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REMAKING EUROPE: THE NEW MANUFACTURING AS AN ENGINE FOR GROWTH

Reinhilde Veugelers, editor

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Remaking Europe: the new manufacturing as an engine for growth

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Foreword

A few years ago, the European Union's institutions promoted the goal of increasing the manufacturing sector's share of EU value added to 20 percent. Meanwhile, the labels 'made in Europe' or 'made in country x' resonate with many politicians in Europe while US president Donald Trump believes that his policies would create "millions of manufacturing jobs".

The different chapters of this report suggest that manufacturing is indeed a special sector. It scores high in terms of value added, salaries in the sector are often higher than elsewhere and innovation is strong. But calls for targeted industrial policy ring hollow: what constitutes 'manufacturing' is a fluid concept. New technologies shape industries while outsourcing and the breaking up of value-added chains create measurement problems. Finally, targeting one sector at the expense of others can lead to major distortions in a market economy and would likely hurt growth and jobs rather than helping.

This report revisits the old questions of whether we need a special industrial policy and if it should target specific sectors, technologies or even consumers. In response, the report proposes a more holistic approach. In my view, three questions are important. First, what kind of framework conditions are missing for different economic sectors to thrive in Europe? One aspect is access to a large and single market, which all too often is still fragmented by different national standards and regulations.

Second, how can policies be shaped that are pre-conditions for successful industries? EU policymakers shape the future of industry with numerous decisions. They decide what basic research to fund. They move more quickly on some regulations than on others. They promote specific educations systems, such as apprenticeship programmes. Third, important decisions on major infrastructure projects underpinning industry shape the future. Is broadband internet access readily available? Does Europe need its own cloud computing infrastructure? Have we agreed on a single standard for charging electric cars to enable the rapid creation of a sufficiently wide network of compatible charging stations?

A 'hands-off' approach, as is often propagated by ordoliberal economists, is thus not the way forward. Instead, the public sector needs to focus on intervention where it is necessary while avoiding the promotion of specific technologies at the expense of others. The state cannot pick winners but not taking the right decisions on basic infrastructure, smart regulation and the best education could leave Europe as a laggard for many generations.

Guntram B. Wolff, Director of Bruegel
September 2017

3 The competitiveness of European industry in the digital era

Carlo Altomonte, Filippo Biondi and Valeria Negri[6]

In the current digital era, the competitiveness of European industry is strictly dependent on information and communications technology (ICT) and related investments. The forthcoming 'fourth industrial revolution,' dubbed Industry 4.0, will further heighten the role of ICT in industrial competitiveness. In fact, pervasive use of ICT and the development of so-called 'cyber-physical systems'[7] will help firms expand their product ranges, customise their services and respond better to client demand. Moreover, these developments could help reduce inefficiency in the use of capital and labour, for example by reducing inventories and transaction costs, which could lead to a more efficient matching of supply and demand and enable the growth of new markets. All these effects should lead to higher productivity growth[8].

In this chapter we assess the link between ICT and the competitiveness of EU industry, from macro and micro perspectives. From the

6 The authors wish to thank Assolombarda Confindustria Milano Monza e Brianza for making their firm-level dataset on the performance of European firms available to us. Any error, opinion and omission in using this data is our sole responsibility.

7 Examples are smart grid, autonomous automobile systems, medical monitoring, process control systems, and robotics systems.

8 Several theories have been proposed to describe the dynamic effects of ICT revolution on competitiveness and to assess possible differences between countries. See in particular Jorgenson, Ho and Stiroh (2002, 2008), Gordon (2000, 2012), van Ark, O'Mahony and Timmer (2008) and Acemoglu *et al* (2014).

macroeconomic point of view, we show how and to what extent ICT has contributed to the value-added and productivity dynamics of the EU manufacturing sector. We then move to firm-level information, exploring in detail the link between the exposure of companies to digitalisation and their productivity, controlling for a number of additional characteristics often related to competitiveness, such as companies' internationalisation and innovation activities. We find that the effects of ICT are on average positive and significant for competitiveness (at the macro level), but that these effects are essentially driven by the most productive companies (the right tail of the productivity distribution at the micro level).

As a result, while ICT and Industry 4.0 are powerful policy tools to foster the competitiveness of EU industry, they are also likely to increase the gap between the most successful companies and those left behind, leading to an increase in territorial and social inequalities, potentially making appropriate accompanying policies necessary.

3.1 The macro view: manufacturing growth and its determinants

Starting with a macroeconomic overview, we use a standard growth accounting approach to assess the main contributions to value added growth in the manufacturing sectors of ten European countries[9]. Growth-accounting exercises typically focus on a given time period and are used to quantify how much of the rate of change in output can be accounted for by the rate of change in different observable inputs, while the residual is interpreted as a measure of the rate of change in Total Factor Productivity (TFP, ie unobservable technology). In this decomposition, the real value added growth of the manufacturing

