ICT, productivity and employment in French manufacturing industries*

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preliminary and incomplete version

Abstract

Is Solow's paradox back, and in France particularly? For the United States, when comparing ICT-using industries in manufacturing, ICT intensity in production is not related to significant productivity gains (Acemoglu, Autor, Dorn, Hanson, and Price, 2014). For France, we develop similar industry comparisons, with additional insights with respect to technological level, workforce composition and situation relative to services. ICT intensity is associated with positive but fragile effects on productivity, and to unambiguous declines in employment for the whole ICT-using manufacturing sector. Further, the labor saving effect of ICT capital is massively concentrated among industries relying on low production technologies. In parallel, ICT intensity goes in hand with widespread increases in the share of administrative and technical professions. For services, ICT use favors both employment and sales significantly, with no distinguishable impact on productivity yet. All in all, ICT investment seems to foster economy-wide structural changes, with strong productivity improvements in declining sectors and labor enrichment in rising ones.

JEL classification: J2, L60, O3

Keywords: technological change, skill bias, firm level data

*This document reflects only its authors' view, and not the position of the Insee in particular.

Introduction

At the end of the 1980s, Robert Solow noticed that computers were everywhere except in productivity statistics. Since then, if signs of an impact have been observed, Acemoglu et al. (2014) however show a mixed picture: for the manufacturing sector in the United States and after the 1990s, labor productivity gains associated with information and communication technologies (ICT) are concentrated in ICT-producing sectors; for ICT-using ones, ICT-related productivity gains are difficult to distinguish. Yet, these results may conceal heterogeneities between industries whose ICT use differs, with diverging consequences on labor demand. On the one hand, ICT can foster automation, machines substituting for labor. On the other hand, ICT investments can also boost innovation, relying on labor and machines complementarity. In the end, the effect of ICT intensity on employment and labor productivity depends on the industry mix between these alternative use of ICT capital.

In this paper, results by Acemoglu et al. (2014) are tested on French data at the industry level, and the approach is prolonged by splitting the manufacturing sector with respect to technological levels. Employment is also disaggregated into broadly coherent sets of professions. Finally, outcomes in manufacturing are compared to equivalents in services. To these ends, long-term series are built at the industry level using administrative data which include balance sheet and production information from the "Bénéfices Réels Normaux" (BRN) for the period 1994-2007, and which are also available for services. As Acemoglu et al. (2014), we use the share of ICT in investment as our measure of ICT intensity. ICT intensity is measured through the category "office and computing machinery".[1] Finer employment data are merged with the BRN using the "Déclarationsiiismsi annuelles de données sociales" (DADS), consisting in compulsory detailed employee-employer forms.

Our main results are the following. Contrary to the United States, productivity is not

[1]This approach was notably used in French works relating to ICT and productivity (Crépon and Heckel, 2000, and Barbesol, Heckel, and Quantin, 2008).

driven to a large extent by ICT-producing industries, revealing the potential underdevelopment of the "French tech" to contribute to aggregate performance. Yet, ICT intensity is associated with positive but fragile effects on productivity, and to unambiguous declines in employment for the whole ICT-using manufacturing sector. Further, the labor saving effect of ICT is massively concentrated among industries relying on basic production technologies, suggesting similitudes with the mechanization of farming during the previous industrial revolution. For mid/high-tech industries, evidence is less straightforward on productivity, notably because production seems to have a richer assortment of job types. Indeed, ICT intensity is related to better outcomes for all job types in mid/high-tech industries relative to low-tech ones. When technology is higher, it even fosters more and more employment of administrative and technical professions. Finally, ICT use in services favors employment and sales significantly, with no distinguishable impact on productivity yet. All in all, ICT use seems to foster economy wide structural changes, with strong productivity improvements in declining sectors and labor enrichment in rising ones.

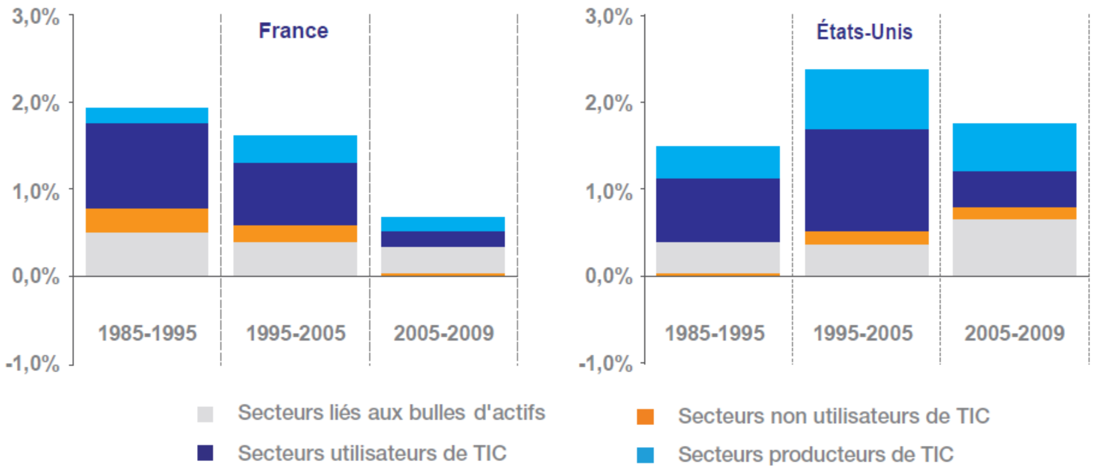
The rest of the paper is organized as follows. Section 1 explains the approach. Section 2 presents our main estimates. Finally, section 3 develops additional extensions.

