AN ATTEMPT TO QUANTIFY THE TECHNOLOGICAL CHANGE IN ITALY THROUGH A MULTISECTORAL FRAMEWORK: A COMPARATIVE ANALYSIS[1]

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1. Introduction

In recent years, European countries are experiencing the so called "Fourth Industrial Revolution" that is meant to have a pervasive impact, in its magnitude and ramification, on all the aspects of the society (Schwab, 2017). Its effects, indeed, would spread in a pervasive way in both private and public sectors, including academia and civil society. This Revolution is intended to be the final point of a slow process that has begun in 1760 with the First Industrial Revolution that introduces the mechanization of production by means of water and steam power. The further development goes in the direction of the introduction of electricity in the production and constitutes the Second Industrial Revolution. The Third Industrial Revolution introduces the automated production by means of information and communication technology. (Mattioli, Lamonica, 2013). This automation tendency would be completed in the Fourth Industrial Revolution that is expected to merge the physical, digital, and biological areas. (Xu, 2018). Even if this latest Revolution is intended to develop the process started during the Third one, it is aimed to create a discontinuity with the previous one in relation to the speed, aim and impact on the whole society. At first, the speed of the recent innovations has an exponential rate, if compared to the previous Revolutions in every industry and country. The strength of the transformations involves the whole productive system and governance. This new environment increases and widens the possibilities of people to access to knowledge by means of mobile devices with extraordinary processing power. This disruptive force emerged by new technology, such as artificial intelligence, robotics, the Internet of Things, and biotechnology. (Wortmann and Flüchter, 2015). Recently, large progress has developed in Artificial Intelligence encouraged by computing power and the huge availability of data, from software to find new drugs to algorithms to calculate cultural interests and monitor life habits of Internet users. The

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Fourth Industrial Revolution could raise income levels and the quality of life of people around the world. Technological progress will also influence the supply side with long term gains in efficiency and productivity. The decrease of costs of transportation and communication and the implementation and development of global supply chains stimulate the emergence of new markets and lead the economic growth. The negative aspect is to be found in the labour market. Machines will substitute the so called "blue collars" workers and there will be a gap between returns to capital and labour. On the other side, new skills will emerge that can include the so called "superstar workers", characterised by higher skilled tasks not subjected to the substitutability between human and machine. (Brynjolfsson and McAfee, 2014).

Our aim is to provide a quantitative and comparative picture of the transition from the Third to the Fourth Industrial Revolution. Such transition is important since, even if they are two distinct phases, the second one is grounded on the first and each country attains the second at different times, according to its performance. (Popkova et al., 2019). For a comparative analysis with our country, we have chosen The Netherlands: this country occupies the 4th position in the Global Competitive Index (hereafter GCI) ranking of 2019, behind Singapore the United States and Hong Kong, overtaking Germany and Switzerland. (Schwab, 2019). Its innovation capability is at 10th place in the world and its ICT adoption is at 24th place. Opposite, Italy is graded at the 30th place (53rd in ICT adoption and 22nd place in Innovation Capability). This work starts from the observation that, starting from the early 2000, the different countries invest in ICT in different time periods and at different time lags, so the technological outcomes do not find immediate and evident feedbacks in the macroeconomic data. To reach this aim, focusing on the period of the Third Industrial Revolution, we would quantify, if possible, and at what extent, the advancement of the technological progress in Italy, based on observed data, in relation to The Netherlands.