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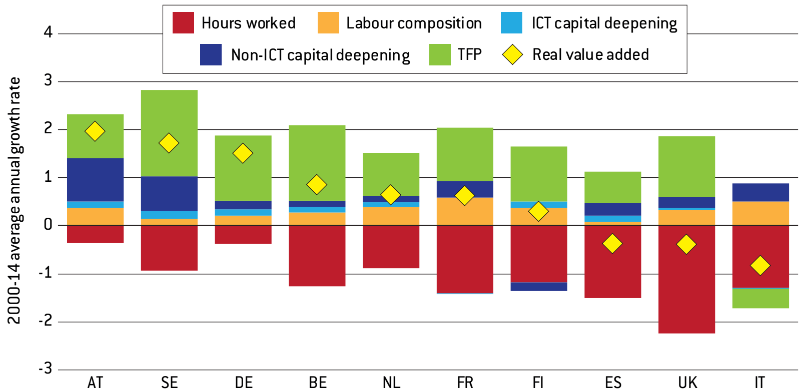
9 In this chapter we rely mainly on the recently updated EU KLEMS Growth and Productivity Accounts, which covers only 10 EU countries for the moment. New releases for all the other EU member states, the US, possibly Japan, and several aggregates are expected to become available in summer 2017. The project has been carried out by The Conference Board, with the financial support of the European Commission under the service contract ECFIN-163-2015/SI2.716986.

sector is broken down into the contributions of TFP growth, of ICT and non-ICT capital, and an hours worked component and a human capital component (based on the skill composition of the workforce).

Figure 1 shows the results of the decomposition of value added growth at constant prices between 2000 and 2014, on averages, for a number of EU countries.

Figure 1: Growth accounting decomposition of manufacturing real value added, 2000-14 averages

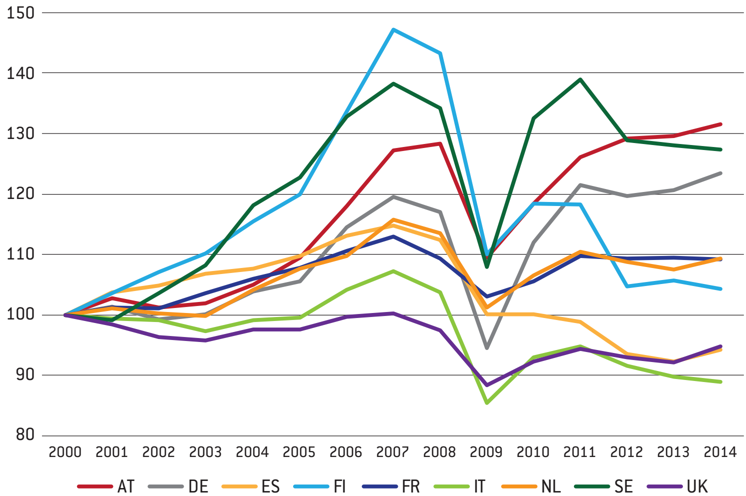


Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision.

Significant differences between countries clearly emerge from the data: average value added growth in real terms ranges from 2 percent in Austria to -1 percent in Italy. The impact of TFP growth was positive, though highly variable, in every country except Italy. The reduction of hours worked, however, acted as a drag on value added growth in all countries. Interestingly, with the exception of Italy and Finland, this is the only component that depresses average growth. **The contribution of ICT capital deepening is smaller but positive in every country considered, particularly in Sweden and Finland**. Finally, the increased availability to workers of fixed assets, machinery and equipment remains a positive driver, particularly to growth in Austria, Sweden and Italy.

These long-term averages, however, mask a great cyclicality of the value added generated by manufacturing. This was evident in particular during the crisis of 2008-09, as shown by Figure 2, which also shows great variation in the speed of recovery of different countries after the crisis.

Figure 2: Long-term dynamics of manufacturing real value added, 2000=100



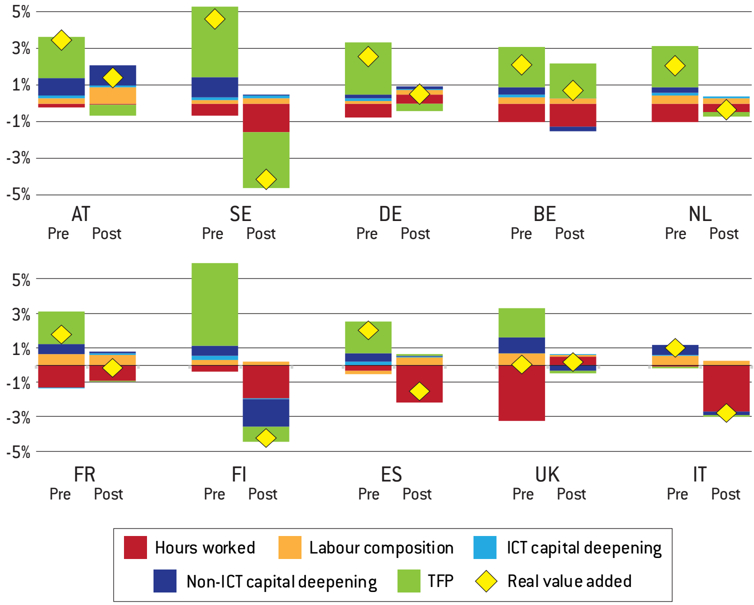
Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision.

In light of the latter, we replicate the analysis excluding the 2008-10 period. Figure 3 shows average contributions during the pre- and post-crisis periods.

As Figure 3 shows, the **post-crisis period** has been characterised by a general slowdown in the average growth rate of real value added in the manufacturing sector. In most of the countries considered, this has been mainly driven by a **collapse in the contribution of TFP and**

a substantial decrease of non-ICT capital deepening, direct consequences of a drop in corporate investment. Furthermore, in Finland, Spain and Italy, where the depressive effects of the crisis were deeper, a remarkable reduction of hours worked (because of both redundancies and closures of firms) further worsened the situation.