1 Approach

1.1 Related literature

This paper is first related to sluggish productivity gains in France since the 2000s and the potential role of lacking ICT investment. The diffusion of ICT had a noticeable impact before the 2000s, and may have brought 0.3 point of annual growth over the period 1987-1998 according to Crépon and Heckel (2000). Yet, as in the United States, and to a higher extent, labor productivity gains in France slowed down between 2005 and 2009 compared to the 1995-2005 period, with a substantial contribution of ICT-using sectors within manufacturing and services (cf. Figure 1).

Figure 1 – Labor productivity in France and in the United States, 1985-2009 (Sode, 2016)



Note : Main ICT-using sectors are business services, wholesale, transports and some manufacturing sectors. Sectors related to asset bubbles are: finance, real estate and agriculture. Source: EU KLEMS Project.

This paper is also related to the relation between ICT investment and firm labor demands in terms of skills and tasks, following the seminal work by Autor, Levy, and Murnane (2003). ICT-producing industries are very intensive in skilled work and ICT capital (Crépon and Heckel, 2000). More generally, ICT investment might drive sharply diverging employment dynamics with respect to technology: Biscourp, Crépon, Heckel, and Riedinger (2002) found a strong effect of the decline in computer prices on the relative demand for unskilled and skilled workers, with varying sensitivities in services and manufacturing.[2] In addition, Pak and Poissonnier (2017) find that technology has a negative contribution on employment concentrated on low educational levels, while employment increases for high-skilled.[3]

While not entering into finer aspects of innovation, but considering different technological levels, this study is also built on works on R&D, innovation and productivity. Hall, Lotti,

[2]More precisely, at the general level, a 15 percent fall in computer prices leads to a decline of marginal costs for firms by 0.7 percent and a rise of the ratio between skilled and unskilled workers in employment by 3.5 percent; and relative demand for skilled relative to unskilled work seems stronger in manufacturing than in services, especially for firms within the first size quintile (cf. Biscourp et al., 2002, Figure 8, p.18).

[3]Pak and Poissonnier (2017) decompose employment variations with respect to different qualification levels over 30 years and with an accounting input-output approach.

and Mairesse (2012) notably test the potential complementarity between ICT and R&D on a panel of Italian manufacturing firms. They find that both affect strongly productivity, but probably through different channels. These results might be in line with the hypothesis of a technological dichotomy, where ICT increases productivity through different mechanisms when R&D intensity is either low or high. In particular, Lelarge (2006) shows that higher R&D intensity is associated with more product innovation. The purpose of ICT use in this perspective may largely differ from searching for automation, while both may bring about productivity gains.

While being at the industry level, our approach is linked to the literature on long-term macroeconomic reallocation of the labor force driven by technological change, and the « race against the machine » as commonly dubbed by Brynjolfsson and McAfee (2011). On the empirical side, Spieza, Polder, and Presidente (2016) estimate on OECD countries that the decrease in ICT user cost has short-term effects on labor demands whatever the skill level, but is neutral in the long-run, the estimated elasticity of substitution between labor and ICT capital equaling one in all countries. Indeed, the substitution effect seems to be compensated by a demand one arising from an increase in national income. On the theoretical side, a close diagnosis is defended by Acemoglu and Restrepo (2016) who highlight that R&D can be oriented to the automation of current tasks or the creation of new ones, and that some balance between the former and the later can be reached endogenously such that in equilibrium "the endogenous response of [R&D] restores the labor share and employment back to their initial level". Our results could be interpreted as signs of the presence of these alternative compensating mechanisms at stake with technological change.

1.2 Methodology

Firm level data are taken from the "Bénéfices Réels Normaux" (BRN), a French administrative database, between 1994 and 2007. Firms are gathered at the 4-digit industry level based the Statistical classification of economic activities in the European Community (NACE). Codes notably changed for some firms in ICT-producing industries as their activity became mostly made up by services rather than hardware merchandises. In addition, another NACE revision occurred in 2003 and consisted in the separation of several sectors into new subcategories, which is corrected. ICT-producing industries will be made up by the three following 2-digit groups in line with the extended definition by Acemoglu et al. (2014): office and ICT equipments; radio, television and communication equipment; and medical, optical and watch instruments.

