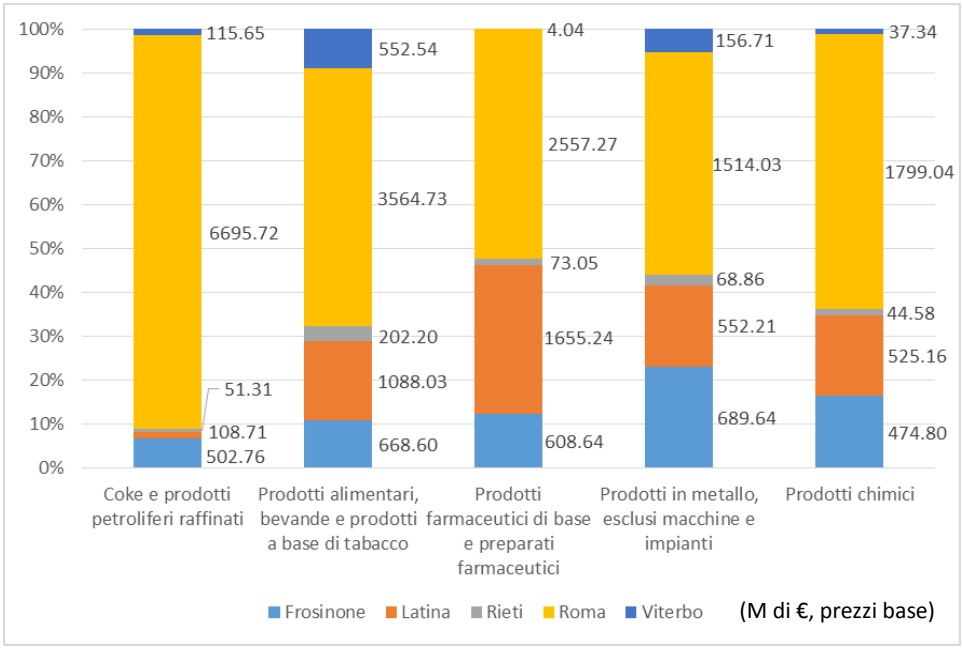

Figure 2-1 Principal products of Lazio: division at provincial level

Table 2-12 Principal products of Lazio: municipalities with greater production

Product	Municipality	Province	Value (M€)	% in Lazio
Produzione comunale - Coke e prodotti petroliferi raffinati	Roma	RM	5549,11	74,24%
	Pomezia	RM	435,38	5,83%
	Ceccano	FR	319,89	4,28%
	Ardea	RM	282,80	3,78%
	Civitavecchia	RM	182,76	2,45%
	Altri			9,42%
Produzione comunale - Prodotti alimentari, bevande e prodotti a base di tabacco	Roma	RM	2043,24	33,63%
	Pomezia	RM	346,89	5,71%
	Cisterna di Latina	LT	245,24	4,04%
	Aprilia	LT	164,46	2,71%
	Latina	LT	155,86	2,57%
	Altri			51,36%
Produzione comunale - Prodotti farmaceutici di base e preparati farmaceutici	Roma	RM	1628,92	33,26%
	Aprilia	LT	1053,48	21,51%
	Pomezia	RM	810,42	16,55%
	Anagni	FR	397,55	8,12%
	Latina	LT	332,66	6,79%
	Altri			13,78%

Table 2-12 Principal products of Lazio: municipalities with greater production (continue)

Produzione comunale - Prodotti in metallo, esclusi macchine e impianti	Roma	RM	826,00	27,70%
	Aprilia	LT	145,53	4,88%
	Latina	LT	118,16	3,96%
	Cassino	FR	114,50	3,84%
	Frosinone	FR	101,70	3,41%
	Altri			56,20%
Produzione comunale - Prodotti chimici	Roma	RM	767,89	26,65%
	Pomezia	RM	649,54	22,55%
	Aprilia	LT	222,41	7,72%
	Latina	LT	194,58	6,75%
	Anzio	RM	147,99	5,14%
	Altri			31,19%

Intermediate use in the Lazio region

Among the 5 principal domestic products for intermediate use in Lazio (Table 2-13), there are refined petroleum products, alimentary products and beverages and metal products.

Table 2-13 Principal domestic products for intermediate use in Lazio

Product	Value	% of all products
Coke e prodotti petroliferi raffinati	3539,92	13,53%
Prodotti alimentari, bevande e prodotti a base di tabacco	3143,50	12,02%
Prodotti in metallo, esclusi macchine e impianti	2747,60	10,50%
Altri prodotti della lavorazione di minerali non metalliferi	1747,46	6,68%
Prodotti dell'agricoltura e della caccia e relativi servizi	1704,00	6,51%
Altri 16 prodotti		50,76%

Figure 2-2 illustrates the distribution of quantity in terms of monetary value of these five products for intermediate use in Lazio. For each of these five domestic products, Table 2-14 shows the first five municipalities in Lazio with the largest consumption in terms of monetary value.

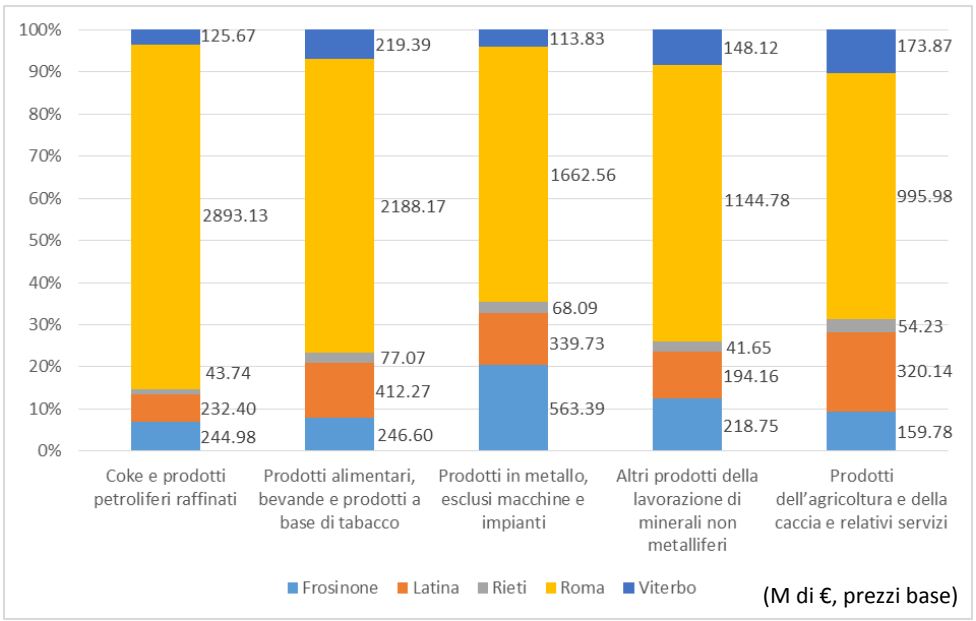

Figure 2-2 Principal domestic products for intermediate use in Lazio: division at provincial level

Table 2-14 Principal domestic products for intermediate use in Lazio: municipalities with greater consumption

Product	Municipality	Province	Value (M€)	% in Lazio
Impieghi intermedi comunali - Coke e prodotti petroliferi raffinati	Roma	RM	1914,19	54,07%
	Fiumicino	RM	459,24	12,97%
	Pomezia	RM	123,61	3,49%
	Latina	LT	64,30	1,82%
	Civitavecchia	RM	54,54	1,54%
	Altri			26,10%
Impieghi intermedi comunali - Prodotti alimentari, bevande e prodotti a base di tabacco	Roma	RM	1540,54	49,01%
	Pomezia	RM	84,09	2,67%
	Latina	LT	78,77	2,51%
	Fiumicino	RM	69,51	2,21%
	Viterbo	VT	53,55	1,70%
	Altri			41,90%
Impieghi intermedi comunali - Prodotti in metallo, esclusi macchine e impianti	Roma	RM	1126,72	41,01%
	Piedimonte San Germano	FR	172,34	6,27%
	Latina	LT	92,23	3,36%
	Cassino	FR	73,92	2,69%
	Aprilia	LT	72,75	2,65%
	Altri			44,02%
Impieghi intermedi comunali - Altri prodotti della lavorazione di minerali non metalliferi	Roma	RM	768,16	43,96%
	Latina	LT	47,41	2,71%
	Pomezia	RM	40,79	2,33%
	Aprilia	LT	33,44	1,91%
	Guidonia Montecelio	RM	27,78	1,59%
	Altri			47,49%
Impieghi intermedi comunali - Prodotti dell'agricoltura e della caccia e relativi servizi	Roma	RM	598,21	35,11%
	Pomezia	RM	66,98	3,93%
	Cisterna di Latina	LT	48,91	2,87%
	Terracina	LT	46,50	2,73%
	Latina	LT	44,80	2,63%
	Altri			52,73%

Among the principal foreign products for intermediate use in Lazio (Table 2-15) there are pharmaceutical products, chemical products and refined petroleum products.

Table 2-15 Principal foreign products for intermediate use in Lazio

Product	Valore (M€, basic prices)	% of all products
Prodotti delle miniere e delle cave	5710,09	30,21%
Prodotti farmaceutici di base e preparati farmaceutici	1992,45	10,54%
Prodotti chimici	1951,39	10,32%
Prodotti informatici, elettronici ed ottici	1678,04	8,88%
Coke e prodotti petroliferi raffinati	1637,32	8,66%
Altri prodotti		31,39%

Figure 2-3 shows, for each of these 5 foreign products most consumed for intermediate use in Lazio, the distribution of consumption at provincial level. For each of these five product, Table 2-16 shows the first 5 municipalities in Lazio with greater consumption.

