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Abstract

Three main shocks have affected advanced economies over the last 25 years, with significant consequences for work, production and economic growth. The first is technological change associated with robotics and the so-called Fourth Industrial Revolution. The second, which is partly related to the first, is the diffusion of ICT and the development of intelligent software applied both to industry and tertiary activities. The third is the strong competitive pressure from low cost and emerging countries, which have changed the geography of world production and trade flows, often within global value chains. Following the seminal papers of Acemoglu and Restrepo (2017) and Dauth, Findeisen, Südekum and Woessner (2017), the aim of this paper is to assess the impact of these three shocks on employment in Italian local labour markets in the period 1991-2011. What is new in our approach is the explicit consideration of the role played by the different typologies of local labour systems and industrial districts. We find that robots do not have any negative effect on employment in local labour markets. On the contrary, robots seem to be associated with a growth in overall employment, mainly due to the tertiary sector. The second result is that there is some evidence of a positive effect of ICT investments on local employment, in particular non-manufacturing employment. The last and most robust result of the econometric analysis is the negative impact of trade with low cost countries on local employment. This result has one almost absolute protagonist: China. All these impacts are not homogeneous across the national territory and partly depend on the characteristics of the local productive systems and industrial districts.

Keywords: Robots, ICT, Globalization, Local Labour Markets, Industrial Districts
JEL codes: F16; F66; L60; L80, O33, R12

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1. Introduction

Three main shocks have affected advanced economies over the last 25 years, with significant consequences for work, production and economic growth. The first is related to the profound technological changes in manufacturing processes associated with robotics and the so-called Fourth Industrial Revolution. The second, which anticipated the first and is partly linked to it, concerns investment in new information and communication technologies and the development of intelligent software (ICT), applied both to industry and, to a greater extent, to many service and tertiary activities. The third shock is the emergence in international trade of highly competitive countries in terms of production costs and industrial system, such as China and some Eastern European countries, which have changed the geography of world production and trade flows, often within global value chains.

Looking at Italy alone, since the mid-1990s and during the following fifteen years, the number of robots installed has increased on average by 7% per year, investments in ICT equipment and software have grown by 3.3% per year, and the share of imports from the main low labour cost countries has increased from 4% in 1994 to 16% in 2011 (see Bonacini et al., 2020).

Several recent works have tried to estimate the impact of these three shocks on the labour market. The emphasis is mainly on employment, but other important variables such as wages and productivity are also investigated.

The main and most interesting strand focuses on the role of robots, thanks to the availability of data provided by the *International Federation of Robotics* (IFR). Robots represent an easily measurable aspect that is also highly evocative of the technological change associated with the Fourth Industrial Revolution and the transformations in manufacturing. The basic idea is that robots and workers compete in performing various work tasks and that new technologies can therefore result in job replacement and lead to unemployment in local labour markets. However, the productivity gains expected from new technologies, together with increased demand for more productive capital, can improve the efficiency of industry, increase demand for goods and services and contribute to the expansion of the economy even in sectors not directly involved in automation. The corresponding growth in overall labour demand can offset the negative effects associated with the introduction of robots (Acemoglu and Restrepo, 2019). The empirical analysis aims precisely to verify which of the two effects will prevail.

This essay studies the investment in robots together with investments in ICT capital and the competitive pressure coming from low cost countries. The aim is to assess the impact that this set of phenomena had on employment in Italian local labour markets in the period 1991-2011. Compared to the prevailing approach in the international literature, what is new in our approach is the explicit consideration of the different typologies of local systems and industrial districts. This essay is structured as follows. Paragraph 2 reviews the relevant literature and illustrates some methodological aspects related to the treatment of the main variables used in the empirical analysis. In Paragraph 3, an econometric model is proposed and the main results are presented and discussed. Paragraph 4 outlines the conclusions.

2. Distribution of shocks at the territorial level

The Digital Revolution has been studied from multiple perspectives and on different geographical scales. However, few studies attempt to measure the impact of robots on the economy; fewer still examine it in conjunction with ICT investment and international trade; even fewer studies try to assess its effects where they primarily occur: local productive systems and local labour markets. We dedicate this section to a quick review of this literature in order to highlight some methodological aspects of this approach.

Graetz and Michaels (2015) were probably the first to use the IFR database to assess the impact of robots on the economy. The analysis covers 17 advanced countries (14 European ones) and 14 industries. According to the conclusions of the study, an increase in the number of robots used led to an increase in productivity, value added and wages in the main sectors of economic activity during the period analysed (1993-2007). However, there is no evidence of significant effects in terms of employment.

From the same perspective and with a focus on Europe, Chiacchio, Petropoulos and Pichler (2018) have more recently studied the impact of robots on employment and wages in 116 regions of six European countries, including Italy. Their analysis covers the period 1995-2007. In the specifications used, they also consider the impact of both ICT investments and imports from China and the US, along with other control variables. The results show that regional employment and wages are negatively affected by the increase in robots, while increasing investments in ICT capital seem to have a positive effect.

Two works are particularly important for the purposes of this study. The first is the seminal contribution of Acemoglu and Restrepo (2017, hereinafter AR), with reference to the US, the second is a work of Dauth, Findeisen, Suedekum and Woessner (2017, hereinafter DFSW) who adapt the same investigation methodology of AR to the case of Germany. What is new in these two papers is the choice of a very disaggregated geographical level as a unit of analysis, rather unusual in this literature: the local labour markets. Acemoglu and Restrepo draw inspiration from the contributions of Autor, Dorn and Hanson (2013a) and, more generally, from the American debate on agglomeration economies (see, for example, Henderson and Vernon, 2003; Glaeser, 2008) and from the more recent works of Moretti (2011). This perspective re-evaluates and highlights the importance of the local communities and territories, which has been the focus of the Italian literature on industrial districts for a long time.

AR estimate the effect of the introduction of industrial robots both on employment and on wages in the 722 American local labour markets (*Commuting zones*) from 1990 to 2007. In the analysis, the contribution of robots is distinguished from that of three other main factors that may have impacted employment and wage dynamics: imports from other manufacturing countries (China and Mexico), relocation activities (*offshoring*), and the role of IT capital. From the estimates made, it emerges that there has been a significant substitution of work by robots during the period observed. In particular, up to 670 thousand workers lost their jobs, about 6.2 employees for each robot introduced.

A similar methodological approach is proposed by DFSW (2017). The analysis concerns Germany and the results obtained are somewhat more encouraging than the American study. The authors study the effects of exposure to robots in the 402 German local labour markets in the period 1994-2014. In this case too, the authors take account of how employment is affected by trade (with Eastern Europe and China) and by ICT capital, which, like robots, contributes greatly to technological progress. The authors find that, on average, each robot replaces two manufacturing jobs, significantly less than in the US case, with a total of about 275 thousand jobs lost during the period under consideration. However, the decrease in manufacturing employment has been fully offset by the increase in employment in the service sector. Robots, therefore, seem to affect more the composition of employment rather than the aggregate level.

Another strand of research has focused on the effects of increasing trade penetration from low labour cost countries, and China in particular. For the United States, the main contributions were proposed by Autor, Dorn and Hanson (2013a, 2013b, 2015, 2016). Once again, the idea is that the impact is not homogeneous across a country but geographically differentiated, to a degree that depends on the distribution of industries and employment between the various areas and regions. Territories specialising in low technology and labour-intensive sectors, where China and low-cost countries enjoy comparative advantages, are the most affected.

To estimate these effects, the authors propose an "import competition exposure" index, which distributes the impact of imports between different local labour markets in proportion to their workforce share of total national employment in industries exposed to competition. The study covers the period 1990-2007 and the results obtained confirm the negative effects of imports from China on employment, wages and other labour market indicators. The same methodology was later adopted by AR in their study on the employment impact of robots in the US.

Building on this literature, Dauth, Findeisen and Suedekum (2014) analysed the case of Germany. The units of analysis are again the local labour markets. Compared to previous works, the difference lies in the calculation of the import exposure index. The change in imports is now weighed against manufacturing employment in the local market, instead of national employment in the sector, in order to place greater emphasis on the local impact of the shocks. In addition to China, imports from Eastern European countries, with which Germany has strong trade relationships, are also taken into account.

Trade can be a threat to particular industries but it can also provide an opportunity for the sectors that enjoy comparative advantages. To take account of this, in two later works Dauth et al. (2017a, 2017b) propose a "trade exposure indicator", which calculates the net difference between exports and imports for each sector.

The results show that the overall net effect of trade on employment in local markets is positive, as the growth in exports of medium and high-tech goods in Chinese and Eastern European markets more than offsets the negative impact in local markets specialized in labour-intensive industries.

Due to the characteristics of its industrial system and specialised production, Italy is a country particularly exposed to competitive pressure from low-cost countries. A particularly interesting contribution on this issue is provided by Federico (2014), who analyses the impact on employment of imports from a very wide range of low labour cost countries in the period 1995-2007. The units of analysis are the four-digit manufacturing sectors (230 industries). The results of this study are unequivocal: there is clear evidence of a negative effect of competitive imports on employment, particularly in medium-low technology and more labour-intensive sectors, such as most of the Made in Italy productive systems.

