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ICT AND EMPLOYMENT GROWTH IN ITALIAN INDUSTRIES

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Abstract

With respect to the divergent patterns of employment growth between the EU and US, the mainstream approach has mainly emphasised the rigidities of European labour markets while another school of thought has stressed the importance of technological change which, over the last decade, has been driven by information and communication technologies (ICT). This paper provides a test of the above hypotheses by using newly available data for Italian three-digit industries. Regression results show that, in 1997-2000, the employment growth across Italian industries is mainly explained, with opposite signs, by the growth of output (or demand) and labour costs. The intensity of ICT investment exerts a negative impact on the employment changes of secondary industries while, within service industries, it is positively and significantly associated with the increase of employment.

JEL Classification: J23, O33
Keywords: Technological Change, ICT, Labour demand, Employment growth.

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ICT and employment growth in Italian industries*

1. Introduction

Since the second half of the 1980s, a pessimistic view about the job generation potential of the European economy has affirmed. Compared to the US, experiencing prolonged positive trends in both employment and productivity, European countries were falling behind; the situation worsened in the first half of the 1990s while, from 1995 on, the EU has experienced an employment revival.

Two main explanations of the above phenomena have been put to the fore. The mainstream approach has mainly emphasised the rigidities of European labour markets which have determined higher wages and lower employment. Many of these constraints have been relaxed during the second half of the 1990s and this explains the European employment recovery. Another school of thought has stressed the importance of technological change which, over the last decade, was driven by information and communication technologies (ICT): in the US, along with their positive impact on productivity, ICT have contributed to an expansion of employment via new products, services and business opportunities. According to this approach, ICT diffused across European countries with

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substantial delays and only in the late 1990s they fostered an employment resurgence.

Most of the evidence concerned with the employment changes in the EU and Italy neglects the role of technological change, uses aggregated data and applies a standard framework for labour demand (in which wage and output changes play a crucial role). On the contrary, the few empirical studies focussing on technological change and ICT have not always controlled for the impact exerted by wages. This paper attempts to carry out a comprehensive analysis by using a newly available statistical source which provides, for Italian industries, data disaggregated up to the third digit.

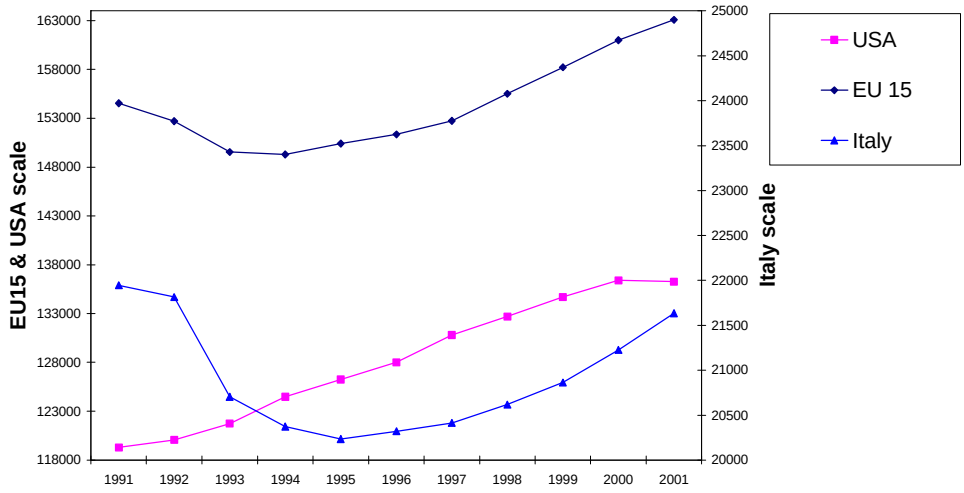
In section 2, we compare the recent employment performances of US, EU and Italy and review the main interpretations proposed in the literature; then, we concentrate on the possible role of ICT in explaining the divergent patterns of employment growth between US and EU. Section 3 is devoted to a descriptive analysis of the employment changes recorded, over the period 1997-2000, by Italian industries distinguished in three 'ICT groups': producers, intensive users and non-ICT industries. In section 4, we estimate across 173 three-digit industries a comprehensive equation for employment growth. This is mainly explained, with opposite signs, by the growth of output (or demand) and labour costs. The intensity of ICT investment exerts a negative impact on the employment changes of secondary industries while, within service industries, it is positively and significantly associated with the increase of employment. Section 5 contains some concluding remarks and addresses the issue of why, in Europe, ICT seem to foster employment growth only, having a non significant impact on labour productivity.

2. Recent employment trends in the US, EU and Italy: is there a role for ICT?

2.1 Basic facts

During the 1990s the problem of unemployment took the lead among the priorities of the EU policy debate. In fact, notwithstanding the increase of European workers during the expansionary cycle of the second half of the 1980s, EU unemployment rate remained quite high and arose further during the first half of the 1990s (with a peak of 10.5% in 1994), in coincidence with a decrease in the number of European workers (see figure 1 and table 1).

Figure 1: Total employment in USA, EU15 and Italy (thousands): 1991-2001



Source: OECD (2002b).

The poor employment performance of the European economy over the period 1991-95 – i.e. a 0.7% annual reduction of the working population - is apparent if one looks at what happened in the US. During the same years, in fact, the US

experienced a significant employment increase (1.4% per year); almost in the same period (1990-95)[1], the annual rates of labour productivity growth (value added per working person) were 1.9 for the EU and 1.1 for the US (cf. van Ark et al., 2003). As a consequence, the better productivity performances of European countries could not be taken as 'good news' since they seem to have been reached at the expenses of employment.

Table 1 – Annual rates of employment and labour productivity growth

Employment	1991-95	1995-2000
EU15	-0.67	1.37
USA	1.43	1.56
Labour productivity	1990-95	1995-2000
EU15	1.90	1.40
USA	1.10	2.50
Employment in Italy	1991-95	1995-2000
Agriculture	-5.16	-3.30
Industry	-1.88	0.00
Construction	-1.58	0.63
Trade, transport & communication	-1.07	1.49
Financial & business services	0.57	4.98
Public & other private services	-0.09	0.78
Total economy	-2.01	0.96

Sources: OECD (2002b) for US and EU employment; van Ark et al. (2003) for US and EU labour productivity; ISTAT (2003) for Italian employment.