From these data, 2-digit groups with the highest labor productivity gains between 1994 and 2007 do not happen to be necessarily those with the highest ICT intensity (Figure 2). Furthermore, employment and ICT intensity do not seem correlated.

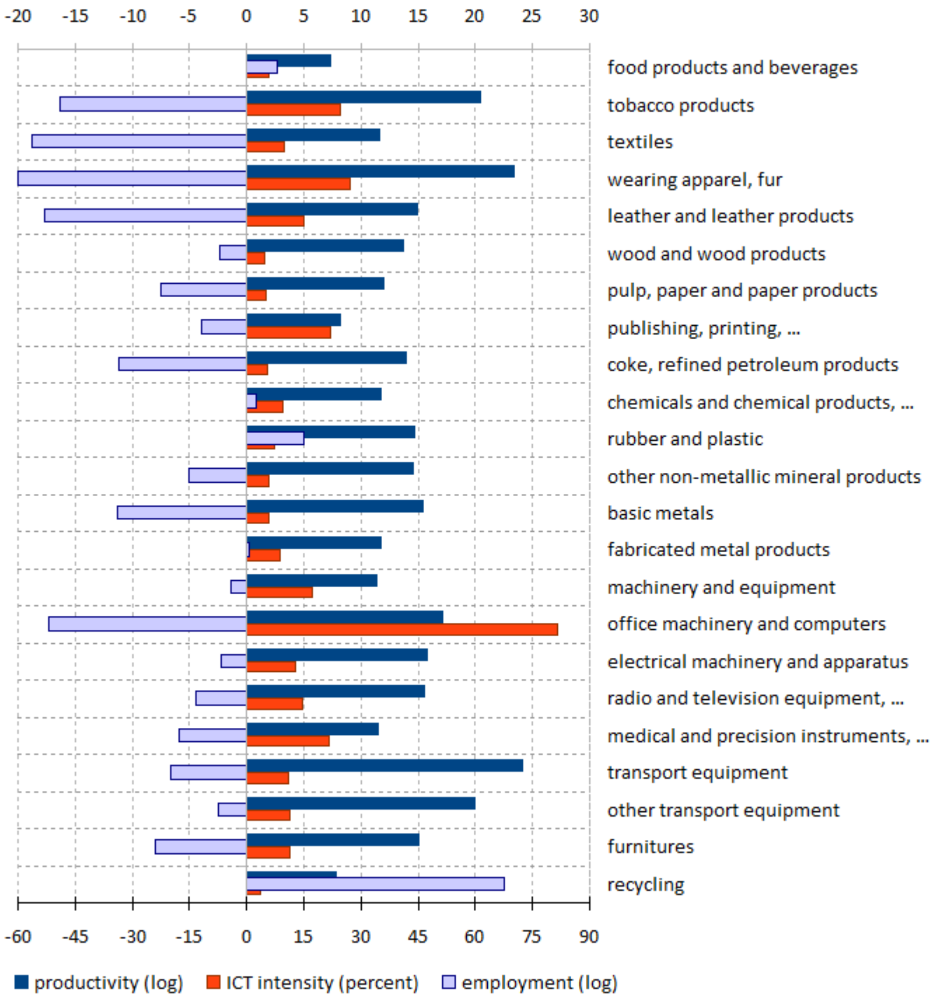
Our main specification is similar to Acemoglu et al. (2014):

$$\log Y_{jt} = \gamma_j + \delta_t + \sum_{t'=1989}^{2007} \beta_{t'} \mathbb{1}_{t'=t} IT_j + \epsilon_{jt}, \tag{1}$$

where Y_{jt} is the explained variable (labor productivity, production or employment); γ_j and δ_t are industry and year fixed effects; IT_j is the ICT intensity; the coefficients $\beta_{t'}$ are the elasticities related to ICT intensity; and ϵ_{jt} are residuals. This specification allows estimating over time the evolution of these elasticities.

ICT intensity is set as the ratio between ICT investment and total investment as in Acemoglu et al. (2014), but also Berman, Bound, and Griliches (1994) and Autor, Katz, and Krueger (1998). IT_j is precisely the mean over time of this ratio. It proved robust to alternative time windows in Acemoglu et al. (2014), and is a smoothed measure of long-term industry behavior. ICT investment taken from the BRN is exactly investment in “office and computing machinery”. Crépon and Heckel (2000), and Barbesol et al. (2008) used this variable for France, and Autor et al. (1998) relied on a similar one for the United States. Labor productivity is the ratio between sales and total employees. Sales are preferable to

Figure 2 – Evolutions of productivity, employment and ICT intensity, 1994-2007



Note : Manufacturing industries are considered at the 2-digit level using NACE codes between 15 (food) to 37 (recycling). Productivity and ICT intensity values correspond to the upper scale while employment to the lower one.

value added as productivity is then unaffected by the choice of deflators for intermediate inputs and ICT in particular. All variables are in nominal terms. Yet, results are very similar to Acemoglu et al. (2014) which also use nominal outcome variables as alternative regressions.[4]

[4]ICT prices are expected to have a limited impact on estimates through the ICT investment ratio. First, all industries are likely to be affected by similar ICT price dynamics. Second, the ratio is a mean over 13 years.