As we have seen, local labour markets are at the core of the most interesting papers in the literature just reviewed. Much of the adjustment to technological and economic shocks, in fact, takes place at local level. However, both the exposure to shocks and the ability of local systems to react depend on their productive, institutional and social characteristics. This is probably the most important legacy of the vast literature on local productive systems and industrial districts, with particular reference to the Italian debate (see, for example, Brusco, 1999).

Since data on robots are available only at national level, the problem is how to evaluate their potential impact on local systems. The idea of AR is quite simple: if the investment in robots is particularly heavy in one specific industry, and if this industry represents an important part of a local economy, than the effects of robots on employment will probably be strongly felt in this local economy.

The distribution of robots at local level can therefore be estimated by calculating, for each manufacturing industry, the change in the number of robots installed in the reference period, weighted by the number of workers, and distributing this variation among the various territories in proportion to the share of employment in the local industry compared to the national total. Building on this intuition, AR propose an index of *exposure to robots* of the entire local labour system, obtained from the sum of all the sectoral indices, as illustrated in the following algorithm:

$$\text{(1) Exposure to Robots}_{\text{AR}}: \ \Delta\text{ROBOT sll} = \sum\nolimits_{\text{J}} \frac{\text{Lj,sll}}{\text{Lj}} * \frac{\Delta\text{ROBOTSj}}{\text{Lj}}$$

where *L* indicates employment in the base reference period, *sll* the local labour market (LLM), *j* the industry, and *Δ* the change in the number of robots during the reference period. Therefore, the index $\frac{\text{Lj,sll}}{\text{Lj}}$ varies between local labour markets according to the relative importance of the industries at local level compared to the national total, while $\frac{\Delta\text{ROBOTSj}}{\text{Lj}}$, the variation in the number of robots, normalised with respect to national employment in the industry so as to assess the intensity of robotization, is the same for all local systems. Exposure to robots is therefore higher in regions where robot intensive industries are more prevalent.

The approach of DFSW is broadly similar to the previous one, but there is a crucial difference in the algorithm used to calculate exposure to robots in local labour markets. As can be seen from the formula below, the change in the number of robots at country level for each industry is now normalised by the total number of workers in the local system, instead of total employment for that specific industry at country level.

$$\text{(2) Exposure to Robots}_{\text{DFSW}}: \ \Delta\text{ROBOT sll} = \sum\nolimits_{\text{J}} \frac{\text{Lj,sll}}{\text{Lj}} * \frac{\Delta\text{ROBOTSj}}{\text{Lsll}}$$

The implication of this change is that, for a given number of local workers in a specific sector, which corresponds to a given share on total national employment for that industry, the impact of a given variation in robots will be greater the more important is this industry at local level in terms of employment (in other words, the smaller the local economy in terms of employment). In the case of AR, in contrast, the exposure would be the same. Therefore, the approach followed by DFSW seems more appropriate for assessing the impact of robots on local systems because it takes into account that a robot-intensive industry may have a greater influence on the local labour market if the local economy is small and therefore offers less scope for adjustment within its boundaries. By prioritising areas where industrial sectors exposed to robotization are more concentrated, the approach of AR is more suitable for analysing the employment effects of robotization at country level (regarding this point, however, see the critical considerations of Mishel and Bivens, 2017).

A problem shared by both approaches concerns the use of robot data, available only at country level. Without knowing where the robots are actually distributed between the different areas, the implicit assumption is that there are no significant geographical differences in the ability to invest in innovation and in efficiency in the use of productive factors. The same number of robots will be assigned to local systems with the same level of employment in a specific industry. In the case of Italy, this assumption is certainly very strong, given the substantial regional disparities in terms of productivity and dynamism of regional economies (Manzocchi et al., 2017; Di Giacinto et al., 2012). This problem is more pronounced in the case of the DFSW approach, because it emphasises the importance of industries at a local level even if their national weight is negligible. However, due to the lack of suitable data at the level of SLLs, this problem cannot be addressed in this research.

By using one or the other algorithm, the hierarchy of local systems most exposed to robotization changes significantly. Therefore, which method is preferable depends on the objectives of the analysis. In this research, the emphasis is on local systems, and therefore the algorithm proposed by DFSW will be used and adapted to Italy. The source of the robot data is the *International Federation of Robotics* (IFR)[1]. In particular, the *operational stocks of robots* for 1993, 2001 and 2011 and for 15 two-digit manufacturing sectors are employed in the analysis. The base year used as a reference is 1991.

Figure 1 shows a map of the 686 Italian local labour systems, identified by ISTAT on the basis of data from the 2001 Population Census. The Figure highlights the change in robot exposure in the twenty-year period 1991-2011, calculated according to the DFSW procedure. In the map, it is possible to clearly identify the local labour systems where robotization has changed the most in the two decades between the two Censuses of 1991 and 2011.

As expected, the exposure to robots is more intense in the more industrialised areas of the Centre and North of the country, especially in the North West. Intensity in the use of robots is, in fact, greater in the transport and *automotive* sectors, in the metal-mechanical, pharmaceutical and rubber-plastic industries, which are widespread in that part of the country. As shown on the map, in Southern Italy local economies are more service-oriented and therefore the expected impact of automation is less significant. However, several Southern local systems have important production sites in the most robotized industries, which account for a high share of local employment.

[1] A robot is defined as "an automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications" (IFR, 2016).