During the second half of the 1990s the situation significantly changed, since both in the EU and US there was a remarkable increase of employment with annual growth rates equal, respectively, to 1.4 and 1.6%; in the same period

[1] Table 1 considers the period 1991-95 (instead of 1990-95) since in the EU and Italy the year 1991 coincides with the inversion of an expansionary phase of employment (starting in the mid-1980s).

(1995-2000) the growth of labour productivity in the two economies amounted to 1.4 and 2.5% per annum.

Thus, although the US economy has recorded better scores with respect to all the economic indicators, in the second half of the 1990s European countries seem to have recovered a substantial capacity of generating jobs. Confronted with these basic facts, influential research bodies, followed by many commentators and policy makers, have rapidly changed attitude: from the pessimistic orientation typical of the so-called 'Eurosclerosis' phase (characterised by the presence of 'growth without employment') to the contemporary optimism. For instance, the positive employment scores of European countries during the second half of the 1990s have led the OECD researchers to speak about an "European job machine" (cf. European Commission, 2002).

Italian employment trends over the 1990s are consistent with those of the EU, even though, in the first part of the decade, the decrease of the working population was more severe and, in the second part, the employment revival less pronounced. Giving the easier access to our national data, in the bottom of table 1 we provide a sectoral breakdown of the Italian employment figures only. Although with a high (and questionable) level of aggregation, it clearly emerges that the rates of employment growth are markedly different across sectors; in particular, the phase of employment expansion starting in 1995 is driven by the service sector as a whole and there is a staggering increase (almost 5% per annum) of people working in financial and business services. As it is widely known, these sectoral patterns are common to the most advanced economies and give rise to a further stylised fact that, in the following discussion, must be kept in mind.

2.2 Two main explanations

Different explanations of the basic facts described in the previous section have been put to the fore. However, for the sake of synthesis, in what follows we shall focus on two main schools of thought: the 'labour market rigidities' approach and that of 'structural and technological change'. Although rooted in extremely different theoretical assumptions, we believe that both approaches must be taken into consideration in order to give a comprehensive account of the recent employment dynamics in the US and EU.

The first approach is the mainstream one. Being mainly based on neoclassical assumptions, it frames unemployment as a temporary out-of-equilibrium phenomenon which 'naturally' disappears as soon as input markets are free to work competitively. Thus, a given aggregate unemployment level can always be absorbed at a lower equilibrium wage rate (cf. Bertolila and Bertola, 1990, Layard et al., 1991, Bertola and Ichino, 1995) but, in order to ensure that markets clear and involuntary unemployment disappears, a suitable labour market (de)regulation – based on the flexibility of working time and wages as well as relaxed hiring and firing conditions - must be in place. The policy debate in Europe has been strongly influenced by the 'labour market rigidities' argument, culminating in the OECD Jobs Study (cf. OECD, 1994) which blamed the over-regulation and low flexibility of European labour markets (as opposed to the US one) as being the main cause of the European employment sclerosis of the 1980s and early 1990s.

The same argument has been applied to explain the European employment resurgence of the late 1990s: in fact, the advocates of the labour market flexibility (see, among others, OECD, 2002a) have argued that this positive employment score is mainly the outcome of a variety of policy interventions,

recently introduced in most European countries, which have relaxed a number of institutional rigidities affecting labour markets. Examples of these interventions are the increasing importance ascribed to de-centralised (or firm-level) bargaining as opposed to centralised wage setting, the possibility of deviating from standard labour contracts when firms are located in the less-developed areas of a country and all the measures that, by reducing hiring costs and entry wages, have favoured the employment of young people and females in search of their first job[2].

Being able to give account of the changes in the European employment trends, the transition from rigid to flexible labour markets is undoubtedly an appealing argument. However, it fails to provide a convincing explanation of the extremely different patterns of employment growth across sectors. Namely, why some service sectors (see, again, the bottom of table 1) did take advantage of labour market flexibility (or exploit the public incentives for youth and female employment) more intensively than other sectors?

Since technological revolutions, at least in the early phases of diffusion, are strongly sector-specific, the 'structural and technological change' framework may help to address the above issue. This approach (based on the Schumpeterian view of capitalist development) departs from the standard market equilibrium framework by stressing that employment expansions and reductions are driven by different paths of technological change (Petit and Soete, 2001b). Although focussing on the structural implications of technological breakthroughs (such as the emergence of new industries in response to radical product innovations or the deep reshaping of the 'old' ones due to the introduction of pervasive technologies), this approach is not based on technological determinism. In fact,

[2] In Italy, similar measures aimed at 'reforming' the labour market have been inserted in a governmental bill (known as 'pacchetto Treu') approved in 1997.

as Freeman and Soete (1987) already pointed out since the mid-1980s, the path of technological change is not straight, smooth and easy; without deep changes in social and economic institutions as well as public policies, many co-ordination failures could emerge and hamper or significantly reduce the (potentially) positive impact of technological change on economic growth and employment. It must be stressed that such institutional changes are far from being confined to labour markets, as suggested by the mainstream approach[3]; much wider changes (including those concerned with public policies and firm organisations) are needed to ensure a ready match between the old and new branches of the economy, the supply and demand of new goods and services, the new skills required and those already available.

This technology-based approach offers a set of interesting explanations also with respect to the recent divergent patterns of employment growth between the US and EU. For instance, according to Pianta and Vivarelli (1999) and Pianta (2001), the neoclassical optimism about the effect of technological change on employment (relying upon the compensation allowed by wage and price changes – see the previous footnote) should be carefully reconsidered. In fact, the most effective compensating mechanisms are the 'real' (or 'schumpeterian') ones, that is those based on the introduction of product innovations which give rise to

[3] In fact, the confidence on wage and price adjustments allows neoclassical scholars to have an optimistic view (at least in the long run) of the relationship between technological change and employment. Moreover, they mainly confine technological change to the introduction of process innovations (which displace labour in the short run) and, often, model it as an exogenous TFP shock. A recent example of this approach can be found in Bertola et al. (2001), who analysed the US unemployment path in the last three decades as opposed to that of other OECD countries. In their empirical model, macroeconomic shocks (including TFP and demographic changes) are treated both separately and in conjunction with some indicators of the labour market institutional setting of each country. They found that the better employment performance of the US is mainly explained by the wage dynamics and the presence of labour market flexibility which, over the period considered, allowed a more ready recovery from exogenous shocks.

entirely new branches of economic activity; process innovations, by definition, have instead a strong labour-destroying potential. By comparing the patterns of innovation and type of R&D activities among the US and EU during the 1980s and early 1990s, Pianta and Vivarelli show that European countries are more based on process rather than product innovations and, as a consequence, are more exposed to 'structural' or 'technological' unemployment. In other words, along with less dynamic institutions and organisations, also the very technological strategies of European firms may hamper the beneficial impact of innovation on employment. Similar arguments could be adduced for explaining the different (and, for the early 1990s, divergent) economic impact of information and communication technologies (ICT) on the US and EU patterns of growth.