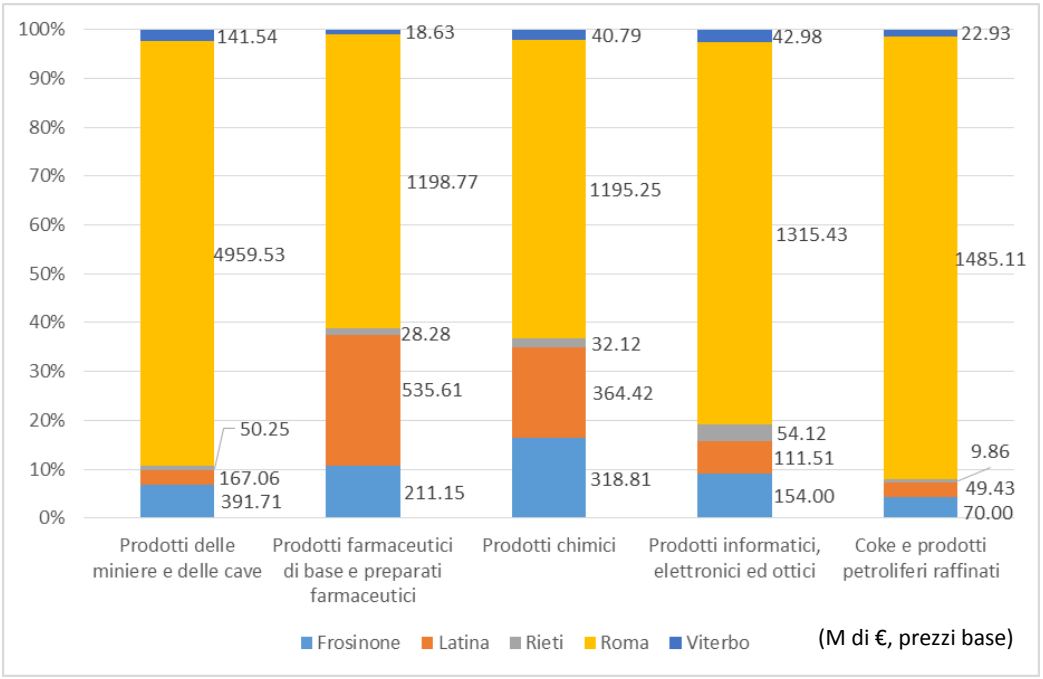

Figure 2-3 Principal foreign products for intermediate use in Lazio: division at provincial level

Table 2-16 Principal foreign products for intermediate use in Lazio: municipalities with greater consumption

Product	Municipality	Province	Value (M€)	% in Lazio
Impieghi intermedi comunali - Prodotti delle miniere e delle cave	Roma	RM	4077,08	71,40%
	Pomezia	RM	278,52	4,88%
	Ceccano	FR	188,68	3,30%
	Civitavecchia	RM	168,82	2,96%
	Ardea	RM	167,28	2,93%
	Altri			14,53%
Impieghi intermedi comunali - Prodotti farmaceutici di base e preparati farmaceutici	Roma	RM	824,19	41,37%
	Aprilia	LT	319,25	16,02%
	Pomezia	RM	247,54	12,42%
	Anagni	FR	119,45	6,00%
	Latina	LT	115,59	5,80%
	Altri			18,39%
Impieghi intermedi comunali - Prodotti chimici	Roma	RM	610,50	31,29%
	Pomezia	RM	342,79	17,57%
	Aprilia	LT	159,16	8,16%
	Latina	LT	110,26	5,65%
	Anagni	FR	103,09	5,28%
	Altri			32,06%
Impieghi intermedi comunali - Prodotti informatici, elettronici ed ottici	Roma	RM	1016,40	60,57%
	Pomezia	RM	106,04	6,32%
	Anagni	FR	62,23	3,71%
	Cisterna di Latina	LT	32,99	1,97%
	Latina	LT	25,63	1,53%
	Altri			25,91%
Impieghi intermedi comunali - Coke e prodotti petroliferi raffinati	Roma	RM	771,76	47,14%
	Fiumicino	RM	569,27	34,77%
	Pomezia	RM	38,25	2,34%
	Civitavecchia	RM	18,23	1,11%
	Latina	LT	17,89	1,09%
	Altri			13,55%

Final consumption expenditure for the families

The consumption of the families relates to the needs of life, there is no correlation detected between the products most consumed by the families and the principal products of the region. Table 2-17 and Table 2-18 show, respectively, the principal domestic and foreign products mostly consumed by the families in Lazio.

Table 2-17 Principal domestic products for the consumption of families in Lazio

Product	Value (M €, basic prices)	% domestic products
Prodotti alimentari, bevande e prodotti a base di tabacco	5237,43	41,28%
Coke e prodotti petroliferi raffinati	1773,55	13,98%
Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	1600,72	12,62%
Prodotti dell'agricoltura e della caccia e relativi servizi	1195,43	9,42%
Mobilio; altri manufatti	786,82	6,20%
Altri 16 prodotti		16,49%

Table 2-18 Principal foreign products for the consumption of families in Lazio

Prodotto	Value (M €, basic prices)	% foreign products
Autoveicoli, rimorchi e semirimorchi	1595,90	21,06%
Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	1149,01	15,16%
Prodotti alimentari, bevande e prodotti a base di tabacco	1075,80	14,20%
Prodotti delle miniere e delle cave	941,32	12,42%
Prodotti informatici, elettronici ed ottici	715,73	9,44%
Altri 16 prodotti		27,72%

As final consumption of households were assumed to be proportional to the population, the percentage of household consumption in the provinces and municipalities remains fixed, while the quantity (expressed in monetary value) varies, in general, according to the variation of the product. The provinces and municipalities with greater coefficient of population are at the first positions, as in Figure 2-4.

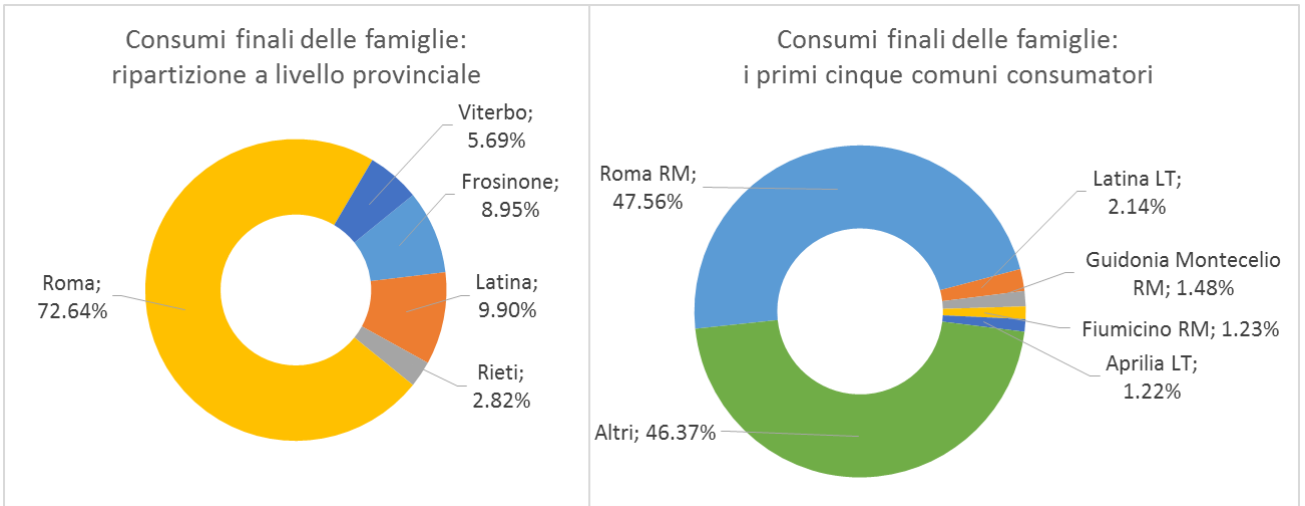

Figure 2-4 Final consumption of the families in Lazio: division at provincial level and municipalities with greater consumption

Exchange with abroad

Among the principal products of Lazio exported to abroad, there are the pharmaceutical products, petroleum products and chemical products again (Table 2-19).

Table 2-19 Principal products of Lazio for export to abroad

Product	Value (M €, basic prices)	% of domestic products
Prodotti farmaceutici di base e preparati farmaceutici	3271,88	20,28%
Coke e prodotti petroliferi raffinati	1546,43	9,59%
Prodotti informatici, elettronici ed ottici	1342,78	8,32%
Prodotti chimici	1250,56	7,75%
Macchine ed apparecchi meccanici n.c.a.	1185,99	7,35%
Altri 16 prodotti		46,70%

The distribution of the export of these products is presented in Figure 2-5. The Rome municipality is the first exporter of all the five products, as in Table 2-20.

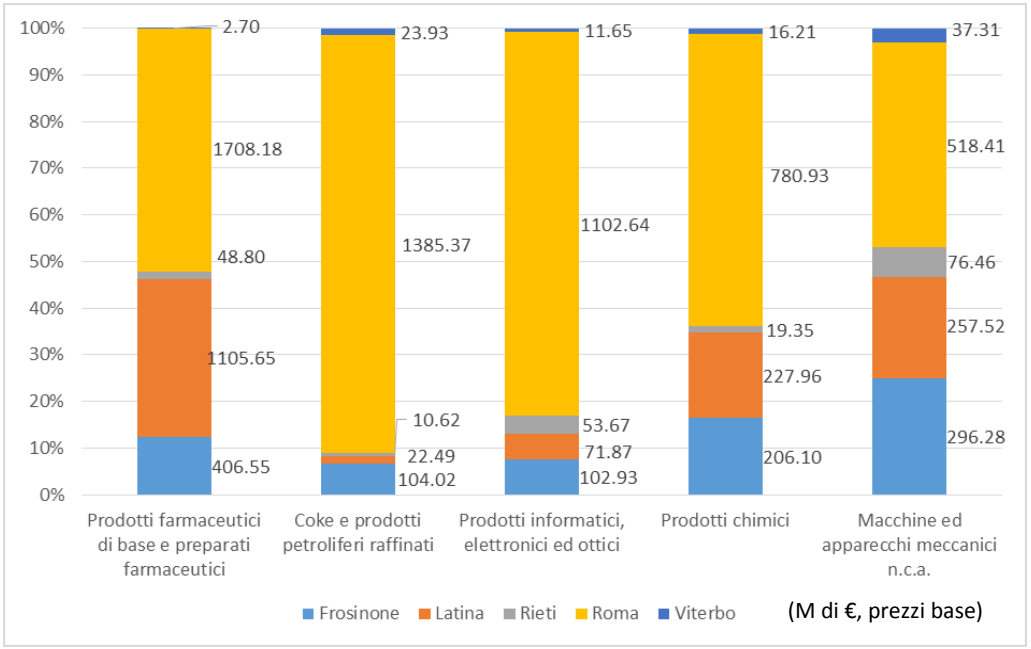

Figure 2-5 Principal products of Lazio for export to abroad: division at provincial level