2 Main estimates

2.1 With or without ICT-producers

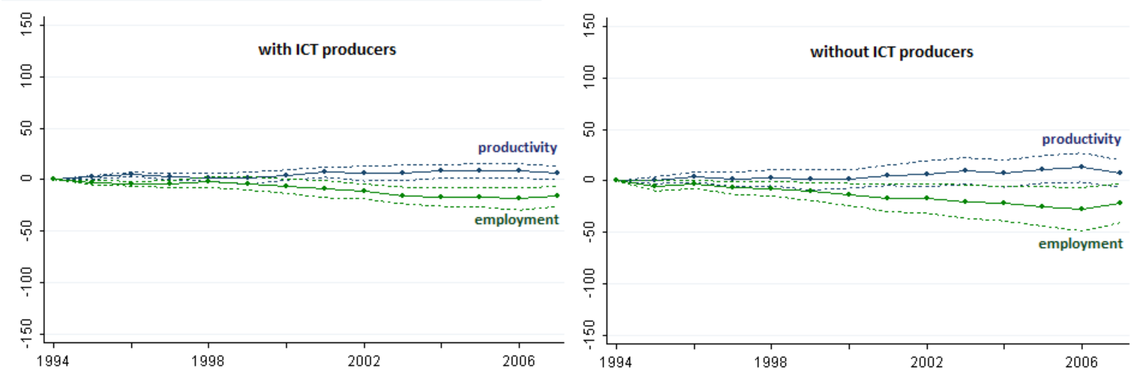
First, similar estimates as in Acemoglu et al. (2014) are made. We compare the manufacturing sector with and without ICT-producing industries, and between France and the United States. We employ data used by Acemoglu et al. (2014) from the NBER-CES Manufacturing Industry Database. The objective is to test whether productivity gains in manufacturing are mostly driven by ICT-producers in France as in the United States and whether some return of the Solow paradox could be seen for ICT-using industries.

Figure 3 shows that ICT intensity is related to significant productivity gains for the whole manufacturing sector in France (Panel A, left). This is similar to the United States, but elasticities are lower (Panel B, left). When excluding ICT-producers, standard deviations increase but effects remain almost significant at the 5 percent level (Panel A, right). Compared to a flat evolution for the United States, the time profile of elasticities displays a slight upward trend (Panel B, right). In each specification, ICT intensity is associated with declines in employment.

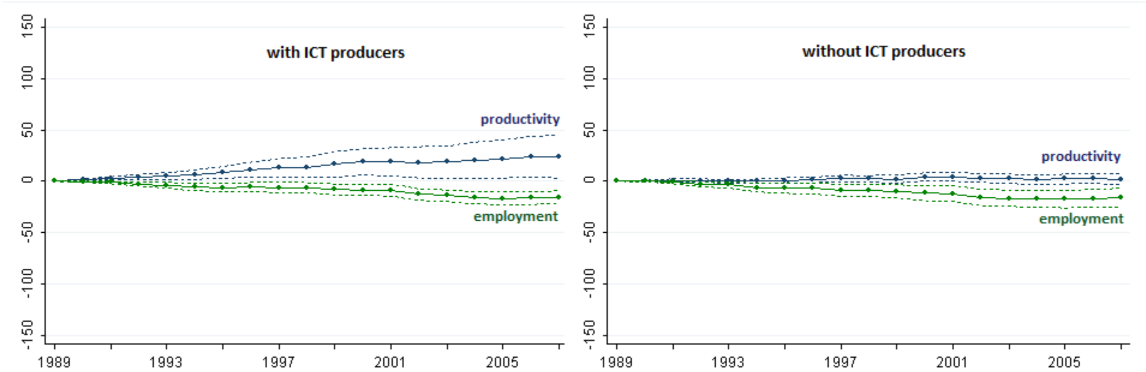
This comparison might illustrate the lower weight of ICT-producers in the French economy, while GAFAs (Google, Apple, Facebook, Amazon, and the like) rose in the United States dramatically. Indeed, the number of new technological leaders, or "unicorns", created in France represents only 6 percent of the European total, compared to 38 percent for the United Kingdom, 25 percent for Sweden and 17 percent for Germany (France Stratégie, 2016). Generally, the "French tech" is indeed characterized by high rates of start-up creation but scarce occurrences of substantial firm growth.

Figure 3 – Effects of ICT intensity on employment in manufacturing industries including ICT producers (left) or excluding them (right)

(a) in France



(b) in the United States



Note: Doted lines correspond to confidence intervals at the 5 percent level. Each point correspond to a coefficient $\beta_{t'}$ for a specific year t'. Over the whole time period, the number of low-tech manufacturing industries is 80 while there are 130 mid-tech ones.