2.3 The role of ICT

An increasing body of research links ICT investments to the recent revival (after two decades of slowdown) of employment and productivity in the US. As argued by Stiroh (2003), the origins of the gains from ICT had to be traced to the tremendous pace of innovation recorded in industries that produce high-tech equipment (semiconductors, computer hardware, and telecommunication devices). Such a remarkable progress – well depicted by Moore's Law (the doubling of the power of semiconductors almost every 20 months) – has determined a price decline of a variety of semiconductor-based products and, at the same time, an improvement of their performance. As a consequence, "the rest of the economy has benefited from a substantial pecuniary externality in the form of rapidly declining prices for high-tech assets" (Stiroh, 2003, p. 3) and this, coupled with new organisational structures and improved software

applications, has provided powerful incentives for US firms to invest strongly in ICT (in the late 1990s, almost 25% of non residential fixed investment of US firms was devoted to ICT).

Although the most relevant impact of ICT has been on productivity growth, considering the employment increases recorded in the whole economy and, particularly, in the service industries that invested more in ICT (computer, finance and business services – see Jorgenson et al., 2002), such a massive introduction of ICT does not appear to have displaced labour at the aggregate level: this means that these new technologies have been associated both with substantial productivity gains (especially in manufacturing) and new growth opportunities (especially in services).

Also in Europe, there were similar expectations with respect to the job creation potential of ICT, both in the light of the overall positive employment impact of the previous waves of technological change and according to the peculiar features of the ICT 'revolution' (see Petit and Soete, 2001b). However, contrary to the US experience, these potential benefits did not show up, at least up to the early 1990s. What reasons can be adduced for this (hopefully temporary) failure?

According to the 'structural and technological change' approach it is possible that, in Europe, during the early phase of diffusion, ICT have been introduced mainly with a labour-saving rationale (as in the case of microelectronics used exclusively for automation purposes), while their equally important job-creation potential has been harmed by different factors and, particularly, by some adverse product market regulations, a lack of private investment and the absence of public policies aimed at fostering the diffusion of digital technologies.

With respect to product regulation, a relevant case is that of the TLC sector, where, in Europe, full deregulation was achieved only in the second half of the

1990s, while in the US was already in place ten years before. With the TLC deregulation, new products and services (mobile phones, new data & voice services, Internet-related services, etc.) have been introduced, reverting, also in Europe, the initial labour saving bias displayed, in this industry, by technological change.

Similarly, while in the US substantial IT investments (especially in computer hardware) were already undertaken at the end of the 1980s, in the EU a critical mass of them was recorded only in the second half of the 1990s. In spite of that, this technology gap is far from being filled: still in 2000, for instance, the share of workers using a computer in workplaces is 56% in the US versus 41% in the EU (cf. Lucchetti et al., 2003). However, in the subsequent (1995-2000) wave of ICT expenditures – more related to software, telecommunication equipment and digital devices for implementing connectivity and electronic commerce – it seems that European firms have been involved in a more effective process of catching-up.

As far as technology policy is concerned, ICT have diffused in the US in conjunction with a variety of public interventions (Petit and Soete, 2001b): military programmes and spillovers from military networks, semiconductor trade agreements, changes in the legislation concerned with intellectual property rights and, last but not least, supports for the building of ICT infrastructure. In the same period, instead, the main goal of EU national governments was that of controlling public expenditures in order to meet the 'convergence parameters' requested to join the European Monetary Union. Only in the late 1990s (with a process culminating in the declaration of the European Council of Lisbon of March 2000) European policy makers have recognised that, for a EU capable of generating growth and jobs, it is necessary to win the digital race with the US economy and, thus, provide substantial public supports in this direction.

Can Europe approach this goal? Or, put it another way, has the European economy changed significantly attitude with respect to the recent wave of technological change based on ICT? A positive relationship between the recent employment revival and the intensity of ICT investment (which, as already said, has significantly increased in Europe during the second half of the 1990s) could be viewed as a first (albeit partial) signal of recovery. This optimistic picture, however, is counterbalanced by the fact that, in the EU economy, ICT investment does not seem to generate substantial productivity gains, comparable to those recorded by the US during the period 1995-2000 (see van Ark et. al., 2002; Stiroh, 2002).

We will address the issue of the low productivity potential of ICT in Europe in the concluding section. In the next two sections, instead, we will show what Italian industry data can say about the relationship between ICT and employment growth. Although our focus is on the impact of ICT investment on employment growth, in the cross-industry analysis developed in section 4 we shall control for the effects exerted by the changes in output and labour costs: in doing so, an attempt will be done to jointly take into account both 'technological change' and 'labour market' variables.

3. ICT intensity and employment growth across Italian industries

This section is devoted to a descriptive analysis of the employment changes recently experienced by Italian industries classified according to their intensity of ICT expenditures. In Italy, the only data source that allows one to carry out this kind of analysis is that provided by the Survey on Firms' Accounts (carried out by ISTAT, the Italian Statistical Office). This data base offers three main advantages: first, it jointly provides information on different types of investment

(included that in ICT) and labour inputs; secondly, data are available with a sufficiently high level of disaggregation (three-digit); third, although with some exceptions, it covers the whole range of secondary and tertiary industries. The main shortcoming of this survey, instead, is that the data useful for our purposes are available only for the period 1997-2000. However, this is the period in which Italian expenditures on ICT have particularly concentrated and, as shown in the previous section, there has been a substantial employment revival. According to National Account statistics, the increase of employment continued during the years 2001-02: although the comparisons can be done with a lower level of disaggregation, National Account figures confirm the sectoral employment changes recorded by the Survey on Firms' Accounts.

3.1 Database characteristics and ICT classification

The Survey on Firms' Accounts (henceforth, SFA), involving 33.000 Italian firms, has a mixed nature, being composed of two different surveys. For firms with fewer than 20 workers a stratified sample of the universe is considered, while for those with 20 workers and more the survey covers the entire Italian population. The survey's results are adjusted for missing answers and re-proportioned to the universe (ISTAT, 2001).