Figure 1 - Exposure to robots in Local Labour Markets, 1991-2011

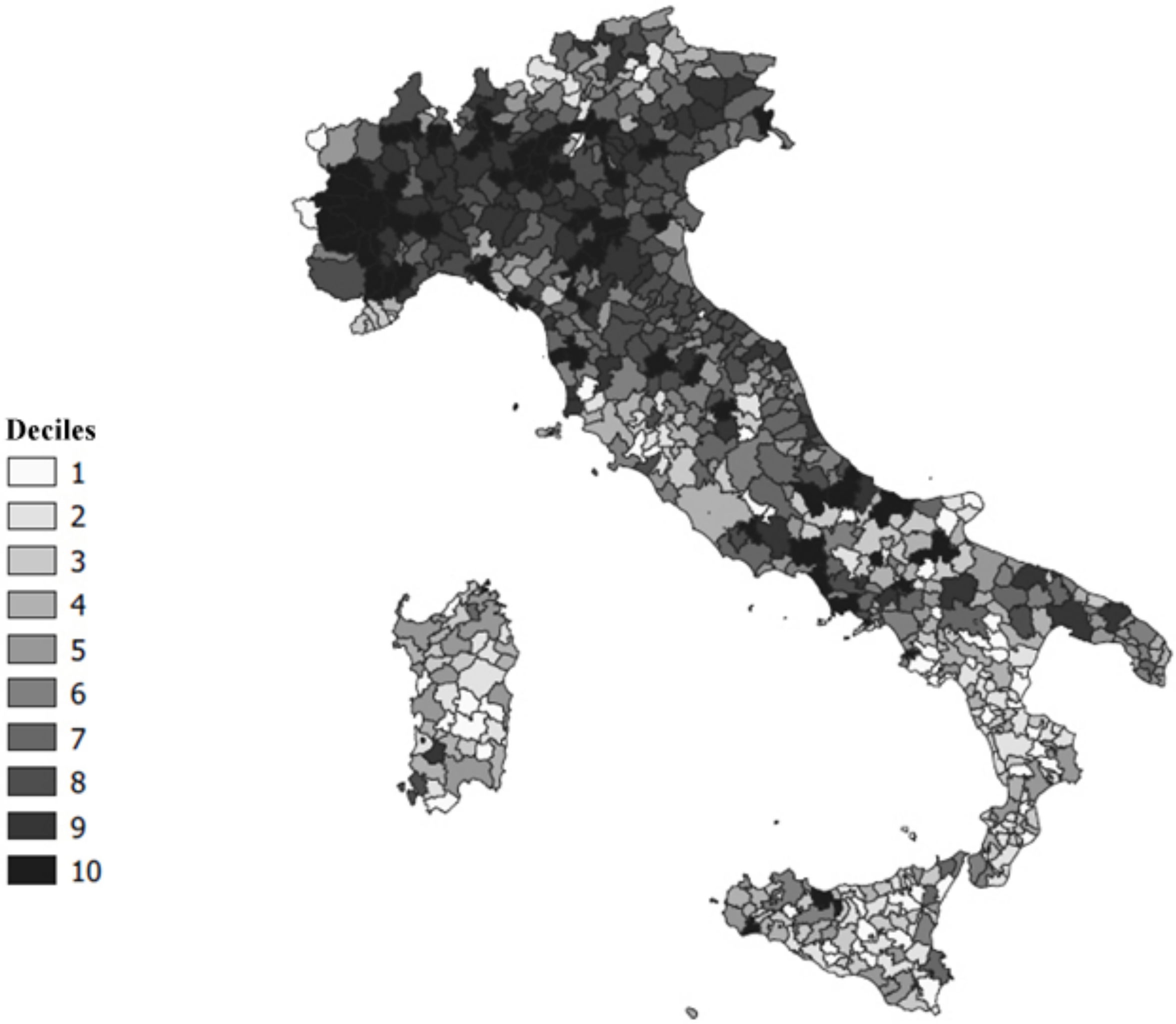


Figure 2 - Exposure to ICTs in Local Labour Markets, 1991-2011

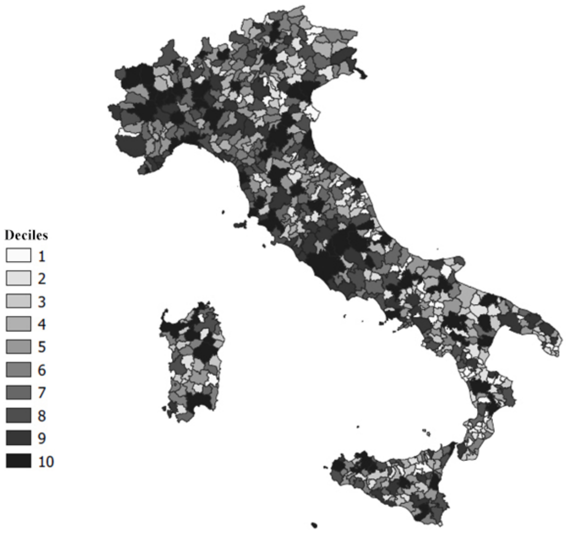
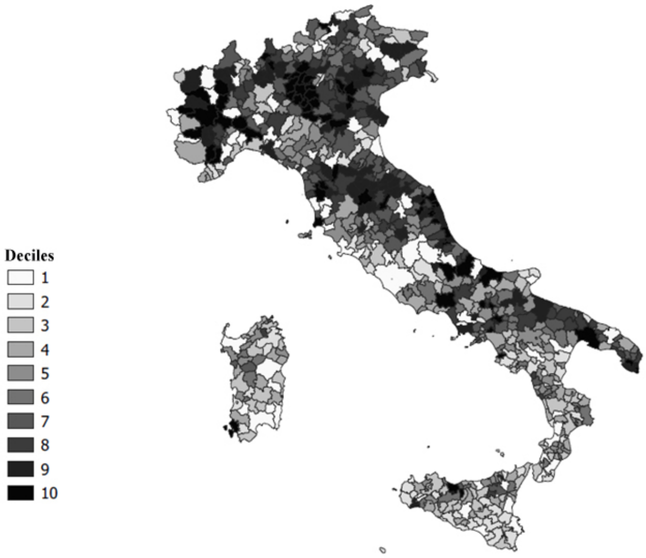


Figure 3 - Exposure to net imports in Local Labour Markets, 1991-2011



Unfortunately, it was not possible to cover the most recent period because of lack of data with the required geographical and sectoral breakdown, necessary to calculate the robot exposure index. In any case, at least for Italy, most of the investments in robots and automation were made in the period examined in the analysis.

In order to calculate the potential impact of both ICT investment and trade on employment in Italian local labour markets, we use the same methodology applied to robots. For the same reasons discussed above, we follows the same approach developed by DFSW, because it allows a better understanding of the dynamics of local economies.

The source of the data is EU-KLEMS. In particular, figures for real fixed capital stock at constant prices (2010) have been merged into a single heading for the items IT and communication equipment, software and databases (ICTS). The ICTS capital exposure algorithm is as follows:

$$\text{(3) Exposure to ICTS}_{\text{DFSW}} : \Delta ICTSsll = \sum_J \frac{Lj{,}sll}{Lj} * \frac{\Delta ICTSj}{Lsll}$$

A total of 33 economic activity sectors were examined (15 in manufacturing). The base reference year is 1991. The period analysed is 1995-2011. Figure 2 shows the Italian local labour systems in which the impact of ICTS is greatest. As can be seen, and unlike the case of robots, the impact of this type of capital is more pronounced in the urban and tertiary areas of the North West, Centre, South and Islands.

Trade data were collected from two databases: *World Integrated Trade Solution* (WITS) and *Comtrade*. The low labour cost countries used as a reference are those that account for a significant share on total Italian imports (imports amounting to at least one billion dollars in 2011). These countries are China, Turkey, India, Vietnam, Thailand, Bangladesh, belonging to the Asian area, and Poland, Romania, Czech Republic, Hungary, Slovakia, Ukraine, Russia, Slovenia, Bulgaria, Croatia, Serbia and Albania, belonging to Eastern Europe. Data are collected for 15 manufacturing sectors. The years examined are 1991, 2001 and 2011. The algorithm for exposure to net imports from low-cost countries is as follows:

$$\text{(4) Exposure to net imports}_{\text{DFSW}}\text{: } \Delta \text{NetImport}_{\text{sll}} = \sum_{\text{J}} \frac{\text{Lsll,j}}{\text{Lj}} * \frac{\Delta\text{IMPj} - \Delta\text{EXPj}}{\text{Lsll, Man}}$$

where *NetImport* indicates the difference between the value of imports (*IMP*) and the value of exports (*EXP*) for the groups of countries under consideration. The *Δ* relates to the period 1994-2011. *Man* indicates manufacturing.

Figure 3 shows the regions in Italy where the competitive pressure from low labour cost countries is most felt. These are the North East, the Centre and the coastal areas of the Adriatic, where many local economies are specialised in the production of textiles and clothing, leather and footwear, but also electrical and electronic products, where the trade deficits with China and other countries are greater.

3. An estimate of the effects of the shocks: the model and the results

In this paragraph, we try to verify whether technological change and exposure to trade have any relationship with the dynamics of employment in the Italian local labour markets in the twenty year period 1991-2011. Employment data were collected from the Industry and Services Censuses of 1991, 2001 and 2011, after appropriate matching. The units of analysis are the 686 Local Labour Markets (LLMs) identified by ISTAT on the basis of the 2001 Population Census. The data refer to 33 sectors of economic activity (15 of which are in manufacturing).

In choosing this period, the potential impact of the 2008 financial crisis with its deep recessionary effects should be taken into account. Unfortunately, by using only ten-year Census data, the information for 2011 is to some extent influenced by the economic downturn of the last three years. The problem stems from the fact that the crisis may not have affected all regions and local systems of the country in the same way and to the same extent, and this can spoil the interpretation and the results.

Some additional data may allow a more precise assessment. Italian employment increased by 10.8% between 1991 and 2011, an increase of about 1.9 million workers. During the same period, manufacturing employment decreased by 28.2%, equal to 1.5 million workers. The change in employment in the service sector, therefore, more than offset the loss of manufacturing jobs. Employment growth was much more pronounced in the first decade, the nineties, as the decline in manufacturing employment was particularly heavy in the second decade (-1.1 million workers), mainly due to the recession in the last years. The overall effect of the first years of the recession can be roughly quantified using data from the Permanent Censuses carried out by ISTAT. Between 2008 and 2011, in just three years, a total of 492,000 employees were lost, equal to 2.1% of employment. ISTAT provides a classification of local labour systems according to a set of economic variables. By using this classification, it can be seen that in the period 2008-2011 there are no major differences in employment dynamics between the different groups of local systems. Figures range from a decrease of 1.5% in non-manufacturing systems, those less affected by the crisis, to a decrease of 2.4% in heavy manufacturing systems, which have suffered more from the economic downturn. The distortion of estimates caused by the crisis does not therefore seem particularly significant, but these differences must be taken into account in interpreting the results.

One of the keys to interpreting the trend in employment in Italy, which is common to all advanced countries, is the gradual replacement of manufacturing employment with employment in the tertiary sector, as shown also by the data mentioned above. This is definitely a positive effect, at least for the labour market, since the growth in services more than compensates for manufacturing losses. In this regard, it is interesting to analyse the behaviour of the Italian local systems in the period examined.

Figures 4 and 5 illustrate the growth rates of manufacturing employment and total employment respectively for the 686 Italian local systems, in relation to employment in the initial period (1991). On the X-axis, the systems are arranged geographically, from the North West, on the left, to the South and Islands on the right. As can be seen, manufacturing employment has declined everywhere and to a substantially similar degree (Figure 4). This reduction can be attributed to various reasons. Some areas probably experienced a withdrawal or considerable retreat of industry, particularly in low tech industries, while in others there is a process of restructuring and change in sectoral composition. A clue can be found in the comparison between the data reported in the Figure and the robot and import exposure maps discussed above. For example, the areas with extensive robotization, which indicate more technologically advanced industries, are located mainly in the North and specifically in the North West of the country.

More interesting is the interpretation of Figure 5, relating to total employment. As can be clearly seen, there is a marked asymmetry between the different regions of the country. In the North, to the left of the graph, most local economies experienced growth (73.5% of the total). In the Centre, this happened to 65% of the local systems. In the South and the Islands, to the right of the figure, only half of the local systems have grown and the negative variations are much more pronounced than in the rest of Italy. This evidence should somehow be borne in mind in interpreting the results of the econometric estimates that will be presented in the next part of this section.