2.2 When technological level intervenes

However, the relations between ICT intensity and productivity previously observed may reflect heterogeneities among different categories of industries. Indeed, just excluding ICT-producing industries affects estimates. Yet, industries differ with respect to their production technology, and ICT capital may not drive the same type of productivity gains whether automation or R&D is mainly pursued. Following the OECD classification of industries with respect to R&D intensity (cf. Figure 4), we divide manufacturing ICT-using industries within two categories: low-tech industries and mid/high-tech ones. The number of industries within these categories are relatively balanced (80 vs. 130 industries), and focusing on two categories preserve parsimony and statistical power. In addition, these categories happen to be very close to those obtained by applying the general estimation framework at the 2-digit group level, and sorting groups with respect to the elasticity sign.

Figure 4 – Classification of manufacturing industries
into categories based on R&D intensities

High-technology industries
Aircraft and spacecraft
Pharmaceuticals
Office, accounting and computing machinery
Radio, TV and communications equipment
Medical, precision and optical instruments

Medium-high-technology industries
Electrical machinery and apparatus, n.e.c.
Motor vehicles, trailers and semi-trailers
Chemicals excluding pharmaceuticals
Railroad equipment and transport equipment, n.e.c.
Machinery and equipment, n.e.c.

Medium-low-technology industries
Building and repairing of ships and boats
Rubber and plastics products
Coke, refined petroleum products and nuclear fuel
Other non-metallic mineral products
Basic metals and fabricated metal products

Low-technology industries
Manufacturing, n.e.c.; Recycling
Wood, pulp, paper, paper products, printing, publishing
Food products, beverages and tobacco
Textiles, textile products, leather and footwear

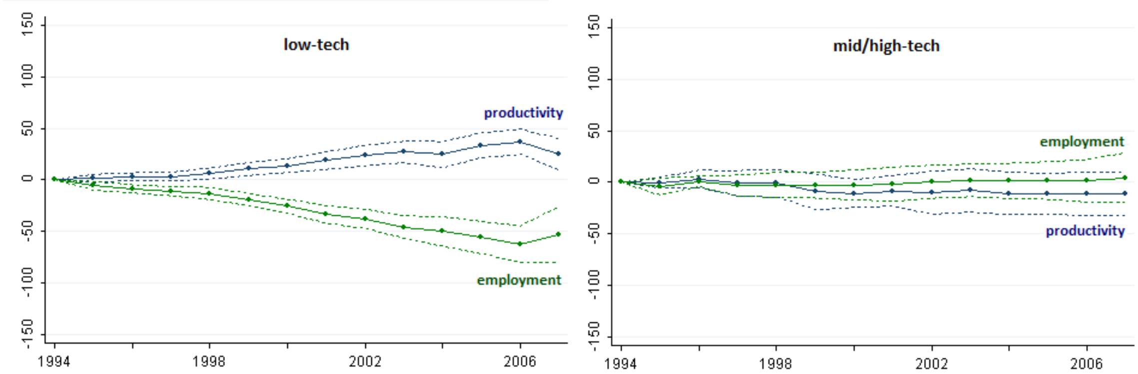
Source: OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division.

Low-tech and mid/high-tech industries display sharply distinct behaviors in France (Figure 5). The most stringent pattern is the strong employment drop for low-tech industries with higher ICT intensity, compared to a slighter decline for mid/high-technology industries relying more on ICT (Panel a). Productivity gains from ICT intensity are even stronger in low-tech industries than for the whole U.S. manufacturing including ICT-producers. We replicate the regression for the United States, following a strict correspondence between the 2-digit level labels in both countries. The patterns are exactly identical to those observed for France, indicating that general drivers may be at stake.

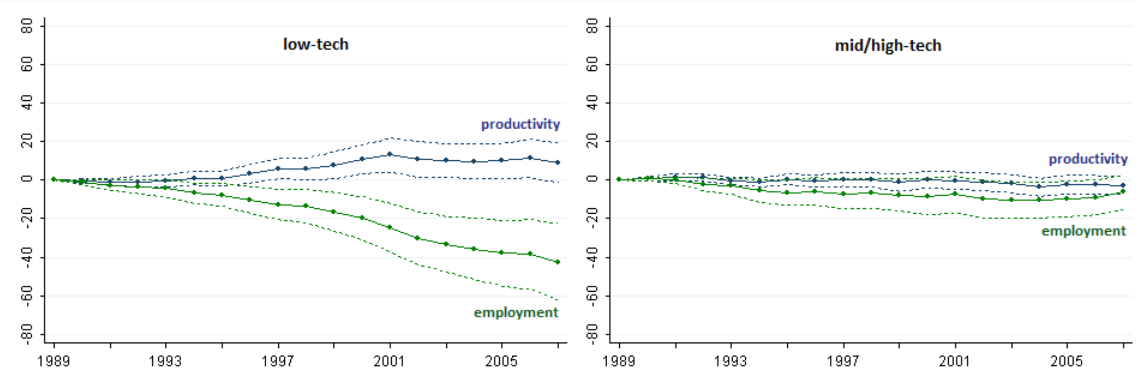
Moreover, the relevance of this divide along the technological dimension is confirmed by a robustness alternative approach at the group level. The low-tech industries can indeed be separated from mid/high-tech ones by simple descriptive statistics. In Figure 6, a positive