The data set offers information about the balance sheet of firms (economic and financial variables), together with specific data on workers (full and part-time), labour costs and investment. Data are released for three-digit industries but only when the number of respondent units does not allow the identification of single firms. Due to the nature of their activities and employers, some important sectors are not included in the SFA: financial intermediation, public administration, defence, compulsory social security and households market activities are the main examples excluded, together with the primary sector.

The data used for the purposes of the present study are the number of workers (total and employees) and hours worked, labour costs, value added, total and ICT investment; they are relative to the 1997-2000 period for all the variables, except for ICT and total investment, which are available for 1998-2000.

In principle, industry classifications by ICT intensity can be constructed either from capital-related data or investment data. Obviously, the former offer a more accurate account of effective ICT inputs, since they directly measure cumulative investment flows, net of obsolescence and scrapping. Unfortunately, industry data on ICT capital stock are not yet available for most OECD countries, Italy included[4].

Moreover, being ICT 'general purpose', flexible and highly pervasive technologies, the intensity of utilisation and the returns to their adoption vary significantly among industries and across corporate functions. Because of that, the most reliable indicator of ICT intensity is that based on the flow of ICT capital services. The latter, being estimated on a user cost-basis, better reflect the intensity of utilisation of each capital item across industries. Again, except for US, no other country offers statistics on ICT capital services by industry. Stiroh (2002) has recently provided estimates of ICT capital services and derived a classification of sectors according to the intensity of ICT utilisation distinguishing between intensive and non-intensive users. Among intensive users, those producing ICT goods and services are classified separately as ICT producers.

[4] The Italian national statistical office (ISTAT), following the efforts of other EU countries (UK, Germany, Netherlands and France), has recently begun to estimate these data, expected to be available in the near future. Unfortunately, their level of disaggregation will be much lower than that allowed by the SFA data used in the present paper (31 versus 187 industries).

With minor changes, Van Ark et al. (2002) have extended the same ICT classification to 16 OECD countries (including Italy) and 49 industries[5]. The hypothesis underlying the geographical extension of the original classification introduced by Stiroh is that, in each industry, ICT would face the same patterns of adoption across countries, considering that of US as the 'optimal' pattern.

Following Van Ark et al. (2002), we have applied the same classification to the Italian case by aggregating 187 three-digit industries. However, before doing that, we checked the adaptability of the original taxonomy by using, as a proxy for ICT intensity, the sum of ICT investments during 1998-2000 on the average number of total workers over the period 1997-2000[6]. This check has lead us to reallocate some industries across the three ICT groups when their ICT intensity was, at least, three times higher or lower than that of the whole ICT group. The description of reallocated industries is provided in the Appendix (see table A.1), which also contains the lists of Italian three-digit industries classified as ICT-users and non-ICT industries (tables A.2 and A.3). Table 4 in this section (see below) provides the list of ICT-producing industries.

Even with the above changes, the findings for Italy are consistent with those arising from Stiroh (2002) and van Ark et al. (2002). Using the ratios of cumulated ICT investment to different measures of labour inputs (total workers, employees, and hours worked)[7], table 2 shows that the most intensive ICT

[5] These 49 industries are constructed by grouping three-digit industries (classified according to the ISIC Rev. 3). For the composition of the original classification, see table 2 in Van Ark et al. (2002).

[6] ICT investments are influenced by business cycle and firms' choices. On the other hand, they are a proxy of the net variation of ICT capital stock, although gross of obsolescence and scrapping. To alleviate the possible bias due to a different timing of investment across industries, we summed up ICT investments over three years (1998-2000). Given the unavailability of industry deflators we cumulated ICT investments in nominal terms.

[7] We employ these indicators of ICT intensity, related to labour inputs, because they are also used for the regression analysis of the next section. However, the results of the descriptive

investors are the ICT-producing industries ('producing'), followed by ICT intensive users ('using') and, at the lowest end, by 'non-ICT' industries.

Table 2 – Intensity of cumulated ICT investment over 1998-2000*

	ICT investment/ Total workers°	ICT investment/ Employees°	ICT investment/ Hours worked°
All industries			
Non-ICT	472	712	417
Producing	2993	3840	2254
Using	1005	1692	975
Total	750	1165	679
Secondary industries			
Non-ICT	529	701	409
Producing	2592	3262	1949
Using	889	1063	617
Total	686	883	514
Service industries			
Non-ICT	413	727	429
Producing	3207	4159	2418
Using	1068	2313	1323
Total	803	1503	877

* Expressed in Euro.
° Average number over the period 1997-2000.
Source: own computations on the Survey on Firms' Accounts (unpublished data).

In secondary industries (mining, manufacturing, utilities, and construction) there is a wide gap between the ICT intensity of producers and that of intensive users: whatever indicator is used, the investment per unit of labour input of an ICT producer is almost three times greater than that of an intensive user. This

analysis do not significantly change when the investment in ICT is related to total investment or value added.

supports the choice of classifying separately producers and intensive users of ICT.

Similarly, independently from the indicator used, service industries are the most intensive ICT investors; however, the difference with secondary industries is particularly high when investment per employee is considered[8]. Moreover, a part from the indicator based on total workers, in services the gap between producers and intensive users is lower.

3.2 Employment changes

Although in a descriptive way, we can first survey the broad association between ICT intensity and changes in labour inputs over the period 1997-2000. Disposing of three different measures of employment, we can also check if particular ICT groups of industries have experienced different performances when we move from total to dependent employment or hours worked, i.e. the indicator which best reflects the effective quantity of labour input. However, as shown by table 3, the three indicators offer a coherent picture of the employment dynamics, both in total and across industries and ICT groups.

Looking at the aggregate figures (top of the table), ICT producing industries show the highest employment growth, while the lowest is that of the ICT using ones. Non-ICT industries fall in between, being rather coincident to the average.

However, strong differences emerge when services are separated from secondary industries. Within the latter, that of ICT producers is the only group recording a decrease of employment and working hours over the period 1997-2000, while secondary ICT users show an almost stationary employment trend.

[8] This finding depends on the higher share of employees on total worker recorded by secondary industries (78%), as opposed to service industries (54%).

Indeed, since only non-ICT industries have increased labour inputs, employment generation in secondary industries appears to be dissociated from ICT intensity.