In this work, the linkage analysis has been performed. Hauknes and Knell, (2009), define intersectoral linkages as "techno-economic connections between industries, embodied in the exchange of tangibles and intangibles". The linkage analysis, pioneered by Leontief in 1936, (Leontief, 1941), began to spread starting from 1950s, in consequence of the acceleration of industrialisation in developing countries. Industrialisation, indeed, induced scholars to focus on how to quantify the relative importance of the various industries, to the aim of identifying key industries for economic development and high-speed economic growth, (Cuello et al., 1992). In particular, the linkage analysis aims at assessing the relationship between and within industries and evaluating the role of the industries and the performance of the economic system and optimize the industrial structure of the national economy. Our work is based on two approaches belonging to the "Classical Multiplier Method", i.e., the Rasmussen and Laumas methods, and compares two Leontief- based linkages showing the differences between a technology-based approach (Rasmussen linkages) and the approach that weights Rasmussen's Forward Linkages for value added and Rasmussen's Backward Linkages for final demand. (Rasmussen, 1956; Laumas, 1976). These traditional outcomes of Input- Output analysis, today acquire a renewed relevance in the study of value chains in terms of upstream and downstream position. (Guerrieri and Meliciani, 2005).

The paper is divided in four Sections. Section 2 describes data and methodology adopted in the work; Section 3 shows the results of linkages analysis. In Section 4, the conclusion.

2. Data description and methodology

Data used in our analysis belong to the World Input-Output Database, (WIOD) that provides an historical series of Input-Output tables of all the European countries. (Timmer et al, 2015). The choice of this database is linked to the fact that it provides a homogeneous statistical basis through which the outcomes can be conveniently compared. From this database we retrieved national Input-Output tables of Italy and the Netherlands. To detect the impact of ICT on macroeconomic data, we have analyzed the four ICT sectors in the 56 sectors classification of WIOD, shown in Table 1.

Table 1 – *ICT Sectors included in Section J of the International Standard Industrial Classification of All Economic Activities Rev. 4 (ISIC 4.0)*

ISIC Code	**Section J — INFORMATION AND COMMUNICATION**
Division 58	Publishing activities
Division 59	Motion picture, video and television programme production, sound recording and music publishing activities
Division 61	Telecommunications
Division 62	Computer programming, consultancy and related activities

In addition, with reference to the recommendations of the International Standard Industrial Classification of All Economic Activities Rev. 4 (ISIC 4.0), and following De Siena (2019), we have further extracted four ICT components from four macro sectors, two sectors related to manufacture, i.e. Manufacture of computer, electronic and optical products and Repair and installation of machinery and equipment, and two sectors related to trade, i.e. Wholesale trade, except of motor vehicles and motorcycles and Retail trade, except of motor vehicles and motorcycles. From each of these four sectors we extract a portion that we attribute to ICT. This component has been obtained, aggregating the four sectors of Section J- ICT and calculating the weights of ICT included in each of these four sectors. By means of these weights, we decompose each of these four sectors, in the part of the sector linked to ICT, and the sector not related to ICT. The newly defined *ICT- related* sectors are shown in Table 2.

Table 2 – *"ICT- related" sectors, our elaborations on International Standard Industrial Classification of All Economic Activities Rev. 4 (ISIC 4.0)*

ICT related sectors	
Division 26- ICT	Manufacture of computer, electronic and optical products
Division 33-ICT	Repair and installation of machinery and equipment,
Division 46-ICT	Wholesale trade, except of motor vehicles and motorcycles
Division 47-ICT	Retail trade, except of motor vehicles and motorcycles

This new classification leads to a 60 sector Input- Output matrix both for Italy and the Netherlands.

The methodology consists in the linkage analysis. Intersectoral linkages are defined as techno economic connections between industries, determined by the exchange of goods and services. Linkage analysis allows to define and quantify the role of each sector in relation to the provider sectors, upstream position, and customer sectors, downstream position (Hauknes, 2009; Reis and Rua, 2009).

The basic model for the linkage analysis is the Leontief model (Leontief, 1941) that reads as:

$$x = Ax + f \tag{1}$$

where x defines the vector of total output by industry and equals the intermediate consumption vector, Ax, plus the final demand vector by industry, f.
Starting from equation (1), we can write:

$$x = Rf \tag{2}$$

where: $R = (I\text{-}A)^{-1}$ is the Leontief Inverse, i.e., the matrix of direct and indirect intermediate requirements per unit of output. This matrix provides a fundamental tool for the quantification of the relevance of every industry in stimulating upstream the other industries of the economy and contributing downstream to the provision and realization of the sectoral outputs.