Figure 5 – Effects of ICT intensity on employment
in low-tech industries (left) and mid-tech ones (right)

(a) in France



(b) in the United States



Note: Doted lines correspond to confidence intervals at the 5 percent level. Each point correspond to a coefficient $\beta_{t'}$ for a specific year t'. Over the whole time period, the number of low-tech manufacturing industries is 80 while there are 130 mid/high-tech ones.

correlation between ICT intensity and productivity through time appears for each low-tech group. On the contrary, no similar pattern can be observed for mid/high-tech groups. This is confirmed by simple panel regressions with year and group fixed effects, similar to the main specification previously used, but with varying ICT intensity over time and at the group level. Here, the specification is:

$$\log Y_{gt} = \gamma_g + \delta_t + \beta IT_{gt} + \nu_{gt},$$

where the difference with (1) is that the elasticity to ICT intensity β does not depend on time anymore and that all variables are at the 2-digit level. For low-tech industries, the

ICT intensity coefficient on productivity is 0.027, while for mid/high-tech industries, the coefficient is negative at -0.020 (Table 1). For employment, there are also significant effects: in low-techs, -0.171, and in mid/high-techs, 0.284.

Figure 6 – Productivity of groups (y-axis) with respect to ICT intensity (x-axis) in low-tech groups, 1990-2007

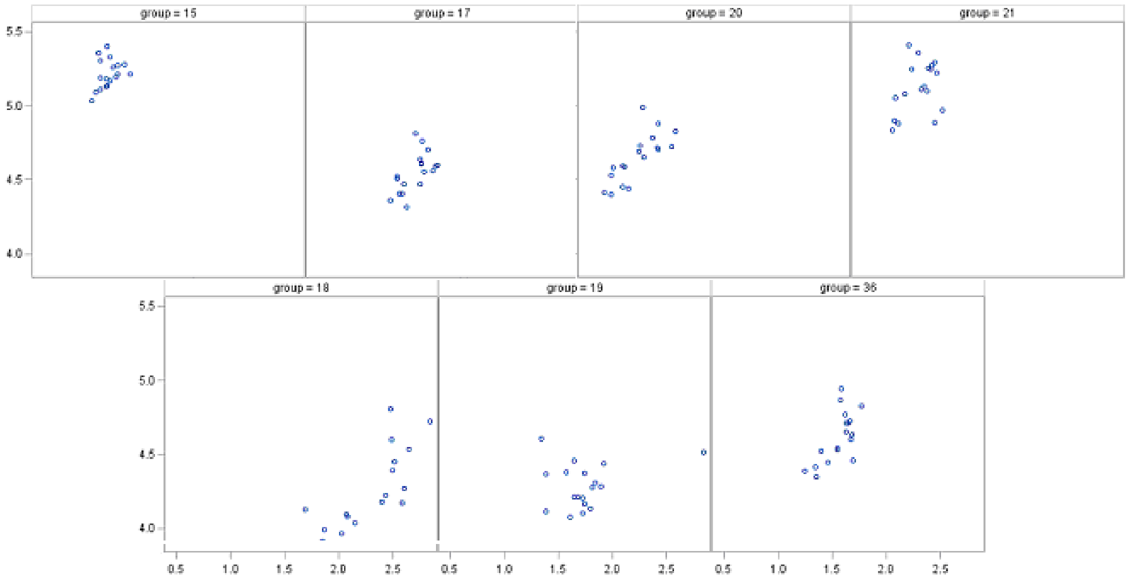


Table 1 – Effects of ICT intensity, aggregate estimates at the 2-digits level

	low-tech	mid/high-tech
productivity	0.027	-0.020
	(-0.003)	(-0.005)
employment	-0.171	0.284
	(-0.021)	(0.000)

So, employment cuts are massive for products with low technological content and when firms compete mainly through production prices. On the contrary, firms in mid/high-tech industries compete more through the creation of products with additional qualitative attributes provided by successful R&D. ICT capital can be used for process or product innovation to improved productivity of current product lines or to generate new ones independently from production workers productivity. Clearly, productivity analyses can not be done without considering these heterogeneities in manufacturing, the interaction between ICT and R&D, and the corresponding labor demands notably.