Table 3 – Absolute and percentage changes of labour inputs in Italy: 1997-2000

	D. Workers	D %	D. Employees	D %	D. Hours worked	D %
All industries						
Non-ICT	724537	8.60	559864	10.07	903824	9.57
Producing	95121	19.30	65717	16.85	110156	16.65
Using	317857	6.76	185326	6.63	356380	7.38
Total	1137515	8.35	810907	9.27	1370360	9.17
Secondary industries						
Non-ICT	181212	4.12	150242	4.52	281442	4.98
Producing	-12969	-6.63	-9366	-6.03	-10203	-3.95
Using	3088	0.18	8195	0.57	39860	1.63
Total	171331	2.71	149071	3.04	311099	3.72
Service industries						
Non-ICT	543325	13.51	409622	18.31	622382	16.40
Producing	108090	36.38	75083	32.00	120359	29.83
Using	314769	10.54	177131	12.95	316520	13.26
Total	966184	13.23	661836	17.24	1059261	16,09

Source: own computations on the Survey on Firms' Accounts (unpublished data).

The negative performance of manufacturing ICT producers (see also table 4) seems patently at odds with the 'compensation theory' (see Vivarelli 1995 and Vivarelli and Pianta, 2000), which suggests that the industries producing 'high-tech' goods should experience the highest employment growth. This apparent contradiction can be solved by taking into account that, in the Italian case, the real explanatory factor of the employment reduction is the loss of competitiveness of electronic and IT producers during the 1990s. As a result, in these industries, Italy lost market shares (both in domestic and foreign markets)

and hence employment, without any causal relation to ICT intensity. Instead, among the different causes of the low employment performance of secondary ICT users, it is possible that the (positive) competitiveness-enhancing effect of ICT has been almost compensated by a (negative) labour-saving effect.

The bottom part of table 3 shows the employment changes in service industries, which, as expected, appear to be far more positive than those of secondary industries. Among the ICT groups, service ICT producers are the strongest employment generators (a phenomenon common to all the most industrialised countries, including the US - cf. Jorgenson et al., 2002). Instead, contrary to what expected, the (albeit positive) performance of service ICT users is worse than that of non-ICT service industries.

From a three-digit disaggregation of ICT-producing industries, provided by table 4, it emerges that, with the exception of hardware consulting[9], all the tertiary ICT producers record positive employment variations and, some of them, very high rates of growth. On the contrary, among secondary (actually, manufacturing) ICT producers, only the industries of electronic components and medical instruments gain employment. Thus, the Italian ICT sector is characterised by two extremely divergent patterns of employment growth: markedly negative in manufacturing and, thanks the industries of software, data processing, computer-related activities and telecommunications, strongly positive in services.

[9] However, it must be noticed that, in terms of employment, the size of this industry, compared to that of software or data processing industries is very small.

Table 4 - Employment changes among ICT producing industries

Nace Rev.1		D Workers	D Employees	D Hours worked
	Secondary industries			
300	Office machinery and computers	-8314	-9067	-14955
	Δ %	-33.58	-38.74	-37.29
313	Insulated wire and cable	0	-108	-277
	Δ %	0.00	-0.82	-1.26
321	Electronic valves and tubes and other electronic components	2560	2725	9312
	Δ %	8.54	9.60	20.13
322	TV and radio transmitters and other communication apparatus	-4841	-4755	-8028
	Δ %	-7.25	-8.40	-8.69
323	TV and radio receivers & recording or reproducing apparatus	-1500	-1267	-1168
	Δ %	-16.63	-15.42	-9.16
331	Medical and surgical equipment and orthopaedic appliances	-874	3106	4913
	Δ %	-1.70	12.13	10.98
	Service industries			
642	Telecommunications	16965	16179	21611
	Δ %	17.91	17.14	13.60
721	Hardware consulting	-2719	-3117	-5527
	Δ %	-41.53	-59.07	-61.65
722	Software consulting and supply	51428	38163	62716
	Δ %	57.04	56.63	52.80
723	Data processing	20294	11868	21983
	Δ %	25.91	22.82	24.71
724	Database activities	716	546	1106
	Δ %	32.78	30.13	35.96
725	Maintenance and repair of office & computing machinery	1452	108	-168
	Δ %	12.21	1.48	-1.29
726	Other computer related activities	19954	11336	18638
	Δ %	150.39	175.13	157.58

Source: own computations on the Survey on Firms' Accounts (unpublished data).

4. Regression results

The aim of this section is to assess the statistical strength of the relationship between the intensity of ICT investment and the employment changes across Italian three-digit industries. For this purpose, instead of ascribing each industry to an ICT group (that of producers, users and non-ICT industries), we will use a continuos variable for ICT intensity; in this way, the heterogeneity in ICT investment within each group will be taken into account. Obviously, to avoid a spurious correlation, ICT cannot be the sole explanatory factor of employment growth but must be inserted in a 'sound' and comprehensive specification.

A labour demand equation for a generic industry, can be derived from the minimisation of total cost, i.e. the sum of products of the profit-maximising input demands and the factor prices (Hamermesh, 1993). Since the same input requirements depend on input prices, output and technology, the cost equation can be represented as

$$C = C(w, r, Y, t) \qquad [1]$$

where w is the wage rate, r is the rental rate of capital, Y is output (all the variable are expressed in real terms) and t denotes the state of technology.

By applying Shepard's lemma, the industry's demand for labour can be obtained from [1] as $L=\partial C/\partial w$, which, in turn, can be written as

$$L = L^{d}(w, r, Y, t) \qquad [2]$$

For estimation purposes, equation [2] can be expressed in natural logs. However, as it usually happens in cross-industry analyses, industry data for the rental price

of capital are not available for Italy so that our equation for labour demand, omitting the random error, reduces to

$$\ln L = \alpha_0 + \alpha_1 \ln Y + \alpha_2 \ln w + \alpha_3 t \qquad [3]$$

The use of equation [3] is possible if one assume that r does not vary across industries or that each industry uses a CES production technology (see Hamermesh, 1993, p. 30). Moreover, along with the above restrictions, it must be noticed that the adopted framework is static and that a straightforward estimate of equation [3] is biased by the endogeneity of output. Instead, the fact that we do not estimate a simultaneous system of labour demand and supply, does not give rise, in our opinion, to a severe shortcoming. In fact, three-digit industries (i.e. our units of observation) are quite small with respect to the whole economy and, as a consequence, the elasticity of labour supply can be treated as infinite.

In order to get a specification for labour inputs' changes, one can take the differences of natural logs of equation [3] and obtain:

$$\Delta \ln(L) = \alpha_0 + \alpha_1 \Delta \ln(Y) + \alpha_2 \Delta \ln (w) + \alpha_3 (I_{ICT}/L) \qquad [4]$$

In equation [4] the change in the state of technology (Δt) is proxied by a measure of ICT intensity, namely the amount of ICT investment (I_{ICT}) per unit of labour. Thus, contrary to the output and wage variables, our aim is not to examine how the change in ICT capital affect labour inputs but simply to test whether the industries with greater ICT intensities experience higher rates of employment growth.