Table 2-20 Principal products of Lazio for export to abroad: municipalities with greater export quantity

Product	Municipality	Province	Value (M€, basic prices)	% in Lazio
Esportazioni comunali - Prodotti farmaceutici di base e preparati farmaceutici	Roma	RM	1088,07	33,26%
	Aprilia	LT	703,70	21,51%
	Pomezia	RM	541,33	16,55%
	Anagni	FR	265,55	8,12%
	Latina	LT	222,21	6,79%
	Altri			13,78%
Esportazioni comunali - Coke e prodotti petroliferi raffinati	Roma	RM	1148,13	74,24%
	Pomezia	RM	90,08	5,83%
	Ceccano	FR	66,19	4,28%
	Ardea	RM	58,51	3,78%
	Civitavecchia	RM	37,81	2,45%
	Altri			9,42%

Table 2-20 Principal products of Lazio for export to abroad: municipalities with greater export quantity (continue)

Esportazioni comunali - Prodotti informatici, elettronici ed ottici	Roma	RM	897,68	66,85%
	Pomezia	RM	131,93	9,83%
	Anagni	FR	80,27	5,98%
	Cisterna di Latina	LT	39,35	2,93%
	Rieti	RI	26,56	1,98%
	Altri			12,44%
Esportazioni comunali - Prodotti chimici	Roma	RM	333,33	26,65%
	Pomezia	RM	281,95	22,55%
	Aprilia	LT	96,54	7,72%
	Latina	LT	84,46	6,75%
	Anzio	RM	64,24	5,14%
	Altri			31,19%
Esportazioni comunali - Macchine ed apparecchi meccanici n.c.a.	Roma	RM	277,13	23,37%
	Aprilia	LT	87,61	7,39%
	Cassino	FR	84,70	7,14%
	Piedimonte San Germano	FR	82,72	6,97%
	Pomezia	RM	75,66	6,38%
	Altri			48,75%

As for import from abroad, the 5 principal imported products from abroad is listed in Table 2-21. Regional import of foreign products is obtained by aggregating all local uses of foreign products.

Table 2-21 Principal foreign products imported in Lazio

Product	Value (M€, basic prices)	% of imported foreign products
Prodotti delle miniere e delle cave	6651.41	23.40%
Prodotti informatici, elettronici ed ottici	3176.35	11.17%
Prodotti farmaceutici di base e preparati farmaceutici	2737.39	9.63%
Autoveicoli, rimorchi e semirimorchi	2259.93	7.95%
Prodotti chimici	2132.58	7.50%
Altri 16 prodotti		40.35%

Considering all consumption of imported foreign products, the province of Rome is the biggest importer (Figure 2-6). The municipalities with greater import are listed in Table 2-22.

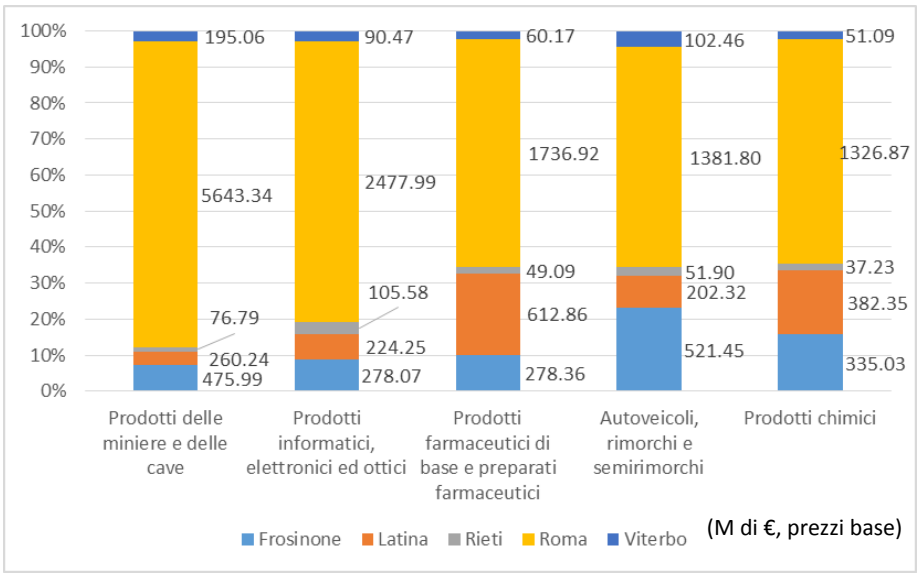

Figure 2-6 Principal foreign products imported in Lazio: division at provincial level

Table 2-22 Principal foreign products imported in Lazio: municipalities with greater import

Product	Municipality	Province	Value (M€, basic prices)	% in Lazio
Importazioni comunali - Prodotti delle miniere e delle cave	Roma	RM	4524.77	68.03%
	Pomezia	RM	288.16	4.33%
	Ceccano	FR	192.63	2.90%
	Civitavecchia	RM	177.59	2.67%
	Ardea	RM	174.84	2.63%
	Altri		1293.42	19.45%
Importazioni comunali - Prodotti informatici, elettronici ed ottici	Roma	RM	1879.98	59.19%
	Pomezia	RM	190.26	5.99%
	Anagni	FR	111.79	3.52%
	Cisterna di Latina	LT	60.55	1.91%
	Latina	LT	46.64	1.47%
	Altri		887.13	27.93%
Importazioni comunali - Prodotti farmaceutici di base e preparati farmaceutici	Roma	RM	1176.39	42.97%
	Aprilia	LT	331.29	12.10%
	Pomezia	RM	257.45	9.40%
	Latina	LT	132.23	4.83%
	Anagni	FR	123.48	4.51%
	Altri		716.55	26.18%
Importazioni comunali - Autoveicoli, rimorchi e semirimorchi	Roma	RM	889.27	39.35%
	Piedimonte San Germano	FR	248.74	11.01%
	Latina	LT	50.44	2.23%
	Cassino	FR	45.31	2.00%
	Colleferro	RM	34.38	1.52%
	Altri		991.79	43.89%
Importazioni comunali - Prodotti chimici	Roma	RM	696.68	32.67%
	Pomezia	RM	344.65	16.16%
	Aprilia	LT	161.37	7.57%
	Latina	LT	114.14	5.35%
	Anagni	FR	103.80	4.87%
	Altri		711.96	33.38%

Exchange with other Italian regions

For each region, the inter-regional export and import of the 21 products are estimated with the FLQ method, and registered in the regional account (represented in Table 2-9) under the entry "Inter-regional export (2)" of "Use of regional products" and "Total (4)" of "Use of inter-regionally imported products", respectively. The inter-regional export and import of Lazio of each product are illustrated in the Figure 2-7.

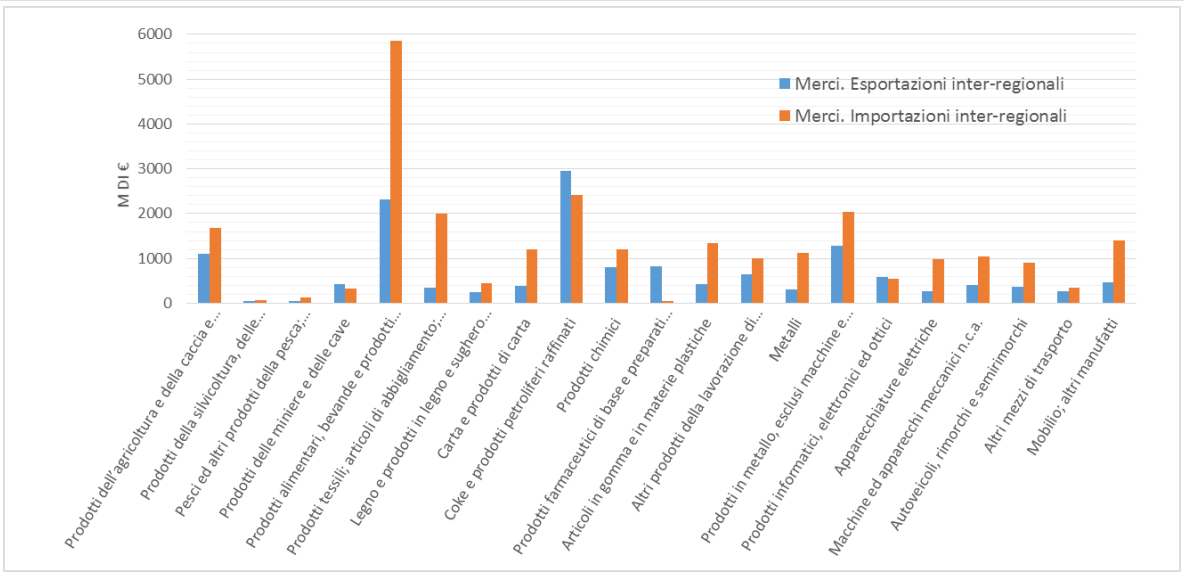

Figure 2-7 Inter-regional export/import of Lazio: 21 products

Table 2-23 and Table 2-24 present the trade flows between the Lazio and other 19 regions of each of the 21 products. These two tables are based on the inter-regional trade flow matrices (section 2.3.4). The Figure 2-8 shows the total trade flows between the Lazio and other regions in graphic form. We recall here that these flows are estimated with the bi-proportional allocation under the very restrictive assumption that inter-regional trade flows are only proportional to the production and consumption in the regions, neglecting other important factors such as the distance and, more generally, relations of complementarity.