Our work is based on the Rasmussen Linkages, (Rasmussen, 1956). This approach is directly based on the Leontief inverse, and for that reason is referred to as technological linkage.

Rasmussen approach provides two indexes, the Backward Linkage that indicates the average direct and indirect impact on the whole productive system, in terms of average purchases of intermediate goods, due to a unitary increase in final demand of the good produced in a given sector. Mathematically:

$$BL_j = \frac{\frac{1}{n}\sum_{i=1}^{n} R_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} R_{ij}} \tag{3}$$

The Backward Linkage of sector *j* is obtained computing the average of the column of the Leontief inverse and dividing matrix *R* by the average of the whole matrix, average coefficient of the sector divided by average coefficient of the whole economy).

The Forward Linkage defines the average direct and indirect impact on the whole productive system, in terms of sales of intermediate good by the sector to the other sectors in the economy, due to a unitary increase in the final demands for the goods produced by all the other sectors. In formulas:

$$FL_i = \frac{\frac{1}{n}\sum_{j=1}^{n} R_{ij}}{\frac{1}{n^2}\sum_{j=1}^{n}\sum_{j=1}^{n} R_{ij}} \tag{4}$$

The Forward Linkage of sector *i* results from the average of the row of the Leontief inverse and dividing it by the average of the coefficients of the whole matrix.

A further analysis will be performed with reference to the linkage weighted by the shares of value added and final demand, (Laumas, 1976). This method highlights the relevance of each sector in facing two basic instances of economic content: the final demand provision and the income generation (value added). Rasmussen linkages are, indeed modified through the correction of each index with the weight of the sector in satisfying its final demand and value added. In particular, the Backward Linkage weighted by Value Added reads as:

$$BL_j^{va} = \frac{\frac{1}{n}\sum_{i=1}^{n} w_j R_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_j R_{ij}} \tag{5}$$

where: $w_i = \frac{va_i}{\sum_{i=1}^{n} va_i}$ is the weight represented by the share of value added of sector *i* over the total value added. The so obtained weighted backward linkage is determined scaling the Leontief inverse by column, with the percentage weight of the sectoral value added with respect to the total value added and dividing the average of the column by the average of the matrix.

The Forward Linkage weighted by the final demand is determined analytically as:

$$FL_i^f = \frac{\frac{1}{n}\sum_{j=1}^{n} w_i R_{ij}}{\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i R_{ij}}$$

where: $w_j = \frac{f_j}{\sum_{i=1}^{n} f_j}$ defines the weight, i.e., the share of final demand of sector *j* over the total final demand. This index is obtained scaling the Leontief by row using the percentage of the final demand of the given sector over the total final demand and dividing the average of the row by the average of the matrix.

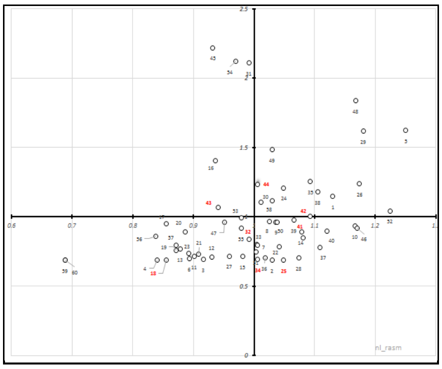
3. Results of Linkage Analysis

Figure 1 shows the outcomes of Rasmussen analysis with reference to the two countries under scrutiny, i.e. The Netherlands and Italy. In the graph, the axes are centred on the value 1. Sectors in the first quadrant have both backward and forward linkages higher than 1, and are defined, following Rasmussen, *Key Sectors*.

