

## Em Análise

### Productivity in the last decade: The role of R&D and Digitalization

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#### 1. Overview

In this essay, we focus our attention into the role played by R&D as well as digitalization in labor productivity and labor productivity growth developments during the last decade. We begin by classifying firms and sectors according to their R&D intensity as laid out in Galindo-Rueda and Verger (2016). This framework allowed us to disentangle manufacturing from non-manufacturing activities, both of which are then grouped into five different categories (high, medium-high, medium, medium-low, and low R&D intensity industries). Moreover, we rely on the structure provided by Calvino et al. (2018) to classify industries according to their level of digital intensity (high, medium-high, medium-low and low digital intensive industries).

Despite modest productivity gains during the last decade, results show a monotonic relationship between labor productivity and both R&D and digital intensity. Although causality between variables may be difficult to establish, since the relation may run both ways, we do find that a higher degree of R&D and digital intensity is associated with higher labor productivity, particularly for firms at the R&D and digital intensity frontier.

#### 2. Productivity and R&D intensity

We begin by examining the relationship between R&D intensity and productivity during the last decade. Using the aggregated version of the taxonomy provided by Galindo-Rueda and Verger (2016) industries were classified according to their level of RD intensity<sup>2</sup>. This framework allowed us to cluster manufacturing and non-manufacturing activities into five groups, namely high, medium-high, medium, medium-low, and low R&D intensity industries<sup>3</sup>. One should note beforehand that R&D intensity, as defined here, should not be interpreted, or referred to as a knowledge or technology-intensity taxonomy. This is particularly true for service industries where R&D expenditure is a less appropriate predictor of technology use, knowledge generation or innovation in general.

Regarding productivity distribution in 2017, Figure 1 suggests pronounced differences amongst R&D intensity categories. Notably, the productivity distribution of lower R&D intensive industries (low and medium-low R&D) is far more skewed to the left which is indicative of a higher concentration of firms of this category in the lower brackets of productivity. By contrast, productivity distributions of higher R&D intensity tiers (high and medium-high R&D) are extremely heavy-tailed to the right.

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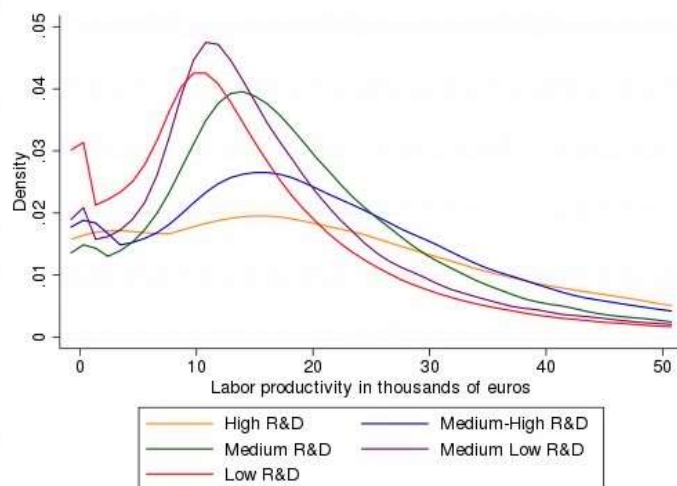
As opiniões expressas não coincidem necessariamente com a posição do Gabinete de Estratégia e Estudos ou do Ministério da Economia e Transição Digital.

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<sup>2</sup> The ratio of R&D to value-added within an industry.

<sup>3</sup> For further details about the industries classification into R&D categories are provided in tables 9 and 10 of annex 2.

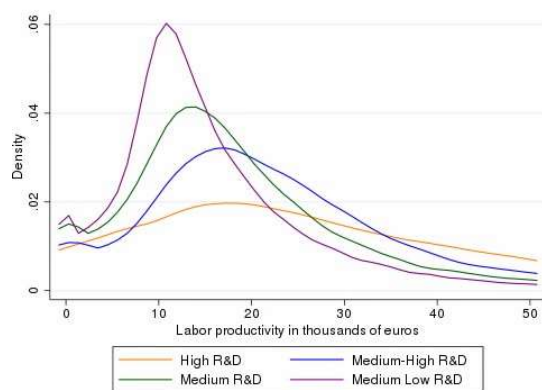
**Figure 1: Productivity Distribution 2017 by R&D intensity | All firms**



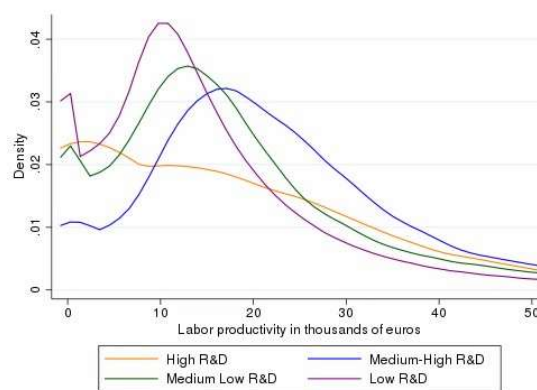
Source: IES and author’s calculations | Notes: Figure 1 shows the distribution of labor productivity in 2017 for all firms. To facilitate the reading of the graph, in the Kernel distribution, productivity figures are truncated between 0 and 50 thousand euros per worker (the distribution has been calculated based on all observations).