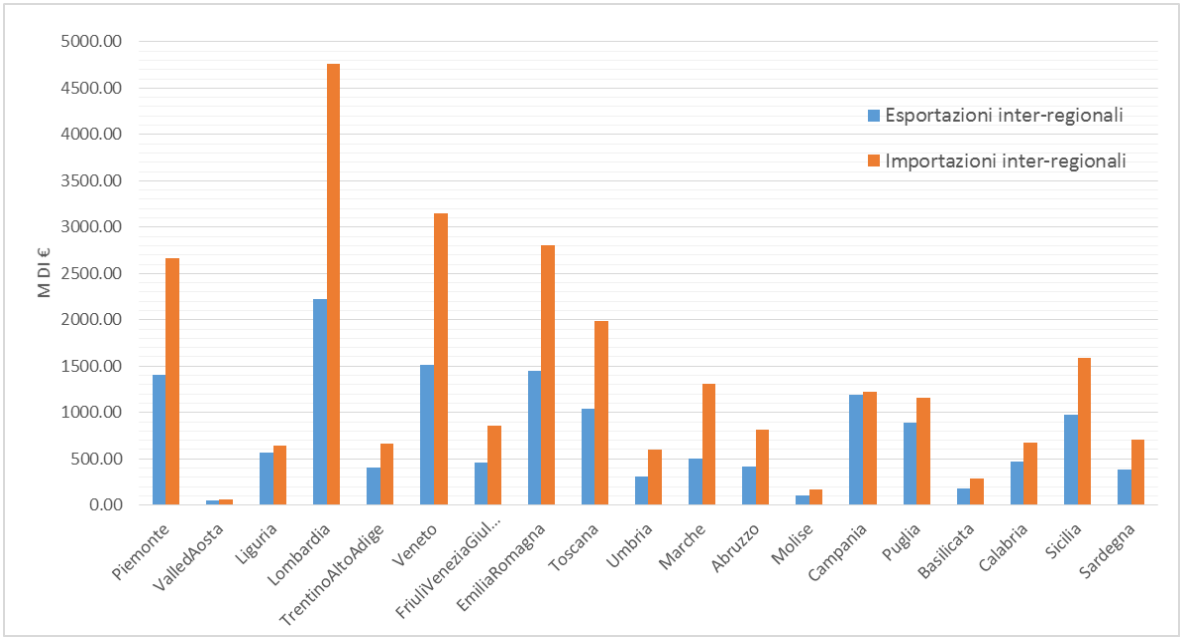

Figure 2-8 Inter-regional export/import of Lazio: exchange with other regions

Table 2-23 Export of products from Lazio to other 19 regions

Export of Lazio (M€, basic prices)		Piemonte	Valle d'Aosta	Lombardia	Trentino Alto Adige	Veneto	Friuli Venezia Giulia	Liguria	Emilia Romagna	Toscana	Umbria	Marche	Abruzzo	Molise	Campania	Puglia	Basilicata	Calabria	Sicilia	Sardegna	Total per product
R01	Prodotti dell'agricoltura e della caccia e relativi servizi	109.53	3.82	42.23	206.55	29.06	83.50	25.23	96.89	69.71	24.93	34.42	35.62	9.77	118.88	62.81	13.98	30.03	67.33	36.89	1101.18
R02	Prodotti della silvicoltura, delle operazioni di taglio e trasporto dei tronchi e servizi connessi	3.17	0.15	1.20	10.61	0.17	5.67	0.98	5.28	0.14	0.02	1.76	1.04	0.24	3.68	4.00	0.18	0.02	4.89	1.20	44.39
R03	Pesci ed altri prodotti della pesca; prodotti dell'acquacoltura; servizi di supporto per la pesca	5.39	0.21	2.59	12.61	1.58	1.04	0.98	2.65	3.87	1.10	0.10	0.50	0.22	5.03	0.05	0.67	0.83	0.17	0.02	39.59
RB	Prodotti delle miniere e delle cave	41.82	2.36	17.57	27.38	11.65	52.04	13.89	54.25	25.44	11.24	15.72	9.53	2.51	37.96	19.20	3.12	12.83	56.99	17.30	432.80
R10_12	Prodotti alimentari, bevande e prodotti a base di tabacco	166.58	11.46	95.57	381.14	84.23	219.74	70.86	165.35	191.06	49.33	82.36	64.83	17.41	179.42	145.26	29.38	106.08	179.73	76.60	2316.40
R13_15	Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	31.34	0.82	9.61	50.76	7.09	33.75	8.55	30.04	38.10	7.94	19.96	10.91	2.52	29.47	22.07	3.91	10.79	26.74	9.34	353.72
R16	Legno e prodotti in legno e sughero (esclusi i mobili); articoli di paglia e materiali da intreccio	19.83	0.81	6.91	37.78	5.69	36.86	12.12	20.58	19.24	4.84	13.42	6.49	1.34	14.25	13.71	2.94	4.86	10.71	5.16	237.53
R17	Carta e prodotti di carta	37.06	1.68	16.85	69.96	11.98	28.74	11.46	43.86	15.21	8.49	11.87	8.82	2.68	33.11	29.07	4.83	13.96	33.24	13.03	395.91
R19	Coke e prodotti petroliferi raffinati	184.95	10.81	132.32	573.35	82.87	352.02	86.32	332.82	226.71	65.76	69.56	76.10	19.47	219.43	193.64	29.90	104.64	149.34	50.79	2960.78
R20	Prodotti chimici	86.63	2.02	24.79	58.26	20.81	106.27	32.31	62.53	51.74	16.10	50.10	26.43	4.26	70.22	51.25	10.48	30.07	67.51	23.91	795.70
R21	Prodotti farmaceutici di base e preparati farmaceutici	85.09	2.33	30.50	56.87	22.71	90.19	24.70	91.82	31.75	17.74	24.26	21.94	6.12	92.71	70.73	8.45	38.03	85.71	30.39	832.06
R22	Articoli in gomma e in materie plastiche	44.94	1.54	14.48	41.79	10.86	42.37	13.84	48.46	39.48	9.59	15.21	13.93	3.67	35.17	27.37	6.96	11.40	26.52	11.16	418.75
R23	Altri prodotti della lavorazione di minerali non metalliferi	72.11	3.38	24.97	146.41	21.18	49.56	18.14	30.15	40.30	13.27	23.85	17.17	5.06	50.33	42.95	8.65	18.35	37.67	19.88	643.38
R24	Metalli	45.76	0.54	8.12	32.57	6.45	46.85	12.08	47.44	18.40	3.68	17.99	10.50	2.12	20.96	5.09	4.47	4.13	10.98	4.15	302.26
R25	Prodotti in metallo, esclusi macchine e impianti	197.60	3.33	39.92	186.97	30.43	144.63	47.47	199.07	82.03	23.08	42.13	39.69	9.27	77.43	51.90	19.85	19.36	47.54	21.42	1283.13
R26	Prodotti informatici, elettronici ed ottici	72.50	2.46	25.76	47.53	16.05	67.79	21.57	54.58	51.52	12.41	23.63	15.70	3.13	57.87	38.31	5.57	15.60	42.35	16.42	590.73
R27	Apparecchiature elettriche	38.77	1.01	9.69	26.55	7.59	17.70	7.00	30.04	20.99	5.61	5.27	9.53	2.24	22.85	17.93	4.49	7.37	18.43	7.30	260.36
R28	Macchine ed apparecchi meccanici n.c.a.	46.75	1.28	18.03	56.98	14.49	39.24	19.28	26.78	41.19	10.85	19.74	13.58	2.55	30.90	24.85	5.18	7.11	21.00	8.22	407.99
R29	Autoveicoli, rimorchi e semirimorchi	42.05	1.18	11.77	69.86	9.09	37.71	9.43	33.29	27.17	6.74	11.20	7.59	2.53	23.09	19.47	5.73	8.11	22.13	9.00	357.15
R30	Altri mezzi di trasporto	26.92	0.43	10.29	52.05	3.53	28.56	9.98	27.07	20.41	5.21	11.09	9.64	1.61	12.89	17.52	3.67	6.23	18.24	5.68	271.02
R31_32	Mobilio; altri manufatti	45.72	1.70	19.16	76.51	12.36	25.83	9.22	44.29	30.45	10.00	11.16	13.94	3.40	51.35	33.52	6.11	17.54	45.08	16.02	473.39
	Totale	1404.53	53.31	562.33	2222.48	409.88	1510.07	455.39	1447.26	1044.91	307.92	504.79	413.47	102.11	1187.01	890.70	178.50	467.33	972.34	383.88	14518.23