Figure 3: Growth accounting decomposition of manufacturing real value added, excluding crisis period

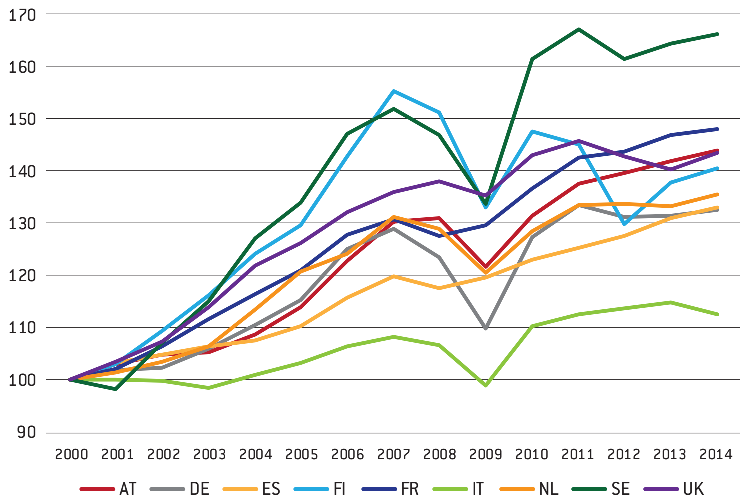


Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision. Note: * last year of post-crisis period is 2013.

3.2 Manufacturing vs. total economy: the same output with fewer jobs?

The aforementioned trends in value added and hours worked drove, though in opposite directions, the dynamics of labour productivity (Figure 4).

Figure 4: Long-term dynamics of labour productivity in manufacturing, 2000=100



Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision.

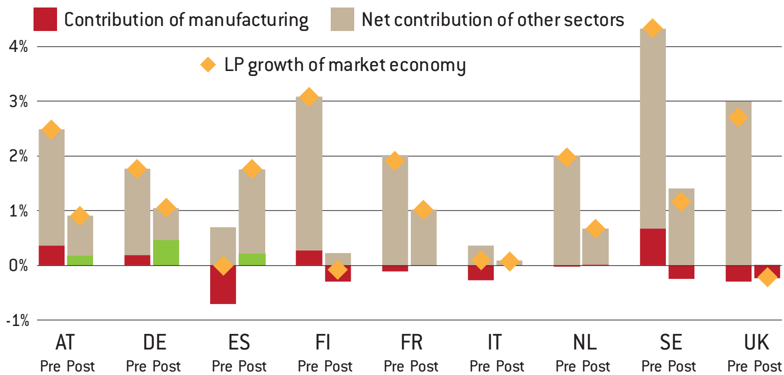
When the trends before and after the crisis are compared, a **slow-down in productivity growth** clearly emerges also for labour productivity. There is certainly a cyclical explanation for that, as similar dynamics were seen after the recession in 2001. In fact, this cyclical slowdown has been mainly **driven by an 'decoupling' of hours worked and production**: the share of hours worked in manufacturing has fallen by between 10 and 30 points in Europe since 2000 and has not recovered (with the only exceptions being Germany and Italy after 2013), while the share of manufacturing output has followed the typical dynamics of the crisis (fall and recovery during 2008-13). These trends in turn led to a cyclical recovery of manufacturing labour productivity.

To build on this evidence, we have estimated the contribution of the manufacturing sector to the growth of labour productivity in the total market economy of each country[10]. Figure 5 shows our estimates, providing a comparison of average contributions before and after the crisis.

Since 2011, the manufacturing sector has positively contributed to the productivity growth of the overall economy only in Austria, Germany and Spain. In France and Italy the manufacturing sector has at least stopped being a drag on productivity growth, while in the other countries the contribution was zero or even turned negative.

The changes in the contribution reflect both the changes in the relative share of hours worked in manufacturing (out of the total market economy hours worked) and the changes in labour productivity in each industry: in general, the **overall contraction of the contribution of manufacturing to the economy can be mainly attributed to the decreasing relevance of manufacturing in terms of hours worked**.

Figure 5: Contribution of manufacturing to labour productivity growth of market economy, average pre- (2001-07) vs. post-crisis (2011-14)



Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision.

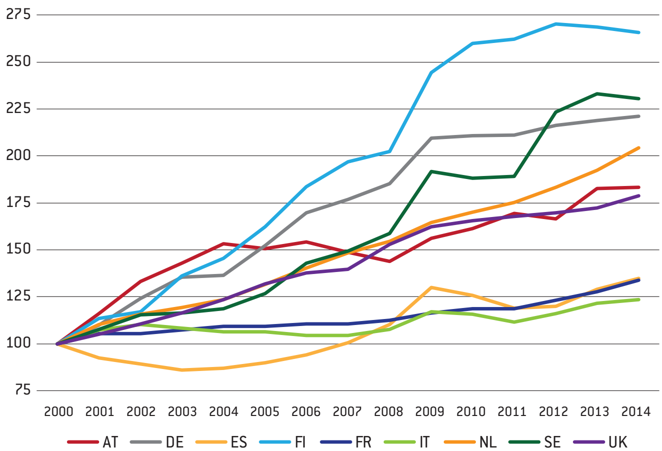
10 In line with the definition of EU KLEMS, the market economy covers all the industries included in the classification NACE Rev.2 with the exception of: real estate activities (cod. L); public administration and defence; compulsory social security (cod. O); education (cod. P); health and social work (cod. Q); activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (cod. T); activities of extraterritorial organizations and bodies (cod. U).