Using the Survey on Firms' Account, equations [4] can be estimated across Italian three-digit industries over the period 1997-2000. Labour input (L) is measured both in terms of employees and hours worked[10]; as a proxy of real output (Y), we use value added at 1995 prices, while real wages (w) are identified by total labour costs per employee or hour worked, also expressed at 1995 prices[11].

Changes in labour inputs, value added and unit labour costs are computed as the long differences of natural logs over the period 1997-2000. Instead, the ICT intensity variable (I_{ICT}/L) is measured as the cumulative investment on ICT undertaken during the period 1998-2000 and divided by the average number of employees (or hours worked) between 1997 and 2000.

Differences in natural logs allow one to neglect the problem of idiosyncratic industry effects. Further, the choice of long rather than annual (or first) differences is justified by the fact that single year observations could be too volatile for providing an appropriate measure of ICT intensity: in fact, firms (and, then, industries) that invest a lot in a given year will not necessarily do the same in the next year(s) too. Thus, to avoid the possible bias due to the different timing of investment, we compute ICT intensity over a three-years period.

According to the findings of the previous section, emphasising the different performance and behaviour of secondary and service industries, we include in the regression a dummy for service industries and its interactions with all the other explanatory variables. Moreover, along with OLS estimates, with decided to carry out also WLS (weighted-least-squares) estimates, with industry weights given by the average number of employees or hours worked over the years

[10] In our analysis, the inclusion of wages plays a crucial role. Since, by definition, they depend exclusively on the number of employees and their working hours, the growth of total workers cannot be used as dependent variable.

1997-2000. In this way, one can control whether the OLS results are confirmed when a greater weight is attributed to the Italian industries with a larger employment size and, possibly, higher employment changes in absolute terms. Finally, on the basis of a preliminary examination, we excluded from the regression analysis 14 of the original 187 three-digit industries: six of them belong to the public sector[12] while the other eight industries can be classified as outliers[13].

Table 5 presents the OLS and WLS estimates of equations [4] by using, respectively, the number of employees and hours worked as dependent variables[14]. The reported T-statistics are based on standard errors robust to heteroschedasticity.

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[11] For both value added and labour costs we used the value added deflator of Italian 2-digit industries.

[12] 'Public' industries are neglected since their employment and wage changes depend on the choices (and budget constraints) of central and local governments. They include: Primary, Secondary, and Higher education (Nace Rev. 1 codes: 801, 802, and 803), Human health (852), Social work activities (853), Libraries, archives, museums & other cultural activities (925).

[13] The excluded industries are: Manufacturing of railway & tramway locomotives (352), Steam & hot water supply (403), Scheduled air transport (621), Non-scheduled air transport (622), Post & courier activities (641), Hardware consulting (721), Investigation and security activity (746), Labour recruitment & provision of personnel (745). The industry of Post & courier activities is an outlier with respect to ICT intensity (in fact, contrary to the original classification of Stiroh and van Ark, we decided to include it within the non-ICT group - cf. table A.1 in the Appendix). The legalisation of business firms operating in the field of "Labour recruitment & provision of personnel" occurred , in Italy, just in 1997; as a consequence, this industry is a patent outlier in terms of employment growth (from 1997 to 2000, it recorded a 300% employment increase). The remaining six industries are excluded since, either in 1997 or 2000, they record a value added lower than labour costs.

[14] Obviously, unit labour costs and the ICT intensity per unit of labour are consistent with the labour measures chosen as dependent variables.

Table 5 – OLS and WLS regressions with robust standard errors (T-statistics in brackets; 173 observations)

Dep. Variable	Δ ln Employees 1997-2000		Δ ln Hours worked 1997-2000	
	OLS	WLS°	OLS	WLS°
Constant	-0.025 (2.27)*	-0.003 (0.16)	-0.023 (2.22)	0.005 (0.23)
Δ ln Value Added	0.692 (14.2)**	0.662 (7.91)**	0.697 (14.6)**	0.653 (8.96)**
Δ ln Wage	-0.472 (5.52)**	-0.561 (3.56)**	-0.471 (5.00)**	-0.507 (3.80)**
I_{ICT}/L (ICT intensity)	-0.011 (2.04)**	-0.022 (1.86)*	-0.015 (1.63)	-0.039 (1.87)*
SERVICE	0.035 (0.91)	0.001 (0.02)	0.040 (1.04)	-0.015 (0.36)
SERVICE * (Δ ln Value Added)	-0.064 (0.74)	0.016 (0.12)	-0.074 (0.84)	0.022 (0.18)
SERVICE * (Δ ln Wage)	-0.002 (0.01)	-0.025 (0.10)	0.079 (0.23)	-0.134 (0.52)
SERVICE * (I_{ICT}/L)	0.031 (3.25)**	0.033 (2.05)**	0.050 (2.22)**	0.060 (2.04)**
R^2	0.684	0.606	0.688	0.597

° Industry weights are based, respectively, on the number of employees and hours worked (average 1997-2000).
*=significant at 0.1; **=significant at 0.05.

First of all, no matter how labour input is measured, the employment changes over the period 1997-2000 are closely associated with the changes in value

added (the proxy for industry output or demand). The elasticity of employment with respect to value added is about 0.7 with the OLS estimate and it slightly decreases when the WLS estimate is carried out. The non significant coefficient of the interaction between the service dummy and the growth of valued added indicates that there are no significant differences in the behaviour of secondary and service industries.

The negative impact of unit labour costs on employment is significant and remarkable, especially when a greater weight is ascribed to the larger industries and the changes in the number of employees is taken as the dependent variable (in this case the elasticity is 0.56). Also with respect to the employment-wage relationship, there are not significant difference between secondary and service industries. Thus, it seems that the explanation of employment growth based on the greater flexibility of labour markets and, thus, wages (see section 2.2) plays a relevant role.

However, the estimate of equation [4] shows that also the intensity of ICT investment cannot be neglected. In fact, when the ICT variable is inserted alone, the coefficient is negative (although not significant in one case, and significant at a level of confidence of 10% only in two cases), suggesting that, in secondary industries, a greater intensity of ICT is associated with a loss of employees and hours worked.