Table 2-24 Import of products in Lazio from other 19 regions

Import of Lazio (M€)		Piemonte	Valle d'Aosta	Lombardia	Trentino Alto Adige	Veneto	Friuli Venezia Giulia	Liguria	Emilia Romagna	Toscana	Umbria	Marche	Abruzzo	Molise	Campania	Puglia	Basilicata	Calabria	Sicilia	Sardegna	Total per product
R01	Prodotti dell'agricoltura e della caccia e relativi servizi	93.53	0.78	10.92	149.66	69.67	181.13	52.53	212.22	94.66	48.42	68.04	43.98	15.10	50.56	102.11	23.30	328.12	104.06	33.11	1681.89
R02	Prodotti della silvicoltura, delle operazioni di taglio e trasporto dei tronchi e servizi connessi	4.95	0.10	1.87	4.93	4.39	2.41	1.93	2.22	17.94	6.77	1.05	1.84	0.62	2.20	0.77	1.54	6.86	0.55	1.39	64.33
R03	Pesci ed altri prodotti della pesca; prodotti dell'acquacoltura; servizi di supporto per la pesca	0.87	0.04	4.28	2.68	0.70	20.87	4.64	15.31	5.44	0.31	11.71	6.79	1.47	3.88	11.17	0.08	4.38	28.73	11.94	135.29
RB	Prodotti delle miniere e delle cave	20.13	0.73	7.88	66.56	11.54	25.42	5.94	32.61	26.36	7.56	8.97	16.03	2.51	10.38	20.96	8.66	5.84	22.04	21.10	321.19
R10_12	Prodotti alimentari, bevande e prodotti a base di tabacco	567.96	19.95	178.96	936.23	210.18	629.62	153.97	802.41	361.17	169.10	220.24	208.03	62.23	336.93	304.66	80.40	150.54	290.20	169.94	5852.73
R13_15	Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	132.09	0.78	8.77	363.36	13.42	311.80	16.77	164.16	422.32	52.79	216.91	63.82	9.88	83.76	93.21	5.54	8.40	14.78	9.55	1992.11
R16	Legno e prodotti in legno e sughero (esclusi i mobili); articoli di paglia e materiali da intreccio	34.43	2.55	6.12	64.99	36.41	70.42	26.88	38.41	34.01	12.71	26.41	11.81	2.63	19.60	20.89	4.20	9.38	16.78	15.98	454.61
R17	Carta e prodotti di carta	105.37	0.43	13.38	233.17	39.10	184.59	50.41	101.35	173.41	35.48	70.44	57.36	3.29	63.69	30.78	4.43	5.67	20.09	8.88	1201.33
R19	Coke e prodotti petroliferi raffinati	217.84	2.90	138.49	316.79	23.07	80.52	21.87	66.15	75.94	11.09	106.40	37.07	5.98	133.95	63.95	22.27	39.45	783.07	271.48	2418.28
R20	Prodotti chimici	115.45	0.47	26.58	440.75	26.67	125.98	19.21	144.43	77.39	19.91	29.97	22.02	8.86	30.39	26.26	2.31	8.44	41.86	27.68	1194.62
R21	Prodotti farmaceutici di base e preparati farmaceutici	3.52	0.02	0.95	26.01	0.63	4.21	0.87	4.90	7.32	0.24	2.41	1.98	0.21	2.11	0.75	0.15	0.10	1.86	0.13	58.35
R22	Articoli in gomma e in materie plastiche	184.77	0.96	20.49	348.63	29.85	192.18	44.78	136.83	69.27	19.59	94.49	41.46	5.76	54.26	37.58	11.78	8.59	24.48	9.71	1335.46
R23	Altri prodotti della lavorazione di minerali non metalliferi	66.83	1.84	20.29	111.28	26.08	136.47	36.38	178.19	82.34	35.47	31.23	49.52	6.93	47.73	53.35	14.12	26.45	59.08	29.41	1013.00
R24	Metalli	105.49	15.82	28.71	312.62	20.51	133.22	60.77	89.40	59.23	44.12	25.62	19.48	2.32	29.97	136.71	5.29	5.15	15.92	22.38	1132.75
R25	Prodotti in metallo, esclusi macchine e impianti	233.12	3.83	42.06	446.65	43.61	296.53	88.12	250.20	106.02	44.93	93.17	59.98	8.77	96.90	86.01	16.44	29.10	58.90	34.14	2038.48
R26	Prodotti informatici, elettronici ed ottici	56.26	1.90	28.14	114.35	9.30	63.19	22.54	69.53	44.28	8.09	24.82	23.45	1.54	38.98	14.03	2.09	6.86	18.97	7.41	555.74
R27	Apparecchiature elettriche	96.94	2.29	25.48	220.30	18.91	161.34	62.10	116.40	52.13	18.41	94.15	16.57	4.12	46.80	15.15	5.65	3.87	11.25	3.27	975.13
R28	Macchine ed apparecchi meccanici n.c.a.	133.95	1.46	31.47	194.24	31.27	139.60	55.13	148.51	84.70	22.95	48.42	25.81	4.31	38.62	35.88	9.31	5.90	19.36	5.98	1036.88
R29	Autoveicoli, rimorchi e semirimorchi	350.98	1.95	9.33	94.30	14.23	45.28	12.70	80.56	33.18	8.17	11.36	62.05	20.12	65.44	27.03	50.52	1.29	14.66	1.14	904.31
R30	Altri mezzi di trasporto	39.08	0.12	19.81	66.96	1.37	36.03	17.03	30.35	34.06	5.93	15.34	10.07	0.75	24.73	20.45	2.29	4.19	14.36	3.78	346.71
R31_32	Mobilio; altri manufatti	101.98	2.19	22.75	250.69	30.17	311.12	99.97	120.48	123.74	26.51	106.57	32.78	4.53	41.25	57.36	15.75	13.17	29.74	13.62	1404.36
	Totale	2665.54	61.11	646.74	4765.13	661.05	3151.95	854.53	2804.63	1984.90	598.54	1307.73	811.89	171.91	1222.15	1159.06	286.14	671.76	1590.74	702.05	26117.55

Based on the data in Table 2-23 and Table 2-24, the following information has been identified:

1. the 5 main regions to which Lazio exports the majority of its products, and 3 principal products exported in each of those regions (Table 2-25);
2. the 5 main products of Lazio that are exported to other regions, and 3 principal regions to which the Lazio exports each of those products (Table 2-26);
3. the 5 main regions from which Lazio imports the majority of products, and 3 principal products imported from each of those regions (Table 2-27);
4. the 5 main products imported in Lazio from other regions, and 3 principal regions from which Lazio imports each of those products (Table 2-28).

Table 2-25 Inter-regional export of Lazio: principal destination

Region	Value (M€)	% total esp.	Principal products exported to destination region	Value (M€)	% region
Lombardia	2222,48	15,31%	Coke e prodotti petroliferi raffinati	573,35	25,80%
			Prodotti alimentari, bevande e prodotti a base di tabacco	381,14	17,15%
			Prodotti dell'agricoltura e della caccia e relativi servizi	206,55	9,29%
			Altri 18 prodotti		47,76%
Veneto	1510,07	10,40%	Coke e prodotti petroliferi raffinati	352,02	23,31%
			Prodotti alimentari, bevande e prodotti a base di tabacco	219,74	14,55%
			Prodotti in metallo, esclusi macchine e impianti	144,63	9,58%
			Altri 18 prodotti		52,56%
Emilia-Romagna	1447,26	9,97%	Coke e prodotti petroliferi raffinati	332,82	23,00%
			Prodotti in metallo, esclusi macchine e impianti	199,07	13,76%
			Prodotti alimentari, bevande e prodotti a base di tabacco	165,35	11,43%
			Altri 18 prodotti		51,82%
Piemonte	1404,53	9,67%	Prodotti in metallo, esclusi macchine e impianti	197,60	14,07%
			Coke e prodotti petroliferi raffinati	184,95	13,17%
			Prodotti alimentari, bevande e prodotti a base di tabacco	166,58	11,86%
			Altri 18 prodotti		60,90%
Campania	1187,01	8,18%	Coke e prodotti petroliferi raffinati	219,43	18,49%
			Prodotti alimentari, bevande e prodotti a base di tabacco	179,42	15,12%
			Prodotti dell'agricoltura e della caccia e relativi servizi	118,88	10,02%
			Altri 18 prodotti		56.38%
Altre 14 regioni	6746.88	46,47%			

Table 2-26 Inter-regional export of Lazio: principal exported products

Product	Value (M€)	% total esp.	Principal destinazion	Value (M€)	% product
Coke e prodotti petroliferi raffinati	2960,78	20,39%	Lombardia	573,35	19,36%
			Veneto	352,02	11,89%
			Emilia-Romagna	332,82	11,24%
			Altre 16 regioni		57,50%
Prodotti alimentari, bevande e prodotti a base di tabacco	2316,40	15,96%	Lombardia	381,14	16,45%
			Veneto	219,74	9,49%
			Toscana	191,06	8,25%
			Altre 16 regioni		65,81%
Prodotti in metallo, esclusi macchine e impianti	1283,13	8,84%	Emilia-Romagna	199,07	15,51%
			Piemonte	197,60	15,40%
			Lombardia	186,97	14,57%
			Altre 16 regioni		54,51%
Prodotti dell'agricoltura e della caccia e relativi servizi	1101,18	7,58%	Lombardia	206,55	18,76%
			Campania	118,88	10,80%
			Piemonte	109,53	9,95%
			Altre 16 regioni		60,50%

Table 2-26 Inter-regional export of Lazio: principal exported products (continue)

Prodotti farmaceutici di base e preparati farmaceutici	832,06	5,73%	Campania	92,71	11,14%
			Emilia-Romagna	91,82	11,04%
			Veneto	90,19	10,84%
			Altre 16 regioni		66,98%
Altri 16 prodotti	6024.68	41,50%			

Table 2-27 Inter-regional import of Lazio: principal origin

Region	Value (M€)	% total imp.	Principal products imported from the origin region	Value (M€)	% region
Lombardia	4765,13	18,24%	Prodotti alimentari, bevande e prodotti a base di tabacco	936,23	19,65%
			Prodotti in metallo, esclusi macchine e impianti	446,65	9,37%
			Prodotti chimici	440,75	9,25%
			Altri 18 prodotti		61,73%
Veneto	3151,95	12,07%	Prodotti alimentari, bevande e prodotti a base di tabacco	629,62	19,98%
			Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	311,80	9,89%
			Mobilio; altri manufatti	311,12	9,87%
			Altri 18 prodotti		60,26%
Emilia-Romagna	2804,63	10,74%	Prodotti alimentari, bevande e prodotti a base di tabacco	802,41	28,61%
			Prodotti in metallo, esclusi macchine e impianti	250,20	8,92%
			Prodotti dell'agricoltura e della caccia e relativi servizi	212,22	7,57%
			Altri 18 prodotti		54,90%
Piemonte	2665,54	10,21%	Prodotti alimentari, bevande e prodotti a base di tabacco	567,96	21,31%
			Autoveicoli, rimorchi e semirimorchi	350,98	13,17%
			Prodotti in metallo, esclusi macchine e impianti	233,12	8,75%
			Altri 18 prodotti		56,78%
Toscana	1984,90	7,60%	Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	422,32	21,28%
			Prodotti alimentari, bevande e prodotti a base di tabacco	361,17	18,20%
			Carta e prodotti di carta	173,41	8,74%
			Altri 18 prodotti		51,79%
Altre 14 regioni	10745.41	41,14%			

Table 2-28 Inter-regional import of Lazio: principal imported products

Product	Value (M€)	% total imp.	Principal origin	Value (M€)	% product
Prodotti alimentari, bevande e prodotti a base di tabacco	5852,73	22,41%	Lombardia	936,23	16,00%
			Emilia-Romagna	802,41	13,71%
			Veneto	629,62	10,76%
			Altre 16 regioni		59,54%
Coke e prodotti petroliferi raffinati	2418,28	9,26%	Sicilia	783,07	32,38%
			Lombardia	316,79	13,10%
			Sardegna	271,48	11,23%
			Altre 16 regioni		43,29%
Prodotti in metallo, esclusi macchine e impianti	2038,48	7,81%	Lombardia	446,65	21,91%
			Veneto	296,53	14,55%
			Emilia-Romagna	250,20	12,27%
			Altre 16 regioni		51,27%
Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti	1992,11	7,63%	Toscana	422,32	21,20%
			Lombardia	363,36	18,24%
			Veneto	311,80	15,65%
			Altre 16 regioni		44,91%
Prodotti dell'agricoltura e della caccia e relativi servizi	1681,89	6,44%	Calabria	328,12	19,51%
			Emilia-Romagna	212,22	12,62%
			Veneto	181,13	10,77%
			Altre 16 regioni		57,10%
Altri 16 prodotti	12134.06	46,46%			

Summary

In summary, Lazio exchanges mainly with three northern regions: Lombardia, Veneto and Emilia-Romagna.