In order to analyse the influence of robots and other variables of interest on employment growth in Italian local systems, we estimate a simple OLS model, following very closely the methodology used by AR and DFSW. Compared to these works, the proposed specification contains an important innovation. Among the control variables, the model includes different typologies of labour local systems. The typologies refer to two main classifications of local labour systems developed by ISTAT and discussed in detail below. It should be noted that, to some extent, these classifications replace the usual control variables related to demographic aspects and production structure (education, age, gender, immigration, manufacturing share) normally used in the reference literature. Many of these

Figure 4 - Local Labour Systems: change in manufacturing employment in 1991-2011 over manufacturing employemt in 1991

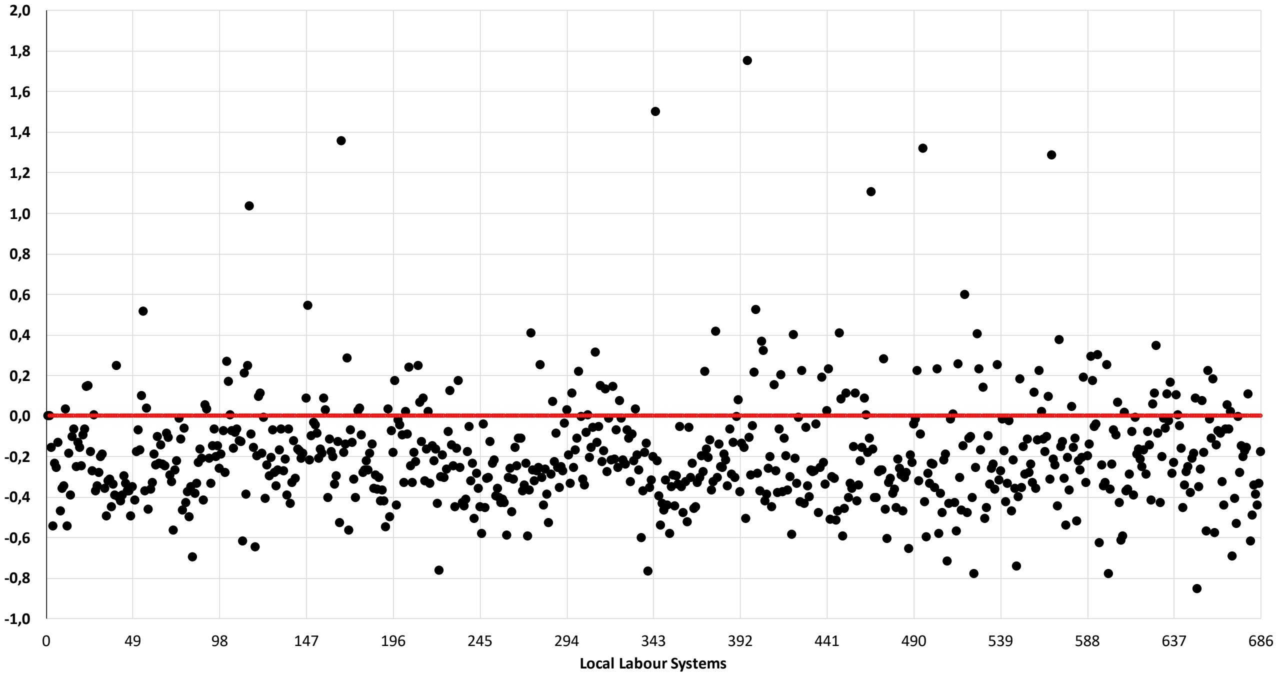
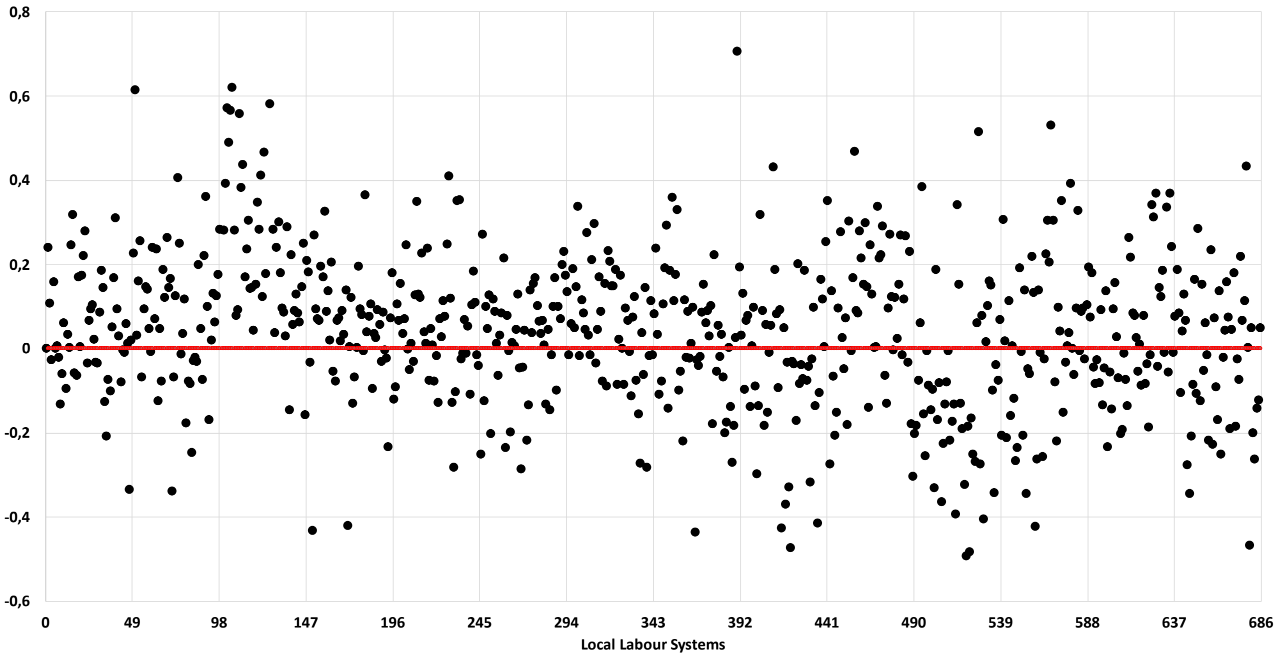


Figure 5 - Local Labour Systems: change in total employment in 1991-2011 over total employemt in 1991



variables, in fact, are reflected in the socio-economic characteristics of the different types of local systems (on this point, see the extensive Italian literature on the subject).

The specification used is described by the following equation:

$$(5)\quad \Delta Y_j = \beta_1 \Delta\, robot_j + \beta_2 \Delta\, ICTS_j + \beta_3 \Delta trade_j + \gamma Spec_j + \theta \Delta\, robot_j * Spec_j + \phi PA_j + \Omega\, reg_j + \varepsilon_j$$

In the model, Δ Y represents the change in total employment between 1991 and 2011 for each local labour market (j). For completeness of the analysis, manufacturing and service employment are also taken into account as dependent variables. The model is also applied to the two sub-periods, 1991-2001 and 2001-2011.[2]. The variables Δ Robot, Δ ICTS and ΔNetImport, described above, are the main variables of interest.

The ***Spec*** vector consists of control variables that specify the nature and specialisation of the local system. This variable is of particular significance. For this reason, two different classifications have been used, allowing a more detailed assessment of the effects of shocks on local systems. The first refers to the breakdown of local systems into three main classes, as suggested by ISTAT. The first class includes systems without manufacturing production specialisation (urban systems, systems based on tourism or agriculture, systems without any specialisation). The second class groups together the Made in Italy systems, characterised by manufacturing specialisation in "light" industries (fashion, furniture, agrifood, jewellery, but also machine tools). The third and final class includes systems specialised in "heavy" manufacturing (means of transport, mechanical engineering, petrochemical and pharmaceutical industries, building materials). It should be noted that these categories do not distinguish between local systems characterised by small and medium enterprises (industrial districts) and medium-large enterprise systems.

The second classification used in the analysis refers to industrial districts, whose main characteristic is the widespread presence of small and medium-sized enterprises. These local economies have played an important role in the dynamics of Italian industry during the period under consideration and are the subject of extensive literature. Once again, following the breakdown proposed by ISTAT with reference to 2001, a distinction is made between four main classes of local systems: industrial districts specialised in the fashion sector ("Fashion"), those specialised in mechanics ("Mechanics"), districts specialised in other manufacturing sectors ("Others", i.e. agrifood, household goods, rubber and plastic, jewellery), and finally the broad class of local systems that do not have the characteristics of a district ("Non-districts").

[2] The table describing the variables used and the model results for the two sub-periods are available on request from the authors.

The specification includes a further geographical control, the PA variable, which measures, for each local system, the share of employment in the public administration on total employment, calculated at base year 1991. This variable tries to identify the local systems, located mainly (but not exclusively) in the South and the Islands, where public sector employment, often controlled by the local political elites, has historically represented a significant channel for job opportunities.

Reg indicates regional *dummies*, the purpose of which is to purge the results of systematic influences due to specific characteristics of the regions. The reference region is Piedmont, which is the area with the highest robotization indices. Finally, $\boldsymbol{\varepsilon}$ is the error term.