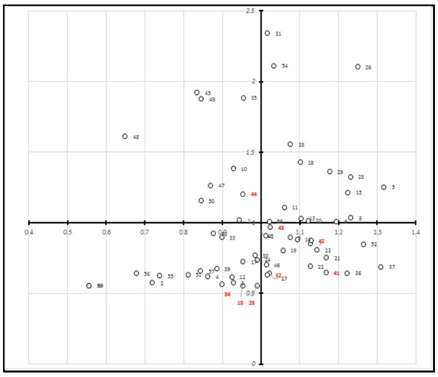
This group of sectors sells and purchases goods and services in an amount higher than the average of all the other sectors. The second quadrant refers to the *Prime Vendors*, i.e., those sectors that sell by an amount higher than the average and purchases for an amount lower than the average of the other sectors. In the third quadrant we can find the *Low Impact Sectors* that sell and purchase goods and services for an amount lower than the average of the other sectors. The fourth quadrant comprises the *Prime Users*, that sell for an amount lower than the average and buy for an amount higher than the other sectors.

In the two Figures, *Key Sectors* are highlighted in red. These Sectors constitute 25% of the total for both Italy and the Netherlands. The difference between the outcomes of the two countries consists in the composition of the sectors. *Key Sectors* for Italy are, in prevalence, traditional sectors, linked to the so called *Made in Italy*, such as: *S6-Manufacture of textiles, wearing apparel and leather products, S8-Manufacture of paper and paper products, S11-Manufacture of chemicals and chemical products, S13-Manufacture of rubber and plastic products, S15-Manufacture of basic metals* and *S16- Manufacture of fabricated metal products, except machinery and equipment.* Differently from Italy, The Netherlands seems to show a higher propensity to services sectors.

Figure 1 – *Outcomes of Rasmussen Linkages for The Netherlands (a) and Italy (b).*



(a)

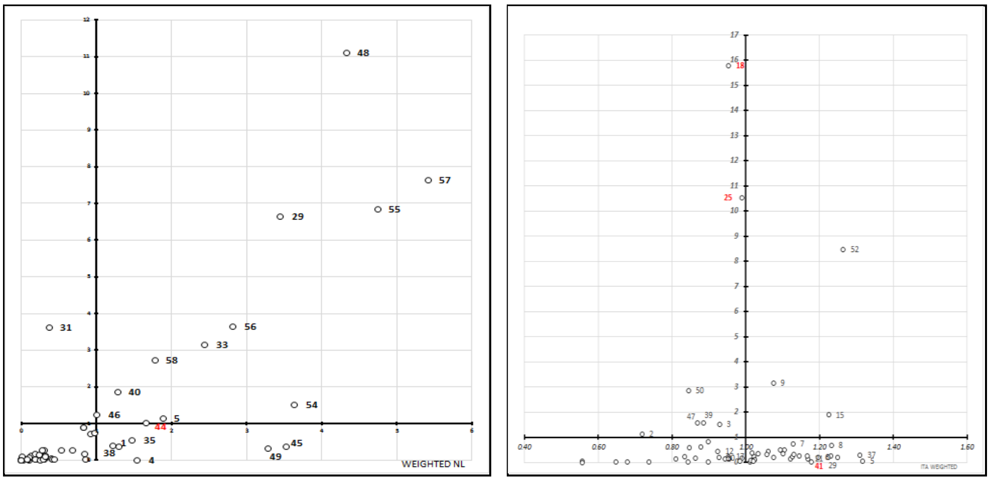


(b)

In The Netherlands, *Key Sectors* group comprises sectors as *S48-Real estate activities and S49-Legal and accounting activities; activities of head offices; management consultancy activities.* In addition, this group includes also *S42-Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities* and *S44-Computer programming, consultancy, and related activities; information service activities*, these sectors, as described in Section 2, belong to the ICT sectors of Section J of ISIC Rev.4. Figures 2(a)- (b) shows the outcome of the Weighted Rasmussen Linkages. Using these indexes, the situation changes radically. Figure 2(a) shows an outcome that seems to underline, even more than that of Rasmussen approach, a propensity of The Netherlands to the shift to sectors linked to services, in terms of fulfilment of final demand and creation of value added. Indeed, within the twelve *Key Sectors* (almost the 20%), retrieved for this country, we can find, *S55- Public administration and defence; compulsory social security*, *S56- Education* and *S57- Human health and social work activities.*