Table 2-29 shows together the principal products of the regional production, the regional uses and the inter-regional exchanges.

Table 2-29 Principal products of regional production and consumption of Lazio

Product	Regional production	Intermediate use of domestic products	Intermediate use of foreign products	Family consumption of domestic products	Export to abroad	Export to other regions	Import from other regions
Coke e prodotti petroliferi raffinati	x	x	x	x	x	x	x
Prodotti alimentari, bevande e prodotti a base di tabacco	x	x		x		x	x
Prodotti farmaceutici di base e preparati farmaceutici	x		x		x	x	
Prodotti in metallo, esclusi macchine e impianti	x	x				x	x
Prodotti chimici	x		x		x		
Altri prodotti della lavorazione di minerali non metalliferi		x					
Prodotti delle miniere e delle cave			x				
Prodotti dell'agricoltura e della caccia e relativi servizi		x		x		x	x
Prodotti informatici, elettronici ed ottici			x		x		
Mobilio; altri manufatti				x			
Prodotti tessili; articoli di abbigliamento; cuoio e relativi prodotti				x			x
Macchine ed apparecchi meccanici n.c.a.					x		
Note: the position of the products does not represent the order of the dimension of production or consumption.							

The products that Lazio mainly produces, consumes and exchanges with other regions and/or with foreign countries are the petroleum products, food and pharmaceutic products. The metal products instead appears in the national production circuit. In our case, though the relationship between products and economic sectors is not unique and exclusive, the greater part of the production of a generic product comes from the corresponding economic sector. Therefore, the industry of food, petroleum, pharmaceutic, as well as the manufacturing of metal products are the main components of the economic system of Lazio; their productive activity generates the major part of the inter-regional trade flows.

2.5 Traffic data

The economy model obtained above describes the economic condition and the demands of freight transport. These data of demands should be converted into traffic information such as, for example, tons transported, the traffic in the road network, ton-km/vehicle-km, etc. One methodology of such conversion may require data about the value density of products, handling factors, modal split, transport distance, vehicle capacity and loading factors. Once the conversion is completed, analyst could then forecast the traffic by estimating the freight transport demand with the economic model. An alternative is to estimate a linkage between the trade flows (derived

from the economic model) and the observed shipping flows (usually originated from statistics resources) based on the OD matrices of road, inner waterway and railway network (Cascetta & Iannò, 2000). With this linkage the variations forecasted of the economic model in terms of freight transport demand will be reflected in the traffic flow patterns; depending on the data contained in the observed shipping flows dataset, such patterns may include traffic distributed in the transport network, and other performance indicators of the freight transport system.

With regard to the observed traffic data, the European project ETISplus has offered an online database of transport at the webpage: http://viewer.etisplus.net . The acronym "ETIS" stands for "European Transport policy Information System". The tables of data are organized in three different sections: "observed data", "harmonized data" and "modelled data" (ETIS PLUS Consortium, 2013):

- Observed data: data originating from official statistics publications, as Eurostat.
- Harmonized data: data obtained by combining, aggregating or splitting one or more observed data sources (for example, combining Eurostat flows by origin with those by destination so as to obtain an O/D matrix).
- Modelled data: data estimated with opportune models (including representation of transport network)

The modelled data is the most complete and it concerns the worldwide traffic information. The classification of goods "Standard Goods for Transport Statistics (NST/R)" is applied, which includes the goods in 52 groups (Eurostat, 1967) (Appendix 2: Classification NST/R). The flows are measured in tons, and modes of transport in the database are: air, road, rail, inland waterways, maritime and multimodal chains.

Focusing on the domestic shipping flows, ETISplus has data on shipping flows in tonnes between the Italian provinces in 2010 for each of the 52 product groups NST/R in relation to the road, rail, inland waterways and maritime transport. Full details of these flows in the Italian provinces are shown in the attached file "Report PRMTL - Annex ETISplus data 2010.xlsx".

The flows have as origin and destination the Lazio region are shown in Figure 2-9, Figure 2-10, and Figure 2-11 for railway, road and sea transport, respectively. Figure 2-12shows instead the total flows. Note that the flow-Lazio Lazio are the flows between the different provinces of the region. In Lazio there are flows of goods along inland waterways.