Table 1 provides basic descriptive statistics of the variables used. Some robustness checks were carried out, both by considering total net imports (instead of Asia and Eastern Europe) and by eliminating *outliers* from the analysis whose robotization index is higher than 30: these were the local systems of Grottaminarda, Termoli, Cassino and Termini Imerese.

Table 2 provides the results of the regressions with the ISTAT classification (Table A1, in the Appendix, describes the variables). The first comment concerns the exposure to robots variable, the main focus of the international literature reviewed in Section 2. This appears to have no impact on local growth only if it is considered in isolation together with the regional *dummies*. However, the coefficient becomes significant and positive (at 5%) when the variables related to the other two shocks are introduced, especially when the effect of robots is controlled by the type of local system. In the full specification (column 5), the positive impact is even greater and more significant at 1%. The result appears robust even when no distinction is made between the areas of origin of the imports and when *outliers* are eliminated from the analysis. It is important to note that the robotization coefficient increases significantly in column (5) and the following columns. This shows how heterogeneous the relationship between robotization and the type of LLM is and that the effect is very different depending on the specialisation of the local system.

The results obtained in terms of trade exposure to low labour cost countries are significant. The coefficients for net imports from Eastern Europe and Asia show values consistent with expectations. While in the first case the coefficient is not significant and therefore net imports from Eastern Europe do not seem to have affected employment, net imports from Asia show a strong negative and significant impact (1%) on the dependent variable. The result appears quite robust: the increase in net imports from Asia, influenced mainly by China, leads to a decrease in employment in local systems.

The ICTS capital variable becomes significant (at 5%) and positive when the PA control is included, which measures the proportion of public sector employment in the base year, and remains so even when the full specifications take the characteristics of local systems into account. Increased

Table 1 - Description of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Δ Employment	682	29,07	30,31	-125,28	180,46
Δ Manufacturing employment	682	-26,40	32,53	-191,74	147,52
Δ Robot	682	0,93	0,97	-0,79	8,62
Δ ICTS	682	1,98	0,74	0,88	12,60
Δ Net imports from Eastern Europe	682	-0,08	0,23	-1,16	1,44
Δ Net imports from Asia	682	1,11	1,02	0,05	6,76
Share of public sector employment in 1991	682	5,63	3,47	1,04	27,23

Table 2 - Analysis of the determinants of the change in employment between 1991 and 2011
Local labour systems according to ISTAT specializations

Dependent variable: Log Δ Employment * 100	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Δ Robot	0.792	1.790**	1.573*	1.989**	8.360***	8.534***	8.338***
Basic variable: Systems without specialization							
Non-manufacturing systems				5.567***	9.540***	9.576***	9.579***
Made in Italy systems				3.402	3.859	3.519	4.009
Heavy manufacturing systems				-0.366	8.745**	7.558*	7.571*
Basic variable: Systems without specialization * Δ Robot							
Non-manufacturing systems * Δ Robot					-6.245*	-6.283*	-6.165*
Made in Italy systems * Δ Robot					-3.491	-3.429	-3.432
Heavy manufacturing systems * Δ Robot					-8.456***	-7.812**	-7.819**
Δ ICTS		0.354	2.138**	1.935**	2.006**	1.886*	1.995**
Δ Net imports from Eastern Europe		-3.891	-3.331	-3.689	0.875		1.169
Δ Net imports from Asia		-2.464**	-3.43***	-3.45***	-2.962***		-2.953***
Δ Total net imports						-3.056***	
Share of public sector employment in 1991			-1.373***	-131.11***	-123.96***	-121.67***	-123.17***
Regiobal dummies	yes	yes	yes	yes	yes	yes	yes
Constant	0.848	1451	4369	0.590	-4743	-5432	-5153
Observations	686	686	686	686	686	686	682
R-squared	0.228	0.237	0.264	0.274	0.290	0.288	0.291

***** p<0.01, ** p<0.05, * p<0.1**

Table 3 - Margins analysis for ISTAT local systems

Δ Robot x ISTAT Specialization	**dy/dx**	**Std. Err.**	**t**	**P>t**	**[95% Conf. Interval]**	
Basic variable: Systems without specialization	8.36	2.98	2.80	0.01	2.50	14.22
Non-manufacturing systems	2.11	2.23	0.95	0.34	-2.26	6.49
Made in Italy systems	4.87	1.42	3.42	0.00	2.08	7.66
Heavy manufacturing systems	-0.10	1.03	-0.09	0.93	-2.12	1.93

exposure to ICTS therefore appears to have a positive impact on growth of local employment. However, this result appears less robust and not as strong as the previous ones.

Focusing on the relationship between type of territory and variation in employment, non-manufacturing systems show a positive and very significant coefficient compared to systems without specialisation, while manufacturing systems do not show any statistically relevant effect. Employment growth therefore seems to affect urban and tourism-oriented systems to a greater degree. This result is consistent with expectations, since employment has grown mainly in services.

The coefficient of the PA variable is actually interesting and shows a negative and significant relationship (1%) with the dependent variable. For the most part, this variable identifies regions of Italy, mainly located in the South, where the public sector has always offered the greatest job opportunities. With the progressive downsizing of the public sector throughout the period examined, these local systems are struggling to follow a path of growth.

The model integrated by interactions between robots and specialisation of local systems is presented in column 5 and the following columns. A first suggestion of the extent to which robotization has had heterogeneous effects among the specialisations of local systems is provided by the coefficient of the Δ Robot variable, which is statistically significant at 1% and is greater than the value in column 4. The subsequent robustness controls (columns 6 and 7) confirm the results discussed above.

Of particular interest is the analysis of the relationship between employment growth and the typology of local systems. This relationship appears positive and significant (1%) for non-manufacturing systems, especially urban and tourism systems, and also for local economies specialised in heavy manufacturing, even if the significance is lower and less robust. However, this result can be better understood and the role of robots in affecting growth can be better assessed by analysing the interaction between robot exposure and local system typology.

The study of the *margins* (Table 3), based on the regression shown in column (5) of the previous table, provides elements for this type of evaluation allowing us to analyse the marginal effect of variation in robotization on the variation in employment for each specialisation of local systems. As can be seen, the Δ Robot coefficient is not significant either for non-manufacturing or for heavy manufacturing systems. In the latter case, the coefficient is negative but not statistically significant. In other words, these local systems grew during the period more than the others, all other conditions being equal, but not as a result of robotization. On the other hand, there seems to have been a positive effect of robotization for systems without specialisation (+8.36) and, although to a less appreciable extent, for Made in Italy systems (+4.87).

Lastly, a few comments on the coefficients of regional *dummies*. Compared to the reference and most robotised region, Piedmont, there are no regions with negative coefficients. On the contrary, Trentino-Alto-Adige, Veneto, Umbria, Marche, Apulia and Sicily have positive and significant coefficients. There are therefore region-specific effects that are not detected by the other covariates that differ between the areas.

Table 4 presents the results of the regressions than include in the specification the local systems according to the industrial district classification. It's worth focusing on the relationship between these type of local systems and the dependent variable, since the results relating to the other independent and control variables are quite similar to those shown in Table 2. The only noteworthy difference is the ICTS variable, which appears more robust in all the regressions with a positive sign and significance of 5%.

Four types of industrial districts are analysed. In general and compared to non-districts, the "Other" districts seem to show a positive and significant (5%) relationship with growth, while the mechanical districts are negatively correlated with the increase in employment.

Here too, the *margins* analysis (Table 5) allows further exploration of these results through evaluation of the interaction between variations in robot and specialisation of districts compared to the variation in employment. The comment refers to the regression of the column (3). This relationship is positive and significant for local systems that do not have the characteristics of a district (+1.88) and even more so for mechanical (+6.27) and fashion (+8.62) districts, while there does not seem to be any relationship with "Other" districts. When the two analyses are crossed, robotization seems to have had positive effects on non-district systems, and especially on mechanical and fashion districts. In the case of the mechanical industry, in particular, the districts that invest most in robots have increased employment *ceteris paribus* more than the less technologically advanced districts.

Table 6 analyses the impact of robots and other variables of interest on the growth of manufacturing employment and separately on the growth of employment services, using both local systems according to the ISTAT classification and industrial districts. As a term of comparison, the results commented above with the total employment dependent variable are also reported.

As a first consideration, the exposure to robots variable – both general and disaggregated by specialisations of districts and LLM types – does not seem to have a statistically significant impact on the growth of either manufacturing or services employment.