In Italy, as highlighted by Figure 2(b), with this approach, there are only three *Key Sectors*, (5% of the total), i.e., *S9- Printing and reproduction of recorded media, S15- Manufacture of basic metals* and *S52- Advertising and market research*. It is worth noting, that, almost all the sectors related to "Made in Italy", even losing their status of *Key Sectors*, keep a relevant position as *Prime Users*. With reference to ICT, the Figures show that, in Italy, there are no ICT-sectors within *Key Sectors* group, while *S44-Computer programming, consultancy, and related activities; information service activities*, is, also in the weighted approach, included in *Key Sectors* for The Netherlands.

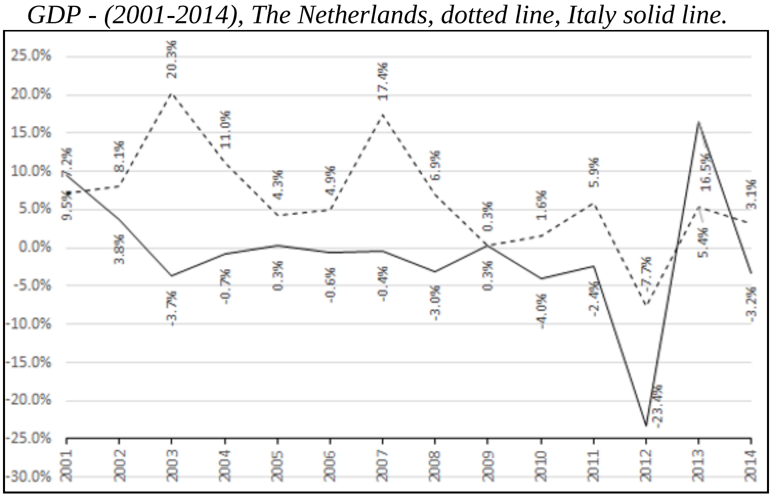
Figure 2 – *Outcomes of Weighted Rasmussen Linkages, The Netherlands (a) and Italy (b).*



(a) **(b)**

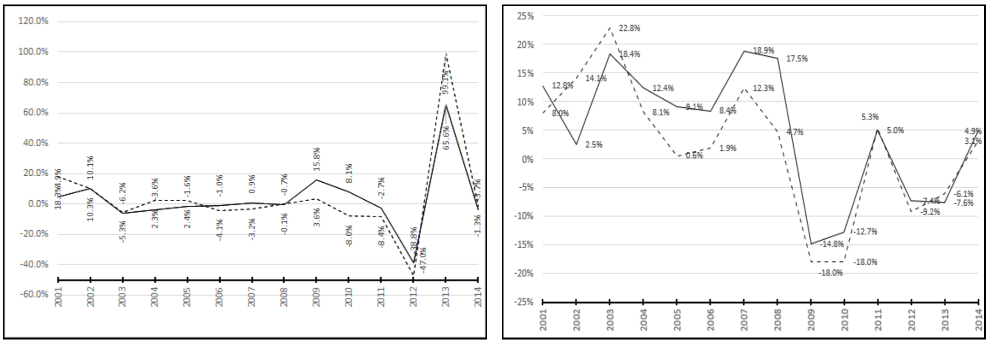
The last analysis has been performed with reference to the historical series of the percentage change of the output in ICT with respect to GDP.