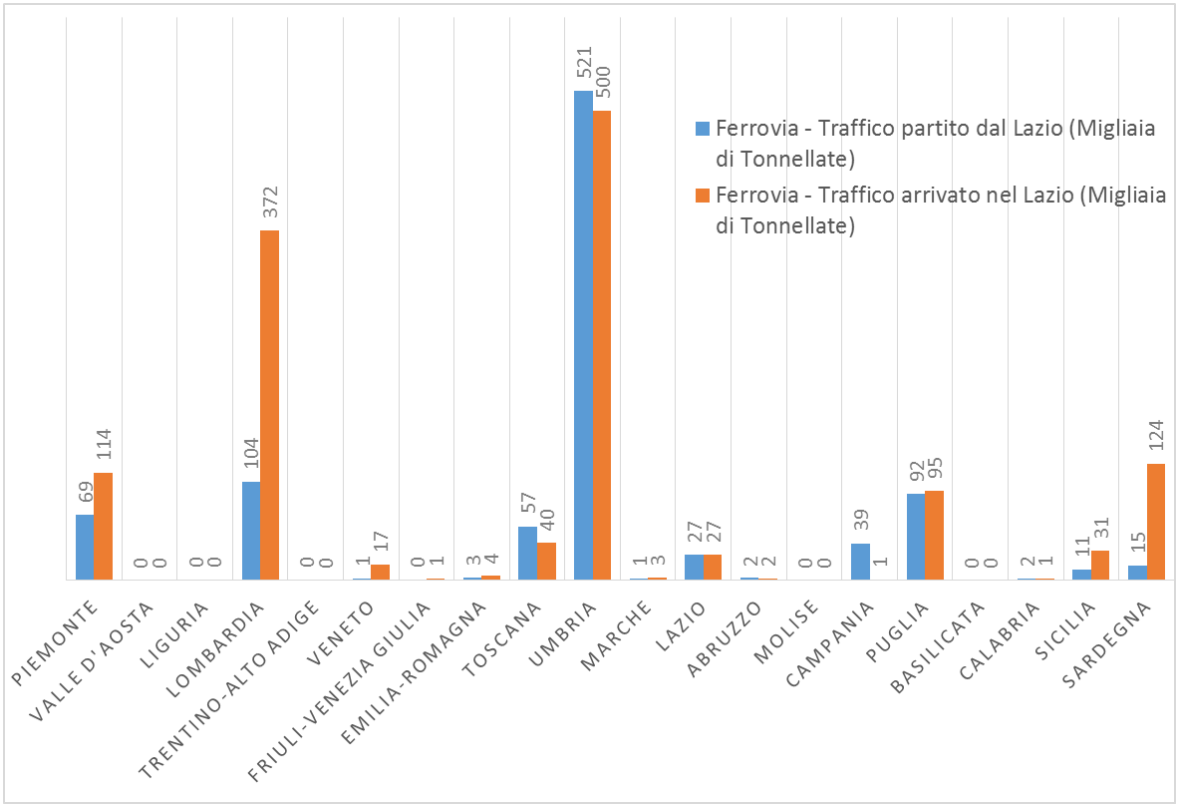

Figure 2-9 Traffic of goods 2010 ETISplus – Railway

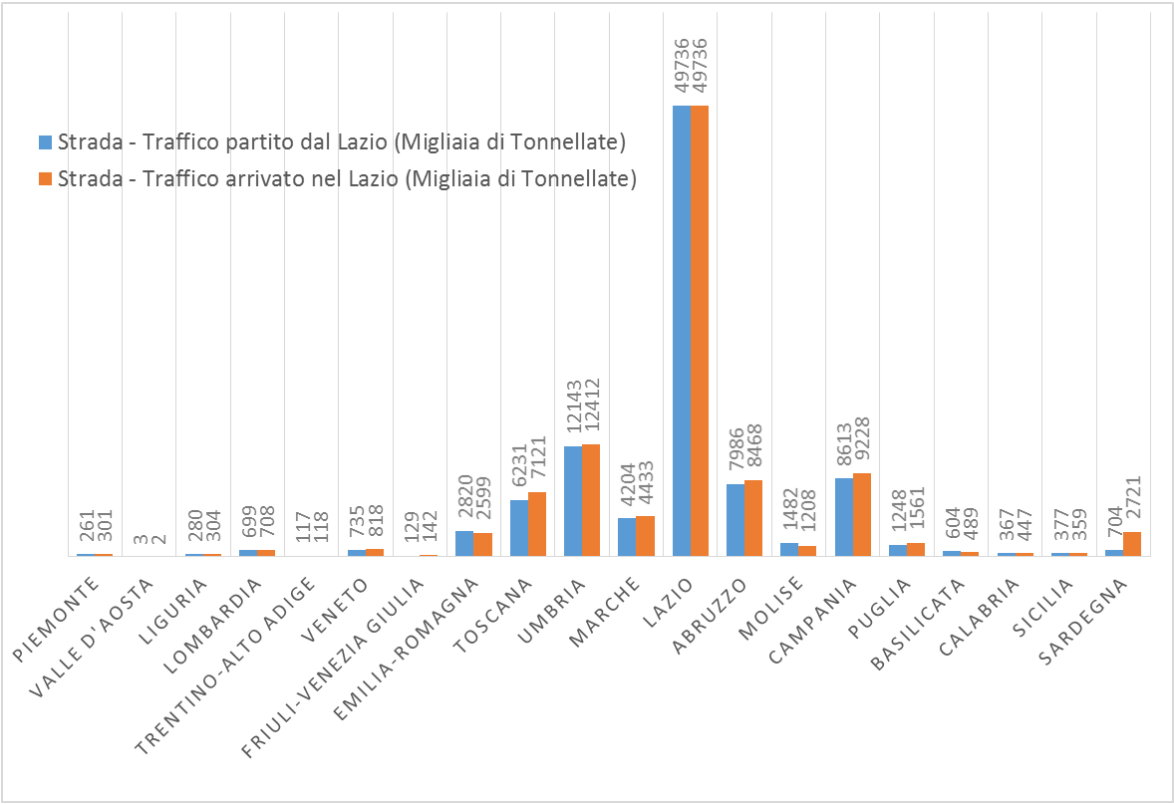

Figure 2-10 Traffic of goods 2010 ETISplus – Road

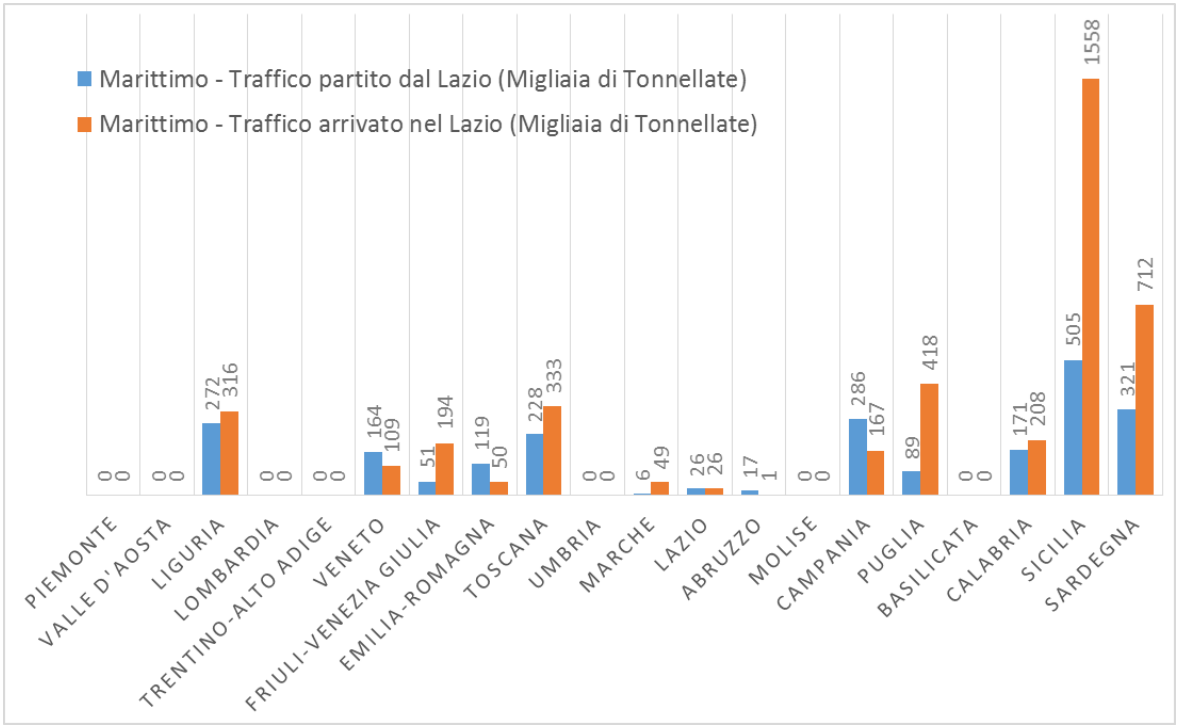

Figure 2-11 Traffic of goods 2010 ETISplus – Maritime

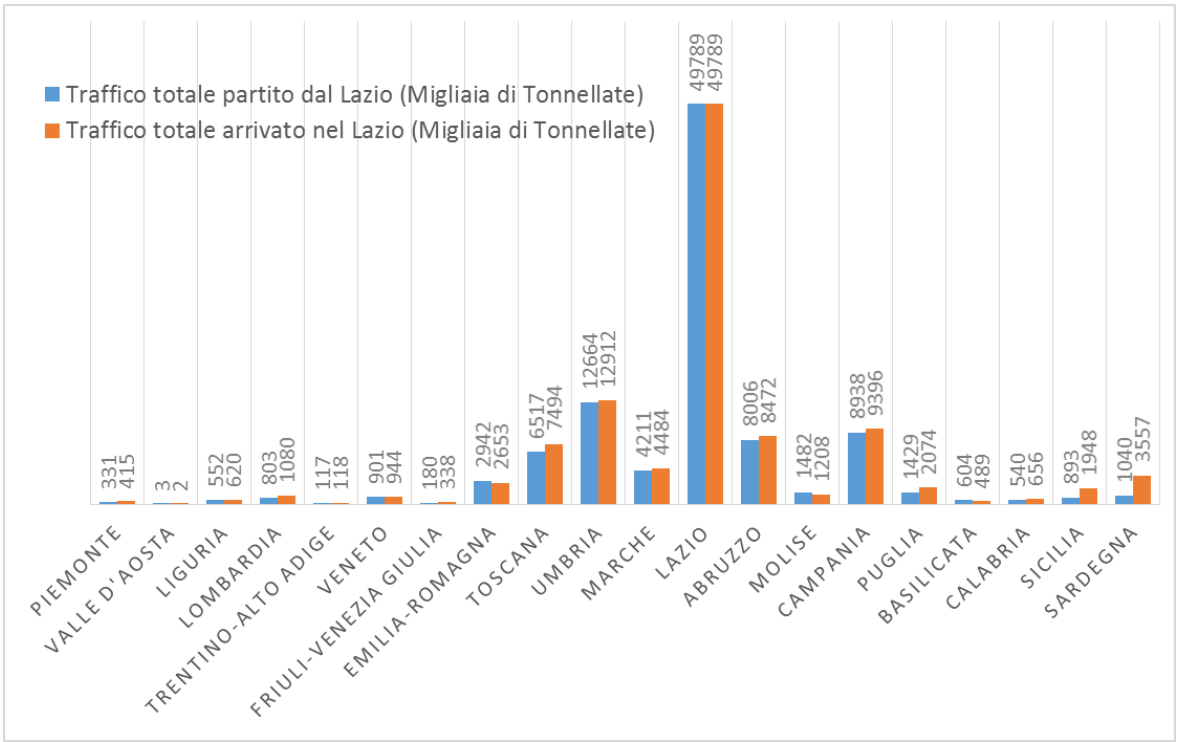

Figure 2-12 Traffic of goods 2010 ETISplus - Total

The matrices of trade flows obtained in the section 2.3.4 indicate the flows (in terms of value) of products from the origin region to the region of final destination, without showing eventual transit points; while the traffic flows of ETISplus (in tons) represents flows between every O-D pair, such a flow may stand for a complete trade flow, or a part of a trade flow that consists of several

transits. The link vector contains 20×20 variables; each variable corresponds to one pair of O-D. This vector will be estimated in a way that with the corresponding variables the trade flows derived above can be converted into traffic flows collected by ETISplus. With the linking vector thusly estimated, when the economic condition varies, the impacts of economic changes on traffics will be captured. The classification of goods used in the traffic database and that of the economic model should be uniformed, or at least harmonized that one can switch the data from one classification to another by simply combining / dividing the corresponding numbers. It is also preferable that all the data are of the same base year.

2.6 Conclusion

The analysis of economy is necessary for freight transport and logistics planning; such analysis needs usually a large dimension and detailed dataset. In the freight transport field, the heterogeneity of data and difficulty in data collection persist. The non-survey methods with relatively lower data requirement can overcome the problems. Based on the data published by national institute of statistics, this study has drawn a picture of the economy condition in the region of Lazio, by using non-survey methodology including Input-Output model, Location Quotients and Bi-proportional model. Compared to the IRIO/MRIO model and gravity model, the combination of these three methods is proved efficient and less complicated in the modelling of trade flows of products between geographic units on a territory. It should be noted that the bi-proportional model is subject to the very restrictive assumption that interregional exchanges are defined as only proportional to the production and consumption in the regions, without taking into account other factors such as, for example, the distance, the cost of transport, the economic complementarity etc. Nevertheless, once the economic model is built, one can establish a link between this and available traffic data; in this way one can forecast the impacts of changes in the economic variables on traffic.