We will now try to understand whether and to what extent the different trends in productivity we have reviewed are related to different degrees of digitalisation of manufacturing production across Europe.

3.3 The role of IT adoption in the manufacturing sector

To provide a macroeconomic overview of digitalisation in manufacturing, we use the estimates of capital stock available in the EU KLEMS database. In particular, we focus on the accumulated amount of computing equipment and computer software and databases. Figure 6 shows how the **IT intensity of manufacturing has evolved differently in different countries over the last fifteen years**.

Figure 6: Real IT capital stock per hour worked in the manufacturing sector, 2000=100



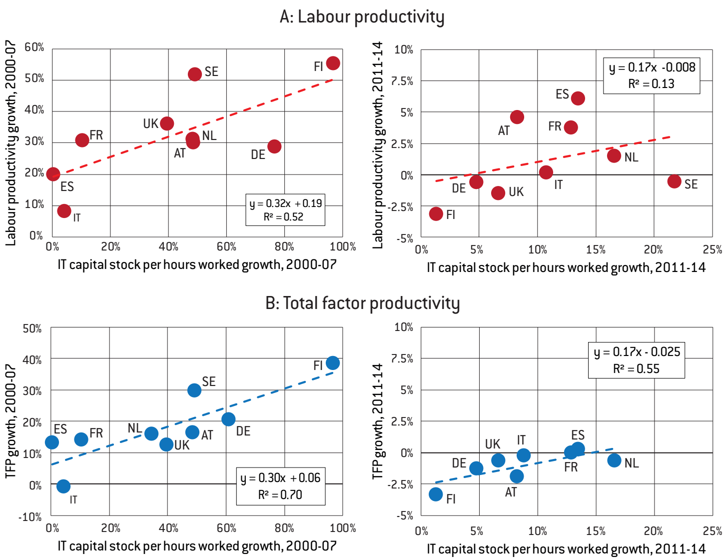
Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision. Notes: Real fixed capital stock (2010 prices). Belgium is missing because of unavailability of detailed capital input data.

The increasing adoption of information technology in manufacturing has been particularly marked in Finland, Germany and Sweden. Investments in IT capital have been significantly lower in the manufacturing sectors of Spain, Italy and France.

To investigate whether and to what extent these differences in IT capital deepening correlate with productivity performance, we compare the growth rates of the IT capital stock (divided by total hours worked) with productivity dynamics in the manufacturing sector.

Figure 7 shows scatter plots for labour and TFP, before and after the crisis. We find that **greater growth in IT capital stock in a country is associated with better productivity performance**, in terms of both labour productivity and TFP. However, it is worth noting how **the magnitude of this relationship changed after the 2008-09 crisis.** For both labour productivity and TFP, the estimated coefficient is lower in the latter period and the same holds for the R^2, meaning that the relationship between the two variables has been affected by other factors. This is not surprising, given the bumpy recovery of the European economy in the post-crisis period, with a significant contraction in aggregate demand.

Figure 7: Productivity and IT capital stock growth in manufacturing



Source: Bruegel based on EU KLEMS Growth and Productivity Accounts, December 2016 revision. Notes: TFP for Sweden was not available in 2014.

We replicate the analysis for different industries within the same group of countries. To account for industry-specific characteristics, we add to the univariate regressions industry dummies and weights based on the value added share of each industry (out of total manufacturing), in order to adjust for country-specific industrial composition. Table 1 shows the results. **The positive relationship during the pre-crisis period is confirmed also at industry level** (though with a slightly lower coefficient), **while in the more recent years the (decreased) IT adoption rate was not correlated with the slowdown in productivity growth**.

Table 1: Productivity & IT capital stock growth in manufacturing, industry-level correlations

	Pre-crisis period (2000-2007)				Post-crisis period (2011-2014)			
	LP growth		TFP growth		LP growth		TFP growth	
IT capital stock per hours worked growth	0.21***	0.29***	0.11***	0.11***	-0.025	-0.031	-0.02	-0.027
	(0.064)	(0.015)	(0.043)	(0.013)	(0.0617)	(0.019)	(0.0662)	(0.0217)
Constant	0.11	0.07***	0.08	0.06***	-0.008	-0.0007	-0.022	-0.02***
	(0.077)	(0.019)	(0.07)	(0.017)	(0.027)	(0.006)	(0.029)	(0.007)
Observa-tions	88	88	88	88	88	88	80	80
R-squared	0.36	0.54	0.28	0.40	0.31	0.33	0.25	0.24
Value added share weights	No	Yes	No	Yes	No	Yes	No	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1								

Source: Bruegel. Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. TFP for Sweden was not available in 2014. Industry C19 (Coke and refined petroleum products) has been excluded.

3.4 From macro to micro: evidence from a new survey of firms' strategies

The mixed results in terms of the correlation between ICT investment and productivity growth in EU manufacturing through the crisis can be explored in more detail by looking at firm-level dynamics. As acknowledged by the OECD (Van Ark, 2005), "*within an industry, some leading firms invest heavily in ICT and organisational change and reap the accompanying productivity gains. But there are also laggards with lower productivity growth. These laggards may have also invested heavily in ICT, but were less successful in realising soft savings. Although in time these laggards are likely to either exit or catch-up with the leaders due to competitive pressures, this inevitably takes time. In the meantime, industry performance will reflect both leading and lagging firm performance*".