Figure 3 – *Percentage change of Information and Communication Technology output w.r.t. GDP - (2001-2014), The Netherlands, dotted line, Italy solid line.*



As highlighted by Figure 3, in The Netherlands the growth rate is positive in most of the time interval, while Italy always performed a negative, or nearly zero growth rate. Both of the countries exhibit a negative growth rate around year 2012, probably in consequence of the crisis of subprime mortgages of 2007-2008 and then there is a recovery. The already discussed tendency is also confirmed by the historical series of the percentage changes of private investments and public expenditure in ICT with respect to GDP. Figures 4(a) and 4(b), indeed, show a nearly zero growth rate for Italy and a positive rate for The Netherlands, except for the years after 2007-2008, with negative growth rates in consequence of the economic crisis. In the latest years, Figures show a slight recovery in both countries.

Figure 4 – *Perc. change of investments (solid line) and government. final expenditure (dotted line) in ICT w.r.t. GDP, (a) Italy and (b) The Netherlands, (2001-2014).*



(a) **(b)**

4. Conclusion

In recent years, studies on technological progress highlight the emergence of the era of Fourth Industrial Revolution focused on digitalisation of productive processes. This new phase of Industrial Revolution is intended to lead the transition from Human to Machine to Machine to Machine transformation.

The aim of the work is to concentrate on the previous phase of the Industrial Revolution, i.e., the Third Industrial Revolution considered as a preparatory phase of provision of new tools for the information and communication, at the basis of the expected future technological advance.

The aim of this work is to evaluate quantitatively, as possible, the place of the Italian economy in implementing the Information and Communication Technology, comparing the Italian outcomes with those of The Netherlands, a European country that occupies the 4th place, behind Singapore, the United States and Hong Kong, overtaking Germany and Switzerland. Its innovation capability is at 10th place in the world and its ICT adoption is at 24th place.

The analysis adopts the multisectoral Input-Output viewpoint, starting from the last available Input- Output Flow Tables retrieved from the WIOD database. This database provides a homogeneous statistical basis from which the sectoral macroeconomic results of the two countries can be conveniently compared.

The linkage analysis is referred to Rasmussen linkages, and then final demand and value-added weighted Rasmussen indexes. Emerging results from linkage analysis with Rasmussen show 25% of sectors that exhibit values of linkages higher than the average with respect to the other sectors in stimulating the whole productive system upstream and downstream for both the countries. Nevertheless, it is possible to highlight several peculiarities in the performance of Italian with respect to Dutch economy. In Italy, the majority of Key Sectors seem to pertain to the so called "Made in Italy", traditional sectors. These sectors are included within the category of Low Impact sectors in The Netherlands, where most sectors are linked to services.

Further differences between the two economies emerge when deepening the analysis by means of the weighted Rasmussen Linkages. In this case, Italy has only three Key Sectors (5% of all sectors), while The Netherlands seems to have twelve Key Sectors (20% of all sectors) dealing with services. With reference to the aim of detecting the emergence of ICT in empirical data, there are no ICT-sectors within Key Sectors in Italy while there are two ICT-related Key sectors for The Netherlands with Rasmussen and one ICT-related Key sectors following the weighted Rasmussen approach. The historical series analysis confirms a longer period interest for The Netherlands, in promoting investments and public expenditure in ICT sectors with respect to Italy, even if in recent years Italy exhibits a slight recovery maybe also due to the approaching innovative policies linked to the National Plan Industry 4.0. Further developments go in the directions of extending this comparative analysis to the other European countries.

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SUMMARY

An attempt to quantify the technological change in Italy through a multisectoral framework: a comparative analysis

The fourth Industrial Revolution, centred on the digitalisation of the productive processes, is intended to develop the process started during the Third one, but also to create a discontinuity with the previous one in relation to the speed, aim and impact on the whole society.

The aim of this work is to evaluate quantitatively, as possible, the place of the Italian economy in implementing the Information and Communication Technology, comparing the Italian outcomes with those of The Netherlands, that occupies the 4th place in the Global Competitive Index ranking.

Starting from the last available Input- Output Flow Tables retrieved from the WIOD database, an interindustry linkage analysis is performed, whose results could confirm and detail the different position of the two economies in the world ranking. The linkage analysis confirms the higher propensity of The Netherlands of investing in ICT and the major concern of Italy in the valorisation of the "Made in Italy".

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