In Figures 2 and 3, we disentangle the distribution of productivity between manufacturing and non-manufacturing firms. The most significant difference between the two comes from firms located at the highest level of RD intensity. Notably, top R&D intensity firms from the non-manufacturing sectors concentrate heavily on the lower brackets of productivity. In contrast, their manufacturing peers prevail in the upper brackets of productivity *vis-à-vis* other R&D categories.

**Figure 2: Productivity | Manufacturing**



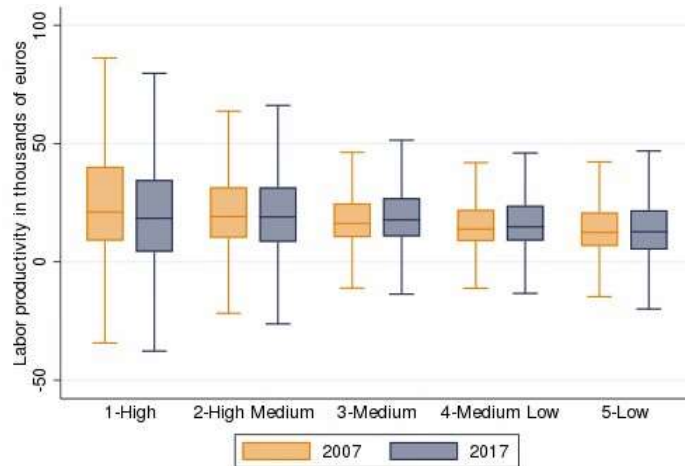
**Figure 3: Productivity | Non-manufacturing**



Source: IES and author’s calculations | Notes: Figures 2 and 3 show the distribution of labor productivity in 2017 by R&D intensity for both manufacturing and non-manufacturing firms. To facilitate the reading of the graph, in the Kernel distribution, productivity figures are truncated between 0 and 50 thousand euros per worker (the distribution has been calculated based on all observations).

More significant, though, is the fact that productivity developments during the last decade were mild at best. Figure 4 portrays these productivity developments across R&D intensity categories during the 2007-2017 period. Strikingly, high R&D intensity sectors stand out as productivity levels experience a slight decrease in real terms during the period.

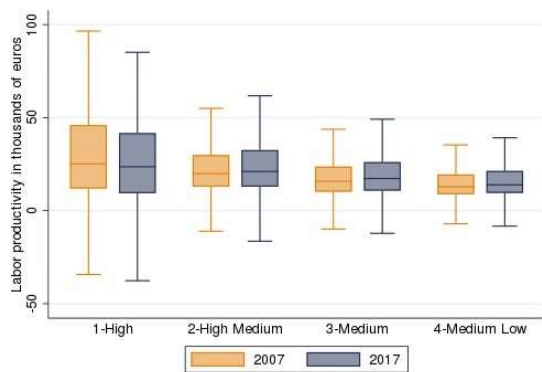
**Figure 4: Productivity Distribution 2007-2017 by R&D intensity | All firms**



Source: IES and author calculations. | ICT classification

Considering manufacturing sectors only, Figure 5 shows similar results as sectors with the highest degree of R&D intensity experienced a setback in terms of productivity compared to 2007. As for non-manufacturing industries, the most outstanding feature is that sectors of medium-high R&D intensity attained higher productivity levels both in 2007 and 2017.