The latter aggregation effect could be particularly relevant in the post-crisis context. The weak economic cycle in Europe might in fact increase the delay during which ICT laggards are reaping the benefits of their investment, leading to the non-significant effect of ICT on productivity that we have found in our macro estimates.

In order to shed more light on this issue, we use a new firm-level dataset made available to us by Assolombarda, the largest local branch of the Italian entrepreneurial association (Confindustria). The dataset is a **representative sample of manufacturing firms with more than 10 employees operating in five large European regions**: Lombardy (Italy), Baden-Württemberg and Bavaria (Germany), Catalonia (Spain) and Rhône-Alpes (France) (Box 1).

Box 1: The Assolombarda Benchmark Dataset - 2013

The dataset uses as a methodological benchmark the 2010 EU-funded cross-country survey European firms in a global economy: Internal policies for external competitiveness (EFIGE). The questionnaire sent to firms covers seven different broad areas:

- Firm structure (company ownership, domestic and foreign control, management);
- Workforce (skills, type of contracts, training);
- Investments and related financing;
- Innovation, patent activity and R&D (and related financing);
- Export and internationalisation processes;
- Financial structure and bank-firm relationship;
- Market structure and competition;
- Bureaucracy and administrative context.

As the survey was run in early 2015, information is mostly collected as a cross-section for the last available budgetary year (ie 2013), although some questions cover the period 2011-13 and/or the behaviour of firms in comparison to the pre-crisis period or during the crisis. Data is integrated with balance sheet information from the Orbis database managed by Bureau van Dijk. For 2013, the regional distribution of available firms in the dataset is described in Table A1.

Table A1: Regional distribution of firms in the survey

Region	Number of Firms
Baden-Württemberg	99
Bayern	100
Cataluña	103
Lombardy	241
Rhône-Alpes	101
Total	644

To measure the exposure of firms to ICT, we exploit a question in the survey that asks firms to state if they adopted in 2013 one or more of: internal information management systems (eg ERP), advanced management systems (eg CRM or Groupware), systems for automatic information sharing between customers and suppliers (eg virtual marketplace)[11]. We define a variable digit as a dummy equal to 1 if the firm has a basic level of digitalisation of its management and marketing, ie it adopts at least one of the listed IT technologies.

We also use other control variables known in the literature to be correlated, along with ICT, with the productivity of firms. One of the most important is the internationalisation of a firm's activities – if the firm operates only on the domestic market or if it imports, exports, outsources or invests in a foreign country. The dummy variable *int_active* will detect whether the firm has pursued at least one of the above activities, or, in other words, if it participates in some way in global value chains. Another variable we consider is the firm's innovation status. The dummy *R&D* is set to a value of 1 if a firm performed any R&D activity in 2013. The dummy *fam_mgmt* meanwhile accounts for governance differences between firms: its value is 1 if a firm's board is entirely composed of members of the family that owns the company, thus operating a selection between family-managed/owned firms and others.

Table 2 reports the distribution of these variables in 2013 for each region, size class and industry[12], and for the overall weighted sample[13].

Only a small majority of the firms in our sample (55.9 percent) adopted at least one IT instrument in 2013, a result that suggests that the digital transition is still far from complete. Regarding internationalisation, a large majority (68 percent) of surveyed firms are internationally active, a figure that is likely related to the lower dimensional

11 Enterprise Resource Planning (ERP) is an example of a digital system for the management of internal information: it integrates all the relevant business processes (sales, purchases, accounting, etc) into the same platform. Customer Relationship Management (CRM) and Groupware software are two examples of advanced management tools. Virtual marketplaces are platforms through which digital information is shared between vendors and customers.

12 Industry defined as 4 macro-sector based on Eurostat-NACE Rev. 2 classification of 2-digit manufacturing industries by R&D intensities.

13 The weighting scheme adopted is described in the Appendix.

threshold of our sample (at least 10 employees); however most surveyed firms participate in international activities at the simplest level (only importing or exporting). Finally, most firms did not pursue any R&D activity in 2013, though there is an increasing likelihood of this kind of investment depending on the industry type. The percentage of firms totally managed by family is remarkably high in Lombardy and in the two German regions, consistent with known evidence of the prevalence of family firms in Italy and Germany.

Table 2: Descriptive statistics for selected variables of the survey, by region and size class

Region	Baden-Württemberg	Bavaria	Rhône-Alpes	Catalonia	Lombardy	Total Sample
% of digitalised firms	55.0	50.2	69.9	61.4	52.2	55.9
% of internationally active firms	58.3	56.7	73.2	80.6	72.7	68.2
% of firms performing R&D	40.2	39.2	53.7	28.4	39.9	39.7
% of family managed firms	47.5	45.8	19.2	41.3	63.5	49.2