3 Extensions

3.1 Illustration of employment dynamics by categories

As previously shown, employment dynamics related to ICT intensity hugely differ between low- and mid/high-tech manufacturing industries. Disentangling them for different employment categories may shed light on the economic drivers behind these discrepancies. To this end, BRN data are merged with the "Déclarations annuelles de données sociales" (DADS) which provide information at the employee-employer level. The time period allowing for sample regularity is 1994-2007.[5] This statistical approach is similar to the firm level one by Barbesol et al. (2008) but differs in that data are aggregated at the 4-digit industry level.[6]

To improve statistical inference and economic meaning, socio-professional categories at the 2-digit level are grouped within three main categories. Their construction is as follows. First, categories whose share in total manufacturing employment is below 1 percent are not integrated.[7] The remaining workforce is 88.8 percent of total employees. Then, categories are grouped along the nature of their work to have relatively homogeneous categories with respect to their exposure to ICT, and such as having a balanced partition of employment. First, we gather professions related to administrative tasks among a category "admins", which encompasses different hierarchical status, corresponding to PCS codes 37, 46 and 54. In manufacturing, this group amounts to 23.4 percent of employment. Then, the second group,

[5]This time window exactly recovers the one employed by Harrigan, Reshef, and Toubal (2016) who also depicts employment dynamics using this database at the firm level with respect to technology and trade.

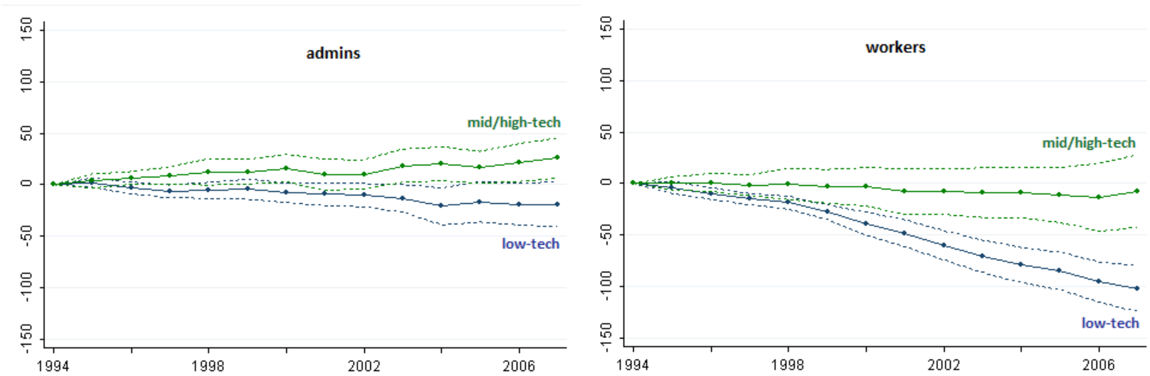
[6]Notably, to test the accuracy of the merged database, previous results are tested with total employment as reported in the DADS and full time equivalent terms, rather that the variable declared in the BRN. These unreported estimations provide identical outcomes.

[7]Some of these categories are "drivers" or "teachers", and often more related to the tertiary sector.

"workers", is made up by industrial workers, either unskilled, skilled or related to supervision, that is PCS codes 48, 62 and 67. This group correspond to 42.9 percent of employment in manufacturing. Finally, professions likely to be more closely related to ICT maintenance and development are considered together, within a group "techies", as in Harrigan et al. (2016), that is PCS codes 38 and 47 including technical managers, engineers and technicians, or 22.5 percent of total manufacturing employment.[8]

Results in Figure 7 depict sharp differences in the effects of ICT intensity on various employment categories and for diverse manufacturing technological levels. First, "admins" always have better employment outcomes in relation to the ICT intensity of an industry compared to "workers". Second, outcomes are better for both "admins" and "workers" in mid/high-tech industries compared to low-tech ones.

Figure 7 – Effects of ICT intensity on employment in manufacturing
with respect to technological level and employment categories



Note: Doted lines correspond to confidence intervals at the 5 percent level. Each point correspond to a coefficient $\beta_{t'}$ for a specific year t'. Over the whole time period, the number of low-tech manufacturing industries is 80 while there are 130 mid-tech ones. "Techies" are not reported to preserve readability. Yet, they are in an intermediate position, slightly below "admins" for both low-tech and mid/high-tech industries.

These results of varying employment evolutions with respect to the R&D level of the industry are notably consistent with Harrison, Jaumandreu, Mairesse, and Peters (2014) who illustrate that employment losses are largely concentrated in non-innovating firms while

[8]This category also intended to be able to compare our results with those by Harrigan et al. (2016).

employment growth is mainly driven by the introduction of new products. The rise of "admins" reflects complementarity between ICT capital and these professions, and confirms Pak and Poissonnier (2017) who find that, in France between 1982 and 2010, the rise in high-skilled jobs is largely due to technology, compared to trade notably, and more precisely to manufacturing industries with higher technological levels, and to R&D for the whole economy.

3.2 Results adding service industries

Similar exercises are run beyond the manufacturing sector in order to put the corresponding results into a broader perspective. For instance, Spieza et al. (2016) illustrate among OCDE countries that the large fall in employment within manufacturing is largely compensated by a symmetric rise in business services specifically, while employment remained relatively stable in construction, energy, finance and real estate in particular.