Within service industries, instead, a higher ICT investment per unit of labour affects positively and significantly both the growth of employees and hours worked. It must be stressed that the results concerned with the impact of ICT intensity do not significantly changes moving from OLS to WLS estimates. Finally, it should be noticed that the dummy for service industries is not significant by itself but only when interacts with the intensity of ICT: thus, the

advantage in terms of employment growth is not generalised to service industries but confined to those with a greater intensity of ICT investment.

5. Concluding remarks

The empirical study presented in this paper indicates that, over the late 1990s and across Italian industries, there have been some positive linkages between the intensity of ICT investment and the increase of employment. The descriptive analysis presented in section 3 has shown that ICT producing industries have experienced a positive and remarkable rate of employment change, greater than that recorded by non ICT-intensive and ICT using industries. However, this phenomenon is due exclusively to the performance of service ICT producers (such as software, computer-related activities and telecommunication).

Obviously, the above findings are limited by the fact that the association between ICT intensity and employment growth is not controlled for the effects exerted by other important variables. As a consequence, a more suitable test for the presence of a significant ICT-employment relationship has been carried out in section 4, by means of regression analyses.

The regression results show that, both in secondary and service industries, the employment increase over the years 1997-2000 have been positively affected by output (or demand) changes, while changes in labour costs have exerted a negative impact. After controlling for the above effects, it emerges that within service industries a higher intensity of ICT investment is positively and significantly associated with the increase of employment while for secondary industries the same relationship is negative. All these results arising from OLS

estimates are confirmed when, by ascribing a greater weight to the industries with a larger employment size, WLS estimates are carried out.

Due to the short period of time considered (which, among other things, prevented us from using lagged explanatory variable and address the problems of endogeneity), these results should be taken with caution. In any case, the ICT-employment relationship has proven to be robust to the inclusion of other (important) explanatory variables and to different estimation procedures. So, at the end, it can be said that, from 1997 to 2000 and thanks to the behaviour of some ICT-intensive service industries, the introduction of ICT has favoured the overall enlargement of the Italian employment basis.

Although the aim of this paper was limited to the quantitative effect of ICT on employment, we are aware that, for a comprehensive assessment of the ICT 'revolution', two other important issues should be addressed.

The first is concerned with the impact of ICT on the quality of jobs. According to the approach of 'skill biased technical change', an intensive introduction of ICT should particularly increase the share of skilled workers; as a consequence, even if the total number of employees might remain unchanged or show a modest increase, the impact of ICT on employment could be still substantial in that more 'productive' people are at work. The data base used in this paper does not provide employment data broken down by skill, qualification or level of education, so that we were unable to test, across Italian industries, the 'skill bias' hypothesis.

The second issue, linked to the former, is concerned with the impact of ICT on labour productivity. In a preliminary attempt to test whether the intensity of ICT investment was significantly associated with the increase of labour productivity (computed as the value added per employees or hours worked), we did not find significant results. Our findings are consistent with those of van Ark et al.

(2002), who have carried out cross-industry regressions for a set of European countries and, for the period 1995-2000, have found an impact of ICT on labour productivity growth barely significant and, in any case, much weaker than that estimated for the US.

A possible explanation for this low productivity effect of ICT is that, in Europe, the process of ICT diffusion, although experiencing a marked acceleration during the late 1990s, is still behind that of the US (some reasons of this delay have been discussed in section 2.3). As a consequence, it is possible that the Italian (and European) patterns of growth during the second half of the 1990s replicated somehow the US experience over the years 1990-95: in fact, in that period, the growth of US labour productivity was slightly lower than that of employment and only in the second half of the 1990s there was a further productivity increase (see section 2.1).

Moreover, there are other elements worth to be noticed. According to the figures provided by Jorgenson et al. (2002), the US productivity acceleration of the period 1995-2000 can be primarily ascribed to ICT-producing manufacturing industries and ICT-using service industries (especially, wholesale trade and financial services) while the productivity contribution of ICT-producing services is extremely modest; in fact, during the second half of the 1990s, these service industries continued to experience a labour input growth higher than that of productivity. Thus, the recent path followed by the most ICT-intensive industries of the Italian tertiary sector is consistent with that recorded in the US; what makes different the Italian (and probably the European) experience from that of the US is probably the low productivity performance of other manufacturing and service industries with intermediate ICT intensities. (cf. van Ark et., 2003).

Appendix

Table A.1 - Changes of ICT classification between Van Ark et al. (2002) and our paper

Nace Rev. 1 code (three-digit)–Industry description	Van Ark et al. classification	Our classification
641-Post and courier activities	ICT Producing	Non-ICT
181-Manufacture of leather clothes	ICT Using	Non-ICT
183-Dressing and dyeing of fur; manufacture of articles of fur	ICT Using	Non-ICT
314-Manufacture of accumulators, primary cells and primary batteries	ICT Using	Non-ICT
352-Manufacture of railway and tramway locomotives and rolling stock	ICT Using	Non-ICT
522-Retail sale of food, beverages and tobacco in specialized stores	ICT Using	Non-ICT
526-Retail sale not in stores	ICT Using	Non-ICT
712-Renting of other transport equipment	ICT Using	Non-ICT
152-Processing and preserving of fish and fish products	Non-ICT	ICT Using
403-Steam and hot water supply	Non-ICT	ICT Using
603-Transport via pipelines	Non-ICT	ICT Using
744-Advertising	Non-ICT	ICT Using
921-Motion picture and video activities	Non-ICT	ICT Using
922-Radio and television activities	Non-ICT	ICT Using
923-Other entertainment activities	Non-ICT	ICT Using
924-News agency activities	Non-ICT	ICT Using