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APPENDIX 1: NACE REV.2 AND CPA 2008 CLASSIFICATION

NACE Rev.2				CPA 2008			
Section		Division		Section		Division	
A	Agriculture, forestry and fishing Agriculture, forestry and fishing	1	Crop and animal production, hunting and related service activities	A	Products of agriculture, forestry and fishing	1	Products of agriculture, hunting and related services
		2	Forestry and logging			2	Products of forestry, logging and related services
		3	Fishing and aquaculture			3	Fish and other fishing products; aquaculture products; support services to fishing
B	Mining and quarrying	5	Mining of coal and lignite	B	Mining and quarrying	5	Coal and lignite
		6	Extraction of crude petroleum and natural gas			6	Crude petroleum and natural gas
		7	Mining of metal ores			7	Metal ores
		8	Other mining and quarrying			8	Other mining and quarrying products
		9	Mining support service activities			9	Mining support services
C	Manufacturing	10	Manufacture of food products	C	Manufactured products	10	Food products
		11	Manufacture of beverages			11	Beverages
		12	Manufacture of tobacco products			12	Tobacco products
		13	Manufacture of textiles			13	Textiles
		14	Manufacture of wearing apparel			14	Wearing apparel
		15	Manufacture of leather and related products			15	Leather and related products
		16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials			16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
		17	Manufacture of paper and paper products			17	Paper and paper products
		18	Printing and reproduction of recorded media			18	Printing and recording services
		19	Manufacture of coke and refined petroleum products			19	Coke and refined petroleum products
		20	Manufacture of chemicals and chemical products			20	Chemicals and chemical products
		21	Manufacture of basic pharmaceutical products and pharmaceutical preparations			21	Basic pharmaceutical products and pharmaceutical preparations
		22	Manufacture of rubber and plastic products			22	Rubber and plastic products
		23	Manufacture of other non-metallic mineral products			23	Other non-metallic mineral products
		24	Manufacture of basic metals			24	Basic metals
		25	Manufacture of fabricated metal products, except machinery and equipment			25	Fabricated metal products, except machinery and equipment
		26	Manufacture of computer, electronic and optical products			26	Computer, electronic and optical products
		27	Manufacture of electrical equipment			27	Electrical equipment
		28	Manufacture of machinery and equipment n.e.c.			28	Machinery and equipment n.e.c9.
		29	Manufacture of motor vehicles, trailers and semi-trailers			29	Motor vehicles, trailers and semi-trailers
		30	Manufacture of other transport equipment			30	Other transport equipment
		31	Manufacture of furniture			31	Furniture
		32	Other manufacturing			32	Other manufactured goods

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

NACE Rev.2				CPA 2008			
Section		Division		Section		Division	
		33	Repair and installation of machinery and equipment			33	Repair and installation services of machinery and equipment
D	Electricity, gas, steam and air conditioning supply	35	Electricity, gas, steam and air conditioning supply	D	Electricity, gas, steam and air conditioning	35	Electricity, gas, steam and air conditioning
E	Water supply; sewerage, waste management and remediation activities	36	Water collection, treatment and supply	E	Water supply; sewerage, waste management and remediation services	36	Natural water; water treatment and supply services
		37	Sewerage			37	Sewerage services; sewage sludge
		38	Waste collection, treatment and disposal activities; materials recovery			38	Waste collection, treatment and disposal services; materials recovery services
		39	Remediation activities and other waste management services			39	Remediation services and other waste management services
F	Construction	41	Construction of buildings	F	Constructions and construction works	41	Buildings and building construction works
		42	Civil engineering			42	Constructions and construction works for civil engineering
		43	Specialised construction activities			43	Specialised construction works
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45	Wholesale and retail trade and repair of motor vehicles and motorcycles	G	Wholesale and retail trade services; repair services of motor vehicles and motorcycles	45	Wholesale and retail trade and repair services of motor vehicles and motorcycles
		46	Wholesale trade, except of motor vehicles and motorcycles			46	Wholesale trade services, except of motor vehicles and motorcycles
		47	Retail trade, except of motor vehicles and motorcycles			47	Retail trade services, except of motor vehicles and motorcycles
H	Transportation and storage	49	Land transport and transport via pipelines	H	Transportation and storage services	49	Land transport services and transport services via pipelines
		50	Water transport			50	Water transport services
		51	Air transport			51	Air transport services
		52	Warehousing and support activities for transportation			52	Warehousing and support services for transportation
		53	Postal and courier activities			53	Postal and courier services
I	Accommodation and food service activities	55	Accommodation	I	Accommodation and food services	55	Accommodation services
		56	Food and beverage service activities			56	Food and beverage serving services
J	Information and communication	58	Publishing activities	J	Information and communication services	58	Publishing services
		59	Motion picture, video and television programme production, sound recording and music publishing activities			59	Motion picture, video and television programme production services, sound recording and music publishing
		60	Programming and broadcasting activities			60	Programming and broadcasting services
		61	Telecommunications			61	Telecommunications services
		62	Computer programming, consultancy and related activities			62	Computer programming, consultancy and related services
		63	Information service activities			63	Information services
K	Financial and insurance activities	64	Financial service activities, except insurance and pension funding	K	Financial and insurance services	64	Financial services, except insurance and pension funding
		65	Insurance, reinsurance and pension funding, except compulsory social security			65	Insurance, reinsurance and pension funding services, except compulsory social security
		66	Activities auxiliary to financial services and insurance activities			66	Services auxiliary to financial services and insurance services
L	Real estate activities	68	Real estate activities	L	Real estate services	68	Real estate services
M	Professional, scientific and	69	Legal and accounting activities	M	Professional, scientific and	69	Legal and accounting services
		70	Activities of head offices; management consultancy activities			70	Services of head offices; management consulting services

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Section		Division		Section		Division	
	technical activities	71	Architectural and engineering activities; technical testing and analysis		technical services	71	Architectural and engineering services; technical testing and analysis services
		72	Scientific research and development			72	Scientific research and development services
		73	Advertising and market research			73	Advertising and market research services
		74	Other professional, scientific and technical activities			74	Other professional, scientific and technical services
		75	Veterinary activities			75	Veterinary services
N	Administrative and support service activities	77	Rental and leasing activities	N	Administrative and support services	77	Rental and leasing services
		78	Employment activities			78	Employment services
		79	Travel agency, tour operator and other reservation service and related activities			79	Travel agency, tour operator and other reservation services and related services
		80	Security and investigation activities			80	Security and investigation services
		81	Services to buildings and landscape activities			81	Services to buildings and landscape
		82	Office administrative, office support and other business support activities			82	Office administrative, office support and other business support services
O	Public administration and defence; compulsory social security	84	Public administration and defence; compulsory social security	O	Public administration and defence services; compulsory social security services	84	Public administration and defence services; compulsory social security services
P	Education	85	Education	P	Education services	85	Education services
Q	Human health and social work activities	86	Human health activities	Q	Human health and social work services	86	Human health services
		87	Residential care activities			87	Residential care services
		88	Social work activities without accommodation			88	Social work services without accommodation
R	Arts, entertainment and recreation	90	Creative, arts and entertainment activities	R	Arts, entertainment and recreation services	90	Creative, arts and entertainment services
		91	Libraries, archives, museums and other cultural activities			91	Library, archive, museum and other cultural services
		92	Gambling and betting activities			92	Gambling and betting services
		93	Sports activities and amusement and recreation activities			93	Sporting services and amusement and recreation services
S	Other service activities	94	Activities of membership organisations	S	Other services	94	Services furnished by membership organisations
		95	Repair of computers and personal and household goods			95	Repair services of computers and personal and household goods
		96	Other personal service activities			96	Other personal services
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97	Activities of households as employers of domestic personnel	T	Services of households as employers; undifferentiated goods and services produced by households for own use	97	Services of households as employers of domestic personnel
		98	Undifferentiated goods- and services-producing activities of private households for own use			98	Undifferentiated goods and services produced by private households for own use
U	Activities of extraterritorial organisations and bodies	99	Activities of extraterritorial organisations and bodies	U	Services provided by extraterritorial organisations and bodies	99	Services provided by extraterritorial organisations and bodies

APPENDIX 2: NST/R CLASSIFICATION

NST2	NST2
0	Live animals
1	Cereals
2	Potatoes
3	Other fresh or frozen fruit and vegetables
4	Textiles textile articles and man-made fibres
5	Wood and cork
6	Sugar-beet
9	Other raw animal and vegetable materials
11	Sugars
12	Beverages
13	Stimulants and spices
14	Perishable foodstuffs
16	Other non-perishable foodstuffs and hops
17	Animal food and foodstuff waste
18	Oil seeds and oleaginous fruit and fats
21	Coal
22	Lignite and peat
23	Coke
31	Crude petroleum
32	Fuel derivatives
33	Gaseous hydrocarbons liquid or compressed
34	Non-fuel derivatives
41	Iron-ore
45	Non-ferrous ores and waste
46	Iron and steel waste and blast furnace dust
51	Pig iron and crude steel
52	Semi-finished rolled steel products
53	Bars sections wire rod railway and tramway track construction
54	Steel sheets plates hoop and strip
55	Tubes pipes iron and steel castings and forgings
56	Non-ferrous metals
61	Sand gravel clay and slag
62	Salt iron pyrites sulphur
63	Other stone earths and minerals
64	Cement lime
65	Plasters
69	Other manufactured building materials
71	Natural fertilisers
72	Chemical fertilisers
81	Basic chemicals
82	Aluminium oxide and hydroxide
83	Coal chemicals
84	Paper pulp and waste paper
89	Other chemical products
91	Transport equipment
92	Tractors
93	Other machinery apparatus and appliances engines parts thereof
94	Manufactures of material
95	Glass glassware ceramic products
96	Leather textiles and clothing
97	Other manufactured articles
99	Miscellaneous articles

APPENDIX 3: ATTACHED FILES

1. Thesis attached file – Table of provinces and municipalities of Lazio 2011.xlsx

Content: For each province and municipality in Lazio region, the table that records, in terms of monetary value, the total local production of each of the 21 products (CPA2008), and the total intermediate uses, 6 final consumptions and export to abroad for each of the 21 products domestically produced and imported from abroad.

2. Thesis attached file – Regional account 2011.xlsx

For each region of Italy, the account that presents in terms of monetary value:

- total regional production of each of the 21 products;
- regional uses and export to abroad and to other regions of each of the 21 products locally produced;
- regional uses of each of the 21 products from other regions;
- regional uses and export to abroad of each 21 products imported from abroad.

Regional uses include the total intermediate use and 6 final consumptions.

3. Thesis attached file – Trade flows 2011.xlsx

For each of the 21 products, the matrix that illustrates the estimated trade flows between the regions in terms of monetary value.

4. Thesis attached file – ETISplus traffic data 2010.xlsx

For each transport mode (railway, road, inland waterway and maritime), the matrix that records the total inter-regional trade flows in tons of all 52 products of the classification NST/R. In this dataset the flows with abroad are excluded.