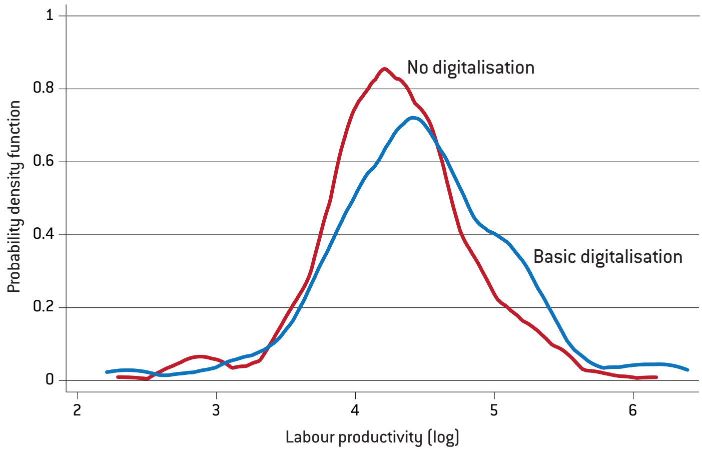
Class-size	Number of employees			
	10-49	50-249	250+	Total
% of digitalised firms	51.2	77	96.2	55.9
% of internationally active firms	65.1	84.9	98.1	68.2
% of firms performing R&D	35.9	59.4	76.5	39.6
% of family managed firms	53.5	20.1	1.4	49.2

Industry-type	Low technology	Medium-low technology	Medium-high technology	High technology	Total
% of digitalised firms	44.9	59.8	65.3	86.1	55.9
% of internationally active firms	61.2	67.5	80.9	86.1	68.2
% of firms performing R&D	34.9	35.3	54.8	56.6	39.6
% of family managed firms	55.9	47.6	43.1	15.2	49.2

Source: Bruegel based on Assolombarda Benchmark data.

Distinguishing by size class, it is not surprising to see that the percentage of firms pursuing digitalisation, performing R&D and being internationally active increases with size, while the share of firms with family management is lower for larger firms. Figure 8 shows the distribution of firm labour productivity in our sample (computed as the value added of each firm divided by the number of employees) relative to the digitalisation variable.

Figure 8: Distribution of labour productivity in 2013, by degree of firm digitalisation



Source: Bruegel based on Assolombarda Benchmark data.

This preliminary evidence confirms the idea that the **overall productivity distribution of firms that adopt at least one ICT tool dominates that of firms not using ICT**. This is confirmed also by running a Kolmogorov-Smirnov test for equality of distribution functions (results reported in the chapter Appendix). Controlling for different levels of ICT adoption (ie one, two or three of the IT tools covered by the survey) we obtain the results summarised in Table 3.

Table 3: Log of labour productivity by number of ICT instruments adopted

	No digitalisation	1 ICT instrument	2 or 3 ICT instruments
Median	4.22	4.39	4.54
Top 25% of firms	4.56	4.70	5.03
Std. Deviation	0.61	0.64	0.64
Observations	247	237	128

Source: Bruegel based on Assolombarda Benchmark data.

Not surprisingly the median productivity of firms grows in line with the number of ICT tools adopted, with a 4 percent productivity increase when adding one ICT tool, and a further increase of 2 percent when moving from one to two or more ICT tools. Firm-level data also makes it possible to look at these effects for the top 25 percent of firms in the productivity distribution. For the top firms, the adoption of one ICT instrument generates a 3 percent gain in productivity compared to the digitally non-active firms. Interestingly, for those ‘top’ firms, adding a second (or more) ICT tool is associated with an 8 percent increase in productivity compared to those firms that use just one digital tool. This is consistent with the intuition put forward by Van Ark (2005) and more recently by Andrews *et al* (2015), who, also using firm-level data, found an uneven process of technological diffusion in which global frontier technologies only diffuse to laggards once they are adapted to country-specific circumstances by the most productive (leading) firms.

To go beyond simple unconditional correlations, ie assessing whether and to what extent the positive relationship between digitalisation and labour productivity robustly holds at different parts of the firm level distribution, we have run different estimations, adding different controls at every step (Box 2).

Box 2: Econometric approach

The general framework is the following:

$$Labour\ Prod = digit \times \beta_1 + \boldsymbol{X} \times \beta' \ [FE]$$

The first specification (1) regresses the labour productivity on the three main dummy variables we analysed in the descriptive statistics part. Controlling for R&D and international activities is coherent with theory and previous researches: internationalisation was found to be positively correlated with labour productivity and even with digitalisation level via OLS regression. Similarly, activities in R&D could be seen as connected to a higher productivity firm. Thus, controlling for these two variables helps us to isolate the effect of digitalisation on productivity.

In the second specification (2), we add as a control the variable fam_mgmt, which describes if a firm's board is family-based. Adding this control operates a selection within our sample, investigating only family-owned firms. Family-managed firms are known to display on average lower levels of productivity as well as lower levels of ICT adoption (see Altomonte et al, 2012).

In all the regressions, we control for regional, sectoral and firm-size fixed effects. To investigate heterogeneous effects beyond the average, and thus exploring the different (if any) behaviour of leading compared to laggard firms, we exploit a simultaneous-quantile regression (considering the 20th, 40th, 60th and 80th percentiles of the productivity distribution).

Table 4 shows the results for the two specifications, for the quantiles of the productivity distribution. Table 4 also shows the average result for the whole sample.

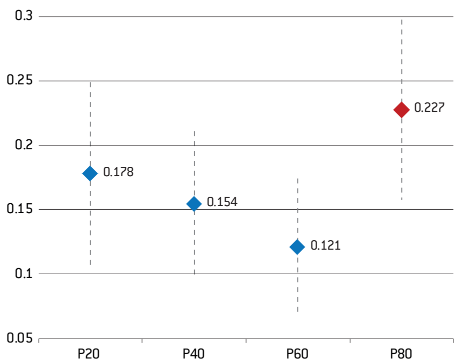
Table 4: ICT and productivity, quantiles and average effect – productivity levels

	Bottom 20%	Bottom 40%	Top 40%	Top 20%	Average
Specification (1)	0.18***	0.15***	0.12**	0.23***	0.16***
Specification (2)	0.15**	0.17***	0.16**	0.25***	0.18***

Note: * Significant at 10%. ** Significant at 5%. *** Significant at 1%. The table reports the coefficient of the digit variable in a quantile regression for the different percentiles, and a standard OLS specification for average effect. Specification (1) controls for internationalisation and R&D activities of firms. Specification (2) replicates specification (1) on family firms also controlling for a governance model carried out through family management. All regressions include regional, sectoral and firm-size fixed effects.