Moving on to the specialisation of districts, the residual ones labelled as "Others" show a positive coefficient with respect to the dependent variable regarding manufacturing employees (the coefficient is of the same sign but much greater than that obtained from the analysis conducted on total employees and, conversely, the sign is negative and weakly significant (at 10%) in the analysis conducted on

Table 4 - Analysis of the determinants of the change in employment between 1991 and 2011
Local labour systems according to the specialization of industrial districts

Dependent variable: Log Δ Employment * 100	**1**	**2**	**3**	**4**	**5**
Δ Robot	0.792	1.826**	1.881**	1.791***	2.869***
Basic variable: SLL not districts					
"Other" districts		2.959	9.455**	9.368**	10.275**
Mechanics		-3.794	-11.889**	-11.848**	-10.544*
Fashion		4.392	-3.020	-3.040	-1.925
Basic variable: SLL not districts * Δ Robot					
"Other" districts * Δ Robot			-4.180*	-4.087*	-5.006**
Mechanics * Δ Robot			4.389	4.408	3.378
Fashion * Δ Robot			6.746**	6.799**	5.810*
Δ ICTS		2.223**	2.183**	2.199**	2.174**
Δ Net imports from Eastern Europe		-3.995	-4.790		-3.407
Δ Net imports from Asia		-4.325***	-4.308***		-4.302***
Δ Total net imports				-4.288***	
Share of public sector employment in 1991		-138.645***	-136.963***	-137.350***	-136.063***
Regional dummies	yes	yes	yes	yes	yes
Constant	0.848	4.927	4.663	4.846	2.761
Observations	686	686	686	686	682
R-squared	0.228	0.270	0.282	0.282	0.286

***** p<0.01, ** p<0.05, * p<0.1**

Table 5 - *Margins* analysis for industrial districts

Δ Robot x District specialization	**dy/dx**	**Std. Err.**	**t**	**P>t**	**[95% Conf. Interval]**	
Basic variable: Non-district systems	1.88	0.90	2.09	0.04	0.11	3.65
Other districts	-2.30	2.21	-1.04	0.30	-6.64	2.04
Mechanics	6.27	2.91	2.16	0.03	0.56	11.98
Fashion	8.63	3.20	2.70	0.01	2.34	14.91

Table 6 - Results with Total Employment, Manufacturing and Non-Manufacturing Employment

Dependent variable: Change (in log) of employment between 1991 and 2011

	Total Employment		**Manifacturing Employment**		**Service Employment**	
	Districts	**Istat Systems**	**Districts**	**Istat Systems**	**Districts**	**Istat Systems**
Δ Robot	1.881**	8.360***	3.168*	2.405	-1.288	5.955
Basic variable: SLL not districts						
Other districts	9.455**		23.897***		-14.442*	
Mechanics	-11.889**		11.502		-23.390**	
Fashion	-3.020		5.508		-8.528	
Basic variable: SLL not districts * Δ Robot						
"Other" districts * Δ Robot	-4.180*		-6.452		2.272	
Mechanics * Δ Robot	4.389		-0.503		4.892	
Fashion * Δ Robot	6.746**		8.336		-1.590	
Basic variable: Systems without specialization						
Non-manufacturing systems		9.540***		-16.944***		26.484***
Made in Italy systems		3.859		6.368		-2.509
Heavy manufacturing systems		8.745**		9.716		-0.971
Basic variable: Systems without specialization * Δ Robot						
Non-manufacturing systems * Δ Robot		-6.245*		2.677		-8.922
Made in Italy systems * Δ Robot		-3.491		3.284		-6.775
Heavy manufacturing systems * Δ Robot		-8.456***		-3.012		-5.444
Δ ICTS	2.183**	2.006**	-2.987	-11.892***	5.170***	3.949**
Δ Net imports from Eastern Europe	-4.790	0.875	0.233	9.032	-5.023	-8.156
Δ Net imports from Asia	-4.308***	-2.962***	-10.744***	-11.892***	6.436***	8.931***
Regional and geographical dummies	yes	yes	yes	yes	yes	yes

employees in services). With reference to the mechanical systems, the coefficient is negative both in the analysis of total employees and with respect to service employees. Finally, it should be noted that in the non-manufacturing systems, the sign is positive in the analysis conducted with respect to total and service employees, while it is negative with respect to manufacturing employees. The coefficients related to the variation in ICTS appear significant and positive in the case of services, but significant and negative in the case of manufacturing employment with ISTAT systems. Compared with exposure to ICTS, therefore, it seems that the sectors reacted heterogeneously with respect to employment dynamics.

Similarly, while net imports from Eastern Europe do not show significant coefficients in any cases, net imports from Asia have a major negative impact on manufacturing employment, with both types of classification of local systems, while they are positive and statistically significant in the case of employment in the service sector.

4. Discussion of the results

The econometric analysis calls for some general considerations on the international debate on the effects of the Fourth Industrial Revolution and specifically on the Italian economy.

The first important result that emerges from the analysis is the absence of negative effects of robots on employment in local labour markets. Machines, at least in the case of Italy and during the twenty years analysed, do not seem to be an enemy of human labour. When territorial controls and other shock variables are introduced, on the contrary, and surprisingly, a positive and statistically significant relationship emerges between technology and employment. This requires a careful explanation.

This result contrasts with the findings of Acemoglu and Restrepo for the United States, where robots have had a marked effect of worker replacement in manufacturing, which has not been offset, in local labour market (c*ommuting zones*), by an increase of jobs in other sectors. The Italian figure, on the other hand, is *apparently* similar to the conclusions of DFSW for Germany, who did not find any evidence of an overall negative impact associated with the introduction of robots in local systems. In the most recent studies by DFSW, the estimates produced *separately* for manufacturing employment indicate a process of work substitution by robots, although to a lesser degree than in the US. What has happened, as the authors point out, is that the loss of jobs in industry is more than offset by growth in the tertiary sector. With the new technologies, therefore, the sectoral composition of employment changes to the detriment of manufacturing, but without negative consequences for local economies (net of other structural or cyclical factors).

In the case of Italy, this result does not seem to emerge. When manufacturing employment is estimated separately (Table 6) no negative effects of robots on employment emerge. What distinguishes Italy from other economies? First of all, the econometric evidence seems consistent with some stylised facts mentioned below. Manufacturing employment as a whole remained stable for almost the entire period, until the onset of the crisis. It was only after 2008 that a substantial drop in employment was recorded. The reduction in employment was, therefore, more a consequence of the recession than of new technologies. Robots were not the cause of significant job replacement in manufacturing, at least from the mid-1990s until 2011. This is also proven by the fact that the number of robots installed has grown steadily and then levelled off over the last three years (IFR figures). Looking closely at the individual sectors that experienced a significant change in robotization (primarily the *automotive* sector, but also the pharmaceutical, chemical and plastic, mechanical and metal, machinery and food industries), employment, at least until the crisis, actually increased compared to the early 1990s.

This evidence raises important interpretative problems, which will need further consideration in the future. In the period examined, Italy may have lagged behind in the transformations associated with the Fourth Industrial Revolution when compared to other advanced manufacturing countries, especially Germany. This seems to be reflected in the differences in intensity of robotization between the two countries: in 2011, in manufacturing, there were 196 robots for every ten thousand workers in Germany, as against 131 in Italy (IFR and KLEMS figures). The data on productivity differentials seem consistent with this assessment. The trend, however, is not uniform across sectors. Intensity is higher in Germany for the *automotive* industry, the most robotic sector universally, and for many other sectors, including those with less technological intensity. However, two very important sectors for Italy are the exception: the mechanical industry and the industrial machinery industry.

Another consideration directly concerns the characteristics of robots and how they are integrated into the production process. Without further information on how these machines transform organisation of work and integrate with other machines, it is difficult to draw reliable conclusions about the consequences on labour markets. Moreover, in several sectors, the presence of robots is negligible and probably limited to a few companies among a multitude of less technologically advanced production units. This does not mean, however, that in these industries are not undergoing major changes in the way they produce and work, albeit less radical than automation.

In more general terms, what really happened in Italian manufacturing in the two decades at the turn of the new millennium? What kind of technological transformations have there been? One possible reading, which is also reflected in various case studies of individual Italian industries, is that much of the restructuring and automation of production processes took place in the 1980s and the first half of the 1990s, with a significant impact on manufacturing employment levels. To get an idea, between 1980 and 1995 about one and a half million jobs (25%) were lost. It is therefore plausible that many of the robots were acquired simply to replace old and obsolete machinery in plants and lines that were *already* automated, without any significant impact on the number of workers. In essence, there has perhaps been a process of *deepening of automation* as discussed by Acemoglu and Restrepo (2019). Lastly, the influence of industrial relations may have played a major role. Much of the technological innovation presumably involves medium and large companies, where trade union agreements have tended to stabilise jobs. In any case, all this is mere conjecture and without an in-depth analysis of sectors and companies, it is difficult to reach more reliable conclusions.

The positive and statistically significant sign of the relationship between robots and employment remains to be interpreted. It appears robust with the introduction of other variables and controls that reinforce rather than weaken the significance and value of the coefficient. The positive effect, however, is rather weak if only manufacturing employment is considered and is cancelled out if only service employment is analysed, as would be expected (Table 6). In both cases, regressions capture dynamics that cannot be understood by looking only at the aggregate employment trends. In this regard, the estimates of regressions in the two sub-periods 1991-2001 and 2001-1991 provide some interesting insights[3]. The positive relationship between robots and employment is particularly strong and robust in the first period, even in the absence of other controls, when, according to IFR data, the introduction of robots experienced its highest growth rates for the most important sectors industries. On the other hand, the coefficients are much less significant and less robust in the second period, especially for manufacturing employment alone. This suggests that in the first decade the many robots used in Italy were indicative of a more general technological restructuring of companies, without radical changes in work organisation and without negative consequences for employment. In the 1990s, the effects associated with the Fourth Industrial Revolution and the latest generations of technology and machinery were probably still not evident. The growth in employment, during both periods, is instead linked to the service sector, which more than compensates for the reduction in manufacturing and is not related to the introduction of robots. This is particularly true in the wealthier and more dynamic areas of the North and in part of the Centre of the country. As we have seen, exposure to robots is greatest in these regions. These are local systems that, even if there are negative shocks in manufacturing, can find the necessary resources within the territory to increase employment in other sectors, including the tertiary sector linked to business services.