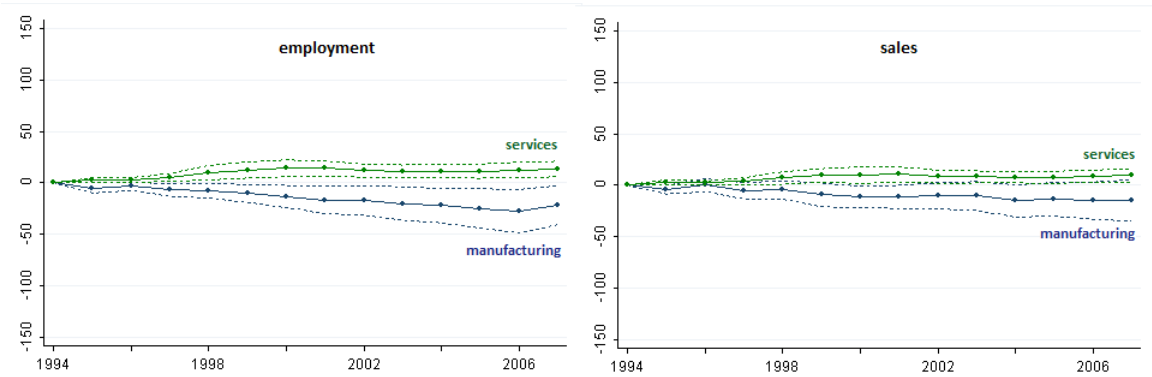
Our notion of services follows the field used by the Insee for the production price index of services in France. It corresponds to sections H, I, J, L, M and N of the 2008 French product classification, which are translated into 2-digit NACE corresponding groups. Services will include hotels and restaurants, transport and communication, business services and will exclude other tertiary activities such as utilities, construction, wholesale, finance, education and health. Mostly, business services include major activities where ICT can be expected to have effects, with consultancy related to ICT, research and development on natural sciences and engineering, management consultancy, real estate, renting of equipments, advertising and legal activities for instance.[9] This set of service industries also allows to abstract from industries where the public sector is present, such as for utilities, education or health.

In Figure 8, the dynamics of employment and sales are significant and symmetric to those

[9] These industries are also interesting as, in the previous subsection, administrative professions seemed to benefit from ICT intensity in relative terms, and that these industries are likely to rely more on administrative work than in manufacturing.

observed for manufacturing. For employment, this reflects trends in general employment statistics. Indeed, Spieza et al. (2016) show that, between 1996 and 2011 among OECD countries, the employment share of manufacturing declined by 5 points while it rose in business services by 4 points, this sector being the major contributor in the positive direction. Our results indicate that ICT contributed to this workforce reallocation over a long time span in France. They also broaden the picture provided by similar estimates for low-tech and mid/high-tech industries, in the sense that ICT may destroy job in specific sectors while having neutral or positive effects in other parts of the economy.

Figure 8 – Effects of ICT intensity on employment and sales
in manufacturing and service industries



Note: Doted lines correspond to confidence intervals at the 5 percent level. Each point correspond to a coefficient $\beta_{t'}$ for a specific year t'. Over the whole time period, the number of low-tech manufacturing industries is 80 while there are 130 mid-tech ones. Productivity is not reported. Provided the dynamics for sales and employment, no significant effects are found.

These results may first be consistent with growing outsourcing, with on the one hand a negative effect of ICT on employment for industries demanding outsourcing services in manufacturing, and a positive one for industries in the service sector providing them. Between 1970 and 2013 in the manufacturing sector, intermediate consumptions of services rose twice as rapidly as total intermediate consumptions (Rignols, 2016). This phenomenon also explains why anti-competitive regulations in services, and more generally in non-manufacturing "upstream" industries, can influence productivity in manufacturing (Cette, Lopez, and Mairesse, 2013). These results are also in line with the development of low-skilled manual jobs in services.

Conclusion

This work employs a methodology between the micro- and macroeconomic scales at the industry and broad employment category levels. It allows revealing heterogeneities in ICT effects among industries with respect to their situation as producer or user of ICT, their technological level, their intensity in various work types, and position within the manufacturing or service sector: ICT-producers do not weight on aggregate estimates; low-tech industries experience tremendous labor savings associated with ICT use; and mid/high-tech manufacturing industries and services display job-enriched production as ICT is more used. All our results suggest that ICT use seems to foster economy-wide structural changes, with strong productivity improvements in declining industries and labor enrichment in rising ones.

Further work could consist in analyzing wages for the industry and employment categories underlined in this paper: it would allow for developing a targeted analysis of skilled-biased technological change and polarization in France; it may also provide necessary empirical reference to structurally interpret our elasticities of labor demands in particular. In addition, as mid/high-tech industries are more exposed to competition related to R&D, and to the extent that ICT and R&D interact, ICT use may not only affect firm outcomes but also have an impact on the overall industry shape. Concentrating on mid/high-tech industries, a structural analysis including firms dynamics, ICT and competition may shed light on potential industrial outcomes that may diverge from the aggregation of individual situations.

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