We found that **on average**, **digitalisation** (in the sense of adopting at least one of the three ICT tools) **is associated with higher productivity levels of firms** ranging, on average, from 16 percent to 18 percent depending on the underlying specification. The coefficient on *digit* is always positive and significant also for the entire productivity distribution. Consistent with our initial assumption, results show in particular that **when ICT is adopted by the top 20 percent most productive firms, it is associated with even higher productivity levels**. It is easy to visually gauge the differences between quintiles by plotting as an example the coefficient results for the first specification (Figure 9).

Figure 9: Estimated coefficient and 95% confidence intervals, first specification



Source: Bruegel.

In order to better link our firm-level analysis to the aggregate evidence we have reported, we computed the post-crisis growth rate of labour productivity of firms (2010-13), and used it as a dependent variable in a similar regression exercise. Table 5 summarises the coefficient results for the two specifications.

Overall, the result is positive and significant only for the last quantile, thus confirming the hypothesis that **only leading firms are able to gain from ICT adoption**. There, the gain over three-year growth from digitalisation ranges from 8 percent to 11 percent, depending on the specification. Interestingly, when we include in the sample only family-managed firms (specification 2), the gap between leaders and laggards is even larger.

Table 5: ICT and productivity, quantiles and average effect – productivity growth

	Bottom 20%	Bottom 40%	Top 40%	Top 20%	Average
Specification (1)	0.002	0.023	0.015	0.082*	0.008
Specification (2)	0.051	0.057	0.041	0.114**	0.056

Note: * Significant at 10%. ** Significant at 5%. *** Significant at 1%. The table reports the coefficient of the digit variable in a quantile regression for the different percentiles, and a standard OLS specification for average effect. Specification (1) controls for internationalisation and R&D activities of firms. Specification (2) replicates specification (1) on family firms also controlling for a governance model carried out through family management. All regressions include regional, sectoral and firm-size fixed effects.

3.5 Conclusion

We have assessed the link between ICT and the competitiveness of EU industry, from both a macro and a micro perspective. From the macroeconomic point of view, we have shown how and to what extent ICT has contributed to the value-added and productivity dynamics of the EU manufacturing sector. The productivity of manufacturing has substantially recovered in Europe, but its contribution to overall productivity is small because the manufacturing sector is losing ground in terms of share of hours worked throughout the EU.

When looking at these dynamics from the perspective of firms, we find that the effects of ICT are on average positive and significant for productivity, but that these are essentially driven by the most productive companies (the right tail of the productivity distribution at the micro level). This is in particular the case if we concentrate our analysis on productivity growth, and especially for firms that have family-based governance.

McKinsey (2016) estimates the EU to be operating at 12 percent of its digital potential, with huge differences within sectors and countries, and some evidence of the early impact of digitalisation, with a correlation in all sectors between productivity growth and digital intensity. Our analyses at the macro level are consistent with these findings.

While **ICT and Industry 4.0 are powerful policy tools to foster the competitiveness of EU industry** (the EU Digital Single Market is estimated to add €375 to €415 billion each year to the EU GDP), our analysis at the firm-level shows that these effects are **also likely to increase the gap between the most successful companies and those 'left behind'**.

This raises a key policy issue: as estimated by McKinsey (2016), Europe could add €2.5 trillion to GDP in 2025 if laggard sectors were to double their digital intensity, thus boosting GDP growth by 1 percent per year over the next decade. Failing to do so would represent a missed opportunity and, in light of our results, might also lead to an increase in territorial and social inequalities.

Appendix

We report the complete estimation results for the different specifications referred to in the text.

Table 5: First specification on productivity levels

$$\ln(Labour\ Prod) = digit \times \beta_1 + rd \times \beta_2 + intActive \times \beta_3\ [FE]$$

	ln_lp	ln_lp	ln_lp	ln_lp	ln_lp
Quantile	P20	P40	P60	P80	linear
digit	0.178***	0.154***	0.121**	0.227***	0.161***
	0.066	0.054	0.052	0.068	0.052
rd	0.039	0.018	0.121**	0.101	0.062
	0.063	0.052	0.062	0.070	0.052
int_active	0.224***	0.146**	0.103	0.222**	0.183**
	0.078	0.063	0.065	0.089	0.059
Region FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Size class FE	Yes	Yes	Yes	Yes	Yes
Constant	3.983***	4.306***	4.513***	4.771***	4.454***
Observations	618	618	618	618	612
Pseudo R2	0.1087	0.1041	0.0904	0.1065	0.1399