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[3] Tables available from the authors on request.

The control on local system typologies that was used in regressions confirms that growth mainly concerned non-manufacturing systems (urban and tourism) – which have experienced a major upswing, especially in services – and heavy mechanical systems, but not as a result of robotization. On the other hand, robots have contributed to the growth of mechanical districts and non-district systems, presumably those characterised by medium-large enterprises. The positive dynamics of the "Other" districts does not, however, seem to be associated with the effects of robotization.

The other major protagonist of the technological revolution in progress for several decades, ICTS capital (IT and communication equipment, software and databases), is the crucial ingredient for the digitalisation of the economy, for the development of artificial intelligence, for the cyber-physical systems that favour integration between machines and between things. The impact on the economy of local systems, however, is very difficult to decipher. Unlike robots, these investments encompass many sectors, far beyond manufacturing, and can play a powerful role of transformation, if not *disruption* in many economic activities, in small and large enterprises, in both low-skilled and highly skilled jobs. These investments, at the same time, represent a powerful engine for innovation and growth, they favour the emergence of new professions, new services and new products, creating job opportunities that can fuel the growth of employment and the economy.

In the contributions from both AR and DFSW, there is no trace of any negative effect of ITC capital on employment in local systems, not least because the software-robots that replace work are much more difficult to census than actual "flesh and blood" robots. Nor is there any evidence of positive and statistically significant effects. From this point of view, the results of our estimates for Italy tell a partially different story. All other conditions being equal, the local systems that invest more in ICTS seem to grow at a faster pace. It is not, it must be said, a particularly strong or robust result, but there is some evidence of a positive effect. In the case of non-manufacturing employment alone, the impact seems more significant. These are investments that grew significantly in the first period, up to 2001-2002. Then there was a marked slowdown and many sectors experienced a decline in capital stock, except for the public administration, which saw a continuous increase until almost the end of the 20 years examined.

The regression analyses carried out separately for the two periods, which found no effect of this variable in the first decade and a negative and significant effect in the second, however, cast further doubts on the overall reliability of the results obtained. Certainly, also in the case of Italy, the growth in tertiary employment has more than compensated for the loss of manufacturing employment in most of the local systems, especially in the Northern regions and, to a lesser extent, in the Centre of the country. However, how much of this growth is attributable to technological innovations and to digitalisation remains to be seen.

The third most convincing result of the econometric analysis is the impact of trade with emerging countries with low labour costs. In all regressions over the entire period, the coefficient of total net imports from these areas was always negative, robust and significant at 1%. This result has one almost absolute protagonist: China. When the variable is split into the two areas of Asia and Eastern Europe, it is still the imports from emerging Asian countries, of which China represents about three quarters, that hurt Italian companies and workers. Eastern Europe where several productions were delocalised by Italian companies during the period analysed, represents more of an opportunity than a threat to our industry. The trade balance is positive for most sectors, which explains why there is no statistically significant impact on employment, even when it is estimated only for manufacturing.

Interestingly, separating manufacturing from services, a strong impact emerges, obviously negative, when the estimate covers manufacturing employment only, but becomes positive and significant in the case of non-manufacturing employment (Table 6). A plausible interpretation is that China's competitive pressure in some areas and sectors has accelerated the downsizing of manufacturing in favour of services and the tertiary sector. The maps presented above allow this assessment to be further explored. There is little overlap between the local systems most exposed to robots and those most affected by competitive imports from Asia. Many of the latter are located in the North-East and the entire Adriatic backbone, as well as various areas of the Centre (Tuscany and Umbria). These are mainly textile-clothing and leather-footwear districts, which have been particularly affected by Chinese competition. These industries are those that have lost relatively more employment (-38%) in the twenty years in question.

The Italian experience in this case seems to be very similar to that of the United States, convincingly documented by Autor, Dorn, and Hanson (2013), who show how exposure to competition from low-cost imports has destroyed jobs in areas specializing in production where China enjoys comparative advantages.

Unlike Italy, in Germany, exposure to trade with China and Eastern Europe has a positive effect on local growth (DFSW, 2017; Dauth et al., 2014). Germany is a major exporter of medium-high technology products and is not specialised in the sectors most easily subject to price competition from emerging countries. Even with China, the trade balance does not present a significant imbalance, as in the case of Italy or, even more so, the United States. Emerging countries represent a valuable target market for German industry, a result that Italian industry still seems to be struggling to achieve.

5. Conclusions

This study represents a first attempt to assess the impact that new digital technologies and the competitive pressure of low labour cost countries have had on employment in Italian local labour markets.

In terms of the technological transformations commonly associated with the Fourth Industrial Revolution, empirical evidence has found no negative impact on employment, not even in manufacturing, unlike the findings in international literature. On the contrary, robots seem to be associated with a *growth* in overall employment, but mainly due to the tertiary sector. Interpreting this result through the filter of local labour market typologies confirmed that the impact is not homogeneous across the national territory and instead depends on the characteristics of specialisation of local productive systems and industrial districts.

There may be several explanations for the absence of a negative relationship between robots and manufacturing employment. It is possible that during the period examined, the Italian industry in general was still rather behind in the processes of technological innovation. A clue to this is the limited trend in productivity, not addressed in this essay but on which there is extensive literature (without considering the countless contributions that have characterised the debate on the decline of Italian manufacturing, it is worth mentioning: Calcaglini and Travaglini, 2014; Aiello and Ricotta, 2016; Federici and Saltari, 2016; Bugamelli and Lotti, 2018; Bonacini et al., 2020). Another possible interpretation is that the new machines replaced previously automated systems that had already caused workers to be replaced in the past. A more in-depth analysis of the dynamics of individual industries and territories will be required for a more accurate assessment. The large and varied world of the tertiary sector merits equal investigation, the expansion of which, partly due to the processes of servitization of industry, has guaranteed the preservation of overall employment in many local contexts, but dynamics of which have still not been widely explored.

With regard to the competitive pressure from low labour cost countries, the results clearly show that by far the most important effect on the employment dynamics of local systems has been trade with China and other Asian economies, which has probably caused many low-tech and labour-intensive sectors to shrink and thrown several territories into crisis. The shift towards high-quality production, which has certainly taken place in many productive systems, was not enough to temper losses in medium to low-quality production, often targeted at the domestic market and widely displaced by imports from Asian countries. Trade is the most obvious aspect, but linked to this and with the same sign, are significant processes of delocalisation of production activities, especially in Eastern Europe, which could not be taken into account explicitly.

Some limitations of the analysis need to be stressed. The first, shared by all the literature on the subject, concerns the implicit assumption that the number of robots installed represents a reliable indicator for identifying the processes associated with the Fourth Industrial Revolution. This assumption must be considered with caution. Much depends on how the new machines and associated technologies are used in production processes and on the substantial changes they cause in the organisation of work (Acemoglu and Restrepo, 2019). Other aspects need to be borne in mind. The last ten years, probably the most intense in terms of technological innovation processes associated with the digital revolution, have not been considered. The effects of the great recession, which accelerated some major transformation processes in Italian manufacturing, could not be taken into account. Other relevant aspects of the labour market, such as trends in wage and productivity, were not analysed. Similarly, interregional and international migration, which have affected Italian society and influenced the growth dynamics of local economies, have not been explored. These are all useful indications for future research.

What emerges clearly is that the analysis of transformations cannot ignore territories. The characteristics of local systems, which summarise features related not only to the economy but more generally to the quality of social relations and institutions, play a crucial role in the processes of innovation, adjustment and growth within the increasingly close-knit networks of the globalised world.

We would like to conclude with two side notes on industrial policy. The fact that no negative correlation emerges between robots (and ICTS) and employment does not mean that there has been no replacement of work with machines and automated procedures. Instead, it means that the compensatory effects brought about by their introduction have so far been stronger. For production systems that have invested and adapted to digitalisation, this has been a factor of increased competitiveness and resilience. In this sense, it seems to us that, at least for now, the incentives adopted (however they are apportioned and in their various forms, which are not discussed here) should be supported. A further observation concerns exposure to competition by low-cost countries. Having clearly been affected by Asian competition makes us reflect on at least two aspects. The first is that those who argued at the time that markets were opening up "too much and too quickly" were perhaps not wrong (e.g. Samuelson, 2004; and Rodrik, 2018). On the other hand, it confirms – and this is the second element – the necessity to move, as far as possible, to the arena where Italy can enjoy a comparative advantage, at least in certain production contexts and in certain markets: quality and characterization of the product. Both elements are underlined by the most aware and attentive writings on local productive systems.