Table A.2 - ICT using industries

Secondary		Services	
Nace Rev.1			
152	Processing and preserving of fish and fish products	511	Wholesale on a fee or contract basis
182	Manufacture of other wearing apparel and accessories	512	Wholesale of agricultural raw materials and live animals
221	Publishing	513	Wholesale of food, beverages and tobacco
222	Printing and service activities related to printing	514	Wholesale of household goods
223	Reproduction of recorded media	515	Wholesale of non-agricultural intermediate products, waste and scrap
291	Manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines	516	Wholesale of machinery, equipment and supplies
292	Manufacture of other general purpose machinery	517	Other wholesale
293	Manufacture of agricultural and forestry machinery	521	Retail sale in non-specialized stores
294	Manufacture of machine-tools	523	Retail sale of pharmaceutical and medical goods, cosmetic and toilet articles
295	Manufacture of other special purpose machinery	524	Other retail sale of new goods in specialized stores
296	Manufacture of weapons and ammunition	525	Retail sale of second-hand goods in stores
297	Manufacture of domestic appliances n.e.c.	527	Repair of personal and household goods
311	Manufacture of electric motors, generators and transformers	603	Transport via pipelines
312	Manufacture of electricity distribution and control apparatus	711	Renting of automobiles
315	Manufacture of lighting equipment and electric lamps	713	Renting of other machinery and equipment
316	Manufacture of electrical equipment n.e.c.	714	Renting of personal and household goods n.e.c.
332	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes	731	Research and experimental development on natural sciences and engineering
333	Manufacture of industrial process control equipment	732	Research and experimental development on social sciences and humanities
334	Manufacture of optical instruments and photographic equipment	741	Legal, accounting, book-keeping and auditing activities; fiscal and management consulting
335	Manufacture of watches and clocks	742	Architectural and engineering activities and related technical consulting

351	Building and repairing of ships and boats	743	Technical testing and analysis
353	Manufacture of aircraft and spacecraft	744	Advertising
354	Manufacture of motorcycles and bicycles	921	Motion picture and video activities
355	Manufacture of other transport equipment n.e.c.	922	Radio and television activities
361	Manufacture of furniture	923	Other entertainment activities
362	Manufacture of jewellery and related articles	924	News agency activities
363	Manufacture of musical instruments		
364	Manufacture of sports goods		
365	Manufacture of games and toys		
366	Miscellaneous manufacturing n.e.c		
371	Recycling of metal waste and scrap		
372	Recycling of non-metal waste and scrap		
403	Steam and hot water supply		

Table A.3 – Non-ICT industries

Secondary		Services	
Nace Rev.1			
10	Mining and quarrying	501	Sale of motor vehicles
151	Production, processing and preserving of meat and meat products	502	Maintenance and repair of motor vehicles
153	Processing and preserving of fruit and vegetables	503	Sale of motor vehicle parts and accessories
154	Manufacture of vegetable and animal oils and fats	504	Sale, maintenance and repair of motorcycles and related parts and accessories
155	Manufacture of dairy products	505	Retail sale of automotive fuel
156	Manufacture of grain mill products, starches and starch products	522	Retail sale of food, beverages and tobacco in specialized stores
157	Manufacture of prepared animal feeds	526	Retail sale not in stores
158	Manufacture of other food products	551	Hotels
159	Manufacture of beverages	552	Camping sites and other provision of short-stay accomodation
160	Manufacture of tobacco products	553	Restaurants
171	Preparation and spinning of textile fibres	554	Bars
172	Textile weaving	555	Canteens and catering
173	Finishing of textiles	601	Transport via railways
174	Manufacture of made-up textile articles, except apparel	602	Other land transport
175	Manufacture of other textiles	611	Sea and coastal water transport
176	Manufacture of knitted and crocheted fabrics	612	Inland water transport
177	Manufacture of knitted and crocheted articles	621	Scheduled air transport
181	Manufacture of leather clothes	622	Non-scheduled air transport
183	Dressing and dyeing of fur; manufacture of articles of fur	631	Cargo handling and storage
191	Tanning and dressing of leather	632	Other supporting transport activities
192	Manufacture of luggage, handbags and the like, saddlery and harness	633	Activities of travel agencies and tour operators; tourist assistance activities n.e.c.
193	Manufacture of footwear	634	Activities of other transport agencies
201	Saw milling and planing of wood	641	Post and courier activities
202	Manufacture of veneer sheets, plywood, particle board, fibre board and other panels	701	Real estate activities with own property
203	Manufacture of builders' carpentry and joinery	702	Letting of own property
204	Manufacture of wooden containers	703	Real estate activities on a fee or contract

			basis
205	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials	712	Renting of other transport equipment
211	Manufacture of pulp, paper and paperboard	745	Labour recruitment and provision of personnel
212	Manufacture of articles of paper and paperboard	746	Investigation and security activities
230	Manufacture of coke, refined petroleum products and nuclear fuel	747	Industrial cleaning
241	Manufacture of basic chemicals	748	Miscellaneous business activities n.e.c.
242	Manufacture of pesticides and other agro-chemical products	801	Primary education
243	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	802	Secondary education
244	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	803	Higher education
245	Manufacture of soap and detergents, cleaning and polishing preparations, perfume	804	Adult and other education
246	Manufacture of other chemical products	851	Human health activities
247	Manufacture of man-made fibres	852	Veterinary activities
251	Manufacture of rubber products	853	Social work activities

Table A.3 (continues) – Non-ICT industries

252	Manufacture of plastic products	900	Sewage and refuse disposal, sanitation and similar activities
261	Manufacture of glass and glass products	925	Library, archives, museums and other cultural activities
262	Manufacture of non-refractory ceramic goods other than for construction purposes +Manufacture of refractory ceramic products	926	Sporting activities
263	Manufacture of ceramic tiles and flags	927	Other recreational activities
264	Manufacture of bricks, tiles and construction products, in baked clay	930	Other service activities
265	Manufacture of cement, lime and plaster		
266	Manufacture of articles of concrete, plaster and cement		
267	Cutting, shaping and finishing of stone		
268	Manufacture of other non-metallic mineral products		
271	Manufacture of basic iron and steel and of ferro-alloys (ECSC)		
272	Manufacture of tubes		
273	Other first processing of iron and steel and production of non-ECSC ferro-alloys		
274	Manufacture of basic precious and non-ferrous metals		
275	Casting of metals		
281	Manufacture of structural metal products		
282	Manufacture of tanks, reservoirs and containers of metal; central heating radiators and boilers		
283	Manufacture of steam generators, except central heating hot water boilers		
284	Forging, pressing, stamping and roll forming of metal; powder metallurgy		
285	Treatment and coating of metals; general mechanical engineering		
286	Manufacture of cutlery, tools and general hardware		
287	Manufacture of other fabricated metal products		
314	Manufacture of accumulators, primary cells and primary batteries		
341	Manufacture of motor vehicles		
342	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers		

	and semi-trailers
343	Manufacture of parts and accessories for motor vehicles and their engines
352	Manufacture of railway and tramway locomotives and rolling stock
401	Production, collection and distribution of electricity
402	Manufacture of gas; distribution of gaseous fuels through mains
410	Collection, purification and distribution of water
451	Site preparation
452	Building of complete constructions or parts thereof; civil engineering
453	Building installation
454	Building completion
455	Renting of construction or demolition equipment with operator

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