* Significant at 10%. ** Significant at 5%. *** Significant at 1%

Table 6: Second specification on productivity levels

$$\ln(Labour\ Prod) = digit \times \beta_1 + rd \times \beta_2 + intActive \times \beta_3 + famMgmt \times \beta_4\ [FE]$$

	ln_lp	ln_lp	ln_lp	ln_lp	ln_lp
Quantile	P20	P40	P60	P80	linear
digit	0.152**	0.177***	0.162**	0.251***	0.176***
	0.068	0.061	0.069	0.078	0.059
rd	-0.024	0.028	0.056	0.018	0.011
	0.068	0.066	0.075	0.089	0.061
int_active	0.228***	0.142*	0.147*	0.157	0.159**
	0.079	0.077	0.081	0.104	0.069
Fam_mgmt	-0.191**	-0.118*	-0.116*	-0.132	-0.162***
	0.082	0.061	0.066	0.092	0.059
Region FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Size class FE	Yes	Yes	Yes	Yes	Yes
Constant	4.166***	4.457***	4.472***	4.863***	4.492
Observations	488	488	488	488	488
Pseudo R2	0.1282	0.1157	0.1005	0.1224	0.5867

* Significant at 10%. ** Significant at 5%. *** Significant at 1%

Table 7: First specification on productivity growth

$$lp\_3\_year\_growth = digit \times \beta_1 + rd \times \beta_2 + intActive \times \beta_3 \ [FE]$$

	growth_ lp_3	growth_ lp_3	growth_ lp_3	growth_ lp_3	growth_ lp_3
Quantile	P20	P40	P60	P80	linear
digit	0.002	0.023	0.015	0.082*	0.008
	0.045	0.036	0.024	0.045	0.033
rd	-0.034	0.021	0.005	-0.039	-0.025
	0.043	0.033	0.028	0.038	0.032
int_active	0.019	-0.034	0.045	0.036	0.027
	0.049	0.040	0.031	0.056	0.038
Region FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Size class FE	Yes	Yes	Yes	Yes	Yes
Constant	-0.174	-0.019	0.073	0.239*	0.076
Observations	604	604	604	604	604
Pseudo R^2	0.0218	0.0134	0.0302	0.0351	0.0273

* Significant at 10%. ** Significant at 5%. *** Significant at 1%

Table 8: Second specification on productivity growth

$$lp\_3\_year\_growth = digit \times \beta_1 + rd \times \beta_2 + intActive \times \beta_3 + famMgmt \times \beta_4\ [FE]$$

	growth_ lp_3	growth_ lp_3	growth_ lp_3	growth_ lp_3	growth_ lp_3
Quantile	P20	P40	P60	P80	linear
digit	0.051	0.057	0.041	0.114**	0.056
	0.051	0.038	0.029	0.047	0.037
rd	-0.067	0.006	-0.005	-0.058	-0.032
	0.051	0.041	0.032	0.045	0.037
int_active	-0.032	-0.031	0.039	0.017	0.038
	0.065	0.042	0.031	0.061	0.044
fam_mgmt	-0.049	-0.021	0.012	0.034	0.0046
	0.062	0.036	0.029	0.049	0.039
Region FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Size class FE	Yes	Yes	Yes	Yes	Yes
Constant	-0.249*	-0.003	0.024	0.244	0.022
Observations	474	474	474	474	474
Pseudo R2	0.0232	0.0131	0.0325	0.0498	0.0264

* Significant at 10%. ** Significant at 5%. *** Significant at 1%

Weighting scheme

Absolute weights have been constructed, splitting the sample into 72 cells by 2 digit NACE Rev. 2 manufacturing industries and the three size classes on which the stratification has been carried out. First, from Eurostat Structural Business Statistics (year 2010), we computed the composition of each region's economic activity by industry and firm size class (ie the population distribution). Second, we repeated the same exercise using the data effectively collected (ie the sample distribution). Then, for each region, the absolute weight for firms in industry *k* and size class *j* was built as follows:

(A1)

$$aw_{kj} = \frac{Pfirms_{kj}/Pfirms}{Sfirms_{kj}/Sfirms}\left(\frac{Pfirms}{Sfirms}\right)$$

where $Pfirms_{kj}$ is the number of firms in industry k and size class j for the population in a given region; $Sfirms_{kj}$ is the number of firms in industry k and size class j in the sample; *Pfirms* and *Sfirms* are the total number of firms in the population and in the sample, respectively. By construction, firms belonging to the same sampling interval (ie to the same combination industry/size classes) share the same weight. The sum of weights over the firms is equal to the total number of firms in the sample by region.

Results of Kolmogorov-Smirnov tests for equality of two distribution functions

We ran a two-sample Kolmogorov-Smirnov test to verify the statistical significance of the differences between the labour productivity distribution functions of firms with 'no-digitalisation', '1 ICT tool' and '2 or 3 ICT tools'.

Smaller Group	Diff	p-value	Exact
A (ie non-digitalised)	0.1638	0.001	
B (ie 1 ICT tool)	-0.0108	0.972	
Combined K-S	0.1638	0.003	0.002

Smaller Group	Diff	p-value	Exact
A (ie 1 ICT tool)	0.1388	0.039	
B (ie 2-3 ICT tools)	-0.0308	0.852	
Combined K-S	0.1388	0.078	0.070

Note: Diff is the measure of the discrepancy between the two empirical distribution functions of the two groups. The first line tests the hypothesis that labour productivity distribution for group A contains smaller values than for group B. Conversely, the second line tests the hypothesis that labour productivity distribution for group A contains larger values than for group B. The null hypothesis for the final line is that the distributions are equal. From the results of the tests, we can clearly reject the hypothesis that the two distributions are equal to each other in both cases.

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