REFERENCES

Acemoglu D., Restrepo P. (2017), *Robots and Jobs: Evidence from US labor markets,* «NBER Working Paper Series», WP/23285.

Acemoglu D., Restrepo P. (2019), *Artificial Intelligence, Automation, and Work,* in Agrawal A., Gans J. e Goldfarb A. (eds), *The Economics of Artificial Intelligence: An Agenda,* University of Chicago Press, Chicago, 197-236.

Aiello, F., Ricotta F. (2016), *Firm Heterogeneity in Productivity across Europe: Evidence from Multilevel Models*, in «Economics of Innovation and New Technology», 25, 1-2, 57-89.

Autor D.H., Dorn D., Hanson G.H. (2013a), *The Geography of Trade and Technology Shocks in the United States*", in «American Economic Review: Papers & Proceedings», 103, 3, 220-225.

Autor D.H., Dorn D., Hanson G.H. (2013b), *The China Syndrome: Local Labor Market Effects of Import Competition in the United States*", «American Economic Review», 103, 6, 2121-2168.

Autor D.H., Dorn D., Hanson G.H. (2015), *Untangling Trade and Technology: Evidence from Local Labour Markets,* «Economic Journal», 125, 584, 621-646.

Autor D.H., Dorn D., Hanson G.H. (2016), *The China Shock. Learning from Labor-Market Adjustment to Large Changes in Trade*, «Annual Review of Economics», 8, October, 205-40.

Bonacini L., Fareri S., Paba S., Solinas G. (2020), *I sistemi produttivi in Italia tra globalizzazione e digitalizzazione*, «DEMB Working Paper Series», WP/166.

Brusco S. (1999), *The Rules of the Game in Industrial Districts*, in Grandori A., ed., *Interfirm Networks: Organization and Industrial Competitiveness*, London-New York, Routledge, 17-40.

Bugamelli M., Lotti F., eds., (2018), *Productivy Growth in Italy. A Tale of Slow-Motion Change,* «Questioni di Economia e Finanza», WP/422.

Calcagnini G., Travaglini G. (2014), *A Time Series Analysis of Labor Productivity: Italy versus the European Countries and the U.S.*, «Economic Modelling», 36, 622-628.

Chiacchio F., Petropoulos G., Pichler D. (2018), *The Impact of Industrial Robots on EU Employment and Wages: A Local Labour Market Approach,* «Bruegel Working Paper», WP/2.

Dauth, W., Findeisen S., Suedekum J. (2014), *The Rise of the East and the Far East: German Labor Markets and the Trade Integration*, «Journal of the European Economic Association», 12, 6, 1643-1675.

Dauth, W., Findeisen S., Suedekum J., Woessner N. (2017a), *German Robots-the Impact of Industrial Robots on Workers*, «CEPR Discussion Paper», DP/12306.

Dauth, W., Findeisen S., Suedekum J., Woessner N. (2017b), *Trade and Manufacturing Jobs in Germany,* «American Economic Review: Papers and Proceedings», 107, 5, 337-342

Di Giacinto V., Gomellini M, Micucci G., Pagnini M. (2012), Mapping Local Productivity Advantages in Italy: Industrial Districts, Cities or Both, «Temi di Discussione», Banca d'Italia, WP/850.

Federici D., Saltari E. (2016), Elasticity of Substitution and the Stagnation of Italian Productivity, «Economics of Innovation and New Technology», 25, 5-6, 503-515.

Federico S. (2014), *Industry Dynamics and Competition from Low-Wage Countries: Evidence on Italy*, «Oxford Bulletin of Economics and Statistics», 76, 3, 389-410.

Glaeser E. (2008), *Agglomeration and Spatial Equilibrium*, Oxford, Oxford University Press.

Graetz G., Michaels G. (2015), *Robots at Work*, «CEP Discussion Paper», WP/1335.

Henderson J., Vernon J. (2003), *Marshall's Scale Economies*, «Journal of Urban Economics», 53, 1, 1-28.

Manzocchi S., Quintieri B., Santoni G. (2017), *Local Manufacturing Productivity Markers: An Empirical Study of the Italian Counties*, «Annals of Regional Sciences», 59, 255-279.

Mishel L., Bivens J. (2017), *The Zombie Robot Argument Lurches On*, «Economic Policy Institute», Report May 24, 1-25.

Moretti E. (2011), *Local Labor Markets*, in Ashenfelter O., Card D. (eds.), *Hanbook of Labor Economics*, London, Elsevier, 1237-1313.

Rodrik D. (2017), *Straight Talk on Trade. Ideas for a Sane World Economy*, Princeton, Princeton University Press.
Samuelson P.A. (2004), *Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization*, «Journal of Economic Perspectives», 19, 3, 135-46.

Table A1 - ISTAT CLASSIFICATION OF SLLs : DESCRIPTION OF THE VARIABLES

BREAKDOWN BY TYPOLOGY OF SPECIALIZATION ISTAT					
Systems without specialization	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	220	19,82	27,22	-85,81	104,88
Δ Manufacturing Employment	220	-23,64	28,37	-136,08	74,25
Δ Robot	220	0,51	0,38	-0,13	3,11
Δ Net imports from Eastern Europe	220	-0,02	0,11	-1,11	0,43
Δ Net imports from Asia	220	0,40	0,26	0,07	1,42
Share of public sector emplyment in 1991	220	8,28	3,64	2,73	27,23
Δ ICTS	220	2,09	0,98	1,42	12,60
Non-manufacturing systems	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	178	45,37	30,53	-44,44	180,46
Δ Manufacturing Employment	178	-36,43	33,71	-191,74	70,93
Δ Robot	178	0,65	0,59	-0,79	3,40
Δ Net imports from Eastern Europe	178	-0,06	0,16	-0,85	0,76
Δ Net imports from Asia	178	0,65	0,46	0,05	2,32
Share of public sector emplyment in 1991	178	5,65	2,79	1,84	18,29
Δ ICTS	178	2,19	0,65	1,05	5,12
Made in Italy systems	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	232	25,33	27,71	-125,28	123,95
Δ Manufacturing Employment	232	-21,14	32,52	-150,95	147,52
Δ Robot	232	1,26	0,85	0,18	5,65
Δ Net imports from Eastern Europe	232	-0,17	0,23	-1,05	0,48
Δ Net imports from Asia	232	2,03	1,09	0,17	6,76
Share of public sector emplyment in 1991	232	3,52	2,04	1,09	12,16
Δ ICTS	232	1,71	0,44	0,88	5,64
Heavy manufacturing systems	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	52	29,09	31,85	-51,56	87,90
Δ Manufacturing Employment	52	-27,28	37,77	-88,96	84,00
Δ Robot	52	2,22	2,04	-0,43	8,62
Δ Net imports from Eastern Europe	52	-0,02	0,50	-1,16	1,44
Δ Net imports from Asia	52	1,56	0,77	0,28	3,18
Share of public sector emplyment in 1991	52	3,80	2,05	1,04	10,30
Δ ICTS	52	2,02	0,53	1,21	3,93
BREAKDOWN BY SPECIASLIZATION OF INDUSTRIAL DISTRICTS					
SLL not districts	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	526	30,06	31,74	-125,28	180,46
Δ Manufacturing Employment	526	-27,96	33,30	-191,74	147,52
Δ Robot	526	0,78	0,92	-0,79	8,62
Δ Net imports from Eastern Europe	526	-0,05	0,21	-1,11	1,44
Δ Net imports from Asia	526	0,76	0,67	0,05	4,38
Share of public sector emplyment in 1991	526	6,38	3,50	1,04	27,23
Δ ICTS	526	2,08	0,80	1,05	12,60
Other districts	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	53	23,11	20,90	-40,08	71,83
Δ Manufacturing Employment	53	-14,85	27,19	-87,41	82,65
Δ Robot	53	1,57	1,06	0,46	6,73
Δ Net imports from Eastern Europe	53	-0,15	0,29	-1,16	0,48
Δ Net imports from Asia	53	1,74	0,67	0,33	3,04
Share of public sector emplyment in 1991	53	3,21	1,63	1,11	9,51
Δ ICTS	53	1,69	0,34	1,00	2,63
Mechanics	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	38	20,87	26,59	-83,98	58,02
Δ Manufacturing Employment	38	-19,19	26,00	-88,44	85,63
Δ Robot	38	1,87	0,99	0,55	4,57
Δ Net imports from Eastern Europe	38	-0,18	0,25	-0,73	0,32
Δ Net imports from Asia	38	1,97	0,74	0,38	3,57
Share of public sector emplyment in 1991	38	2,66	1,19	1,32	6,40
Δ ICTS	38	1,69	0,28	1,23	2,42
Fashion	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Δ Employment	65	30,69	25,86	-94,69	123,95
Δ Manufacturing Employment	65	-27,44	31,69	-150,56	101,16
Δ Robot	65	1,06	0,67	0,26	3,27
Δ Net imports from Eastern Europe	65	-0,21	0,20	-0,65	0,28
Δ Net imports from Asia	65	2,93	1,27	0,62	6,76
Share of public sector emplyment in 1991	65	3,30	2,08	1,09	10,34
Δ ICTS	65	1,55	0,29	0,88	2,74