**Figure 5: Productivity 2007-2017 | Manufacturing**



Source: IES and author's calculations

**Figure 6: Productivity 2007-2017 | Non manufacturing**

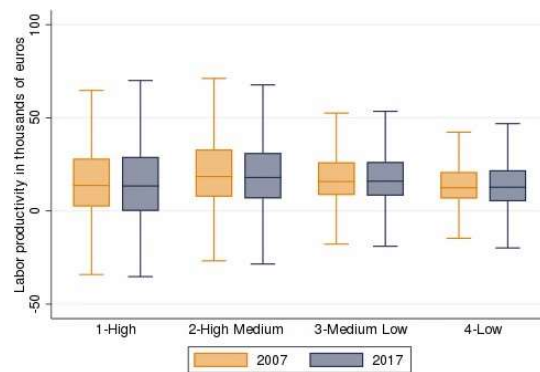
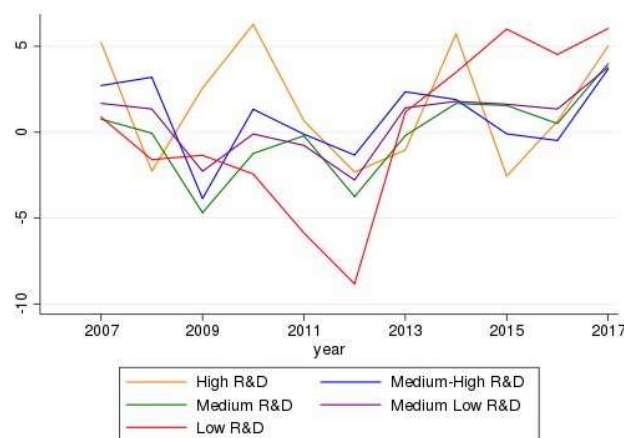


Figure 7 presents labor productivity growth paths of the median firm during the last decade for all R&D intensity categories. During the period, median productivity growth was characterized by intense volatility, particularly in sectors with either high or low R&D intensity.

**Figure 7: Productivity Growth 2007-2017 by R&D intensity**

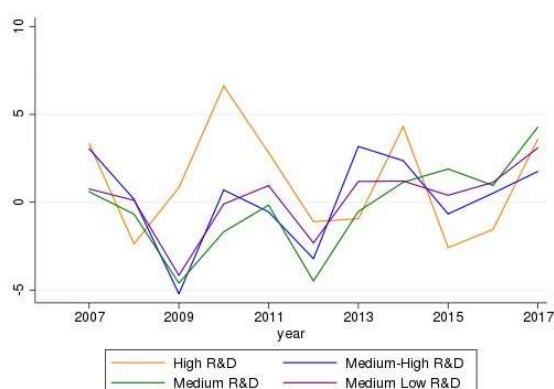


Source: IES and author's calculations

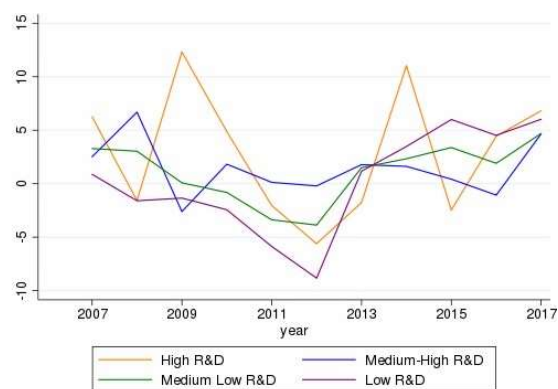
Moreover, low R&D intensive firms seem to have suffered the most in terms of productivity loss during the economic downturn the ensued the global financial crises and the sovereign debt crises that followed. After reaching a period low of almost 10% in 2012, median productivity growth of low R&D firms has been recovering surpassing the remaining groups as soon as 2015.

Considering manufacturing and non-manufacturing firms separately, median productivity rates of sectors with high R&D intensity still display an increased level of volatility *vis-à-vis* the remaining categories.

**Figure 8: Productivity Growth | Manufacturing**



**Figure 9: Productivity Growth | Non manufacturing**



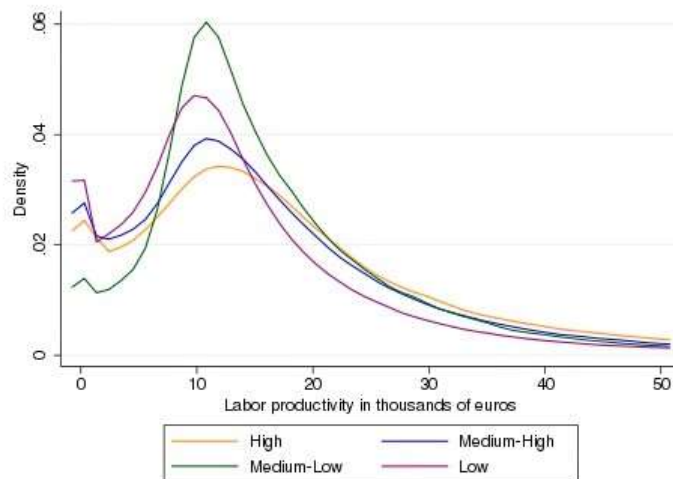
Source: IES and author's calculations

### 3. Productivity and digital intensity

In this section, we explore the relation between digital adoption and productivity of Portuguese firms during the last decade. To do so, we rank sectors according to the extent to which they have gone digital using the framework provided by Calvino et al. (2018). Notably, we rely on the proposed summary indicator of the digital transformation in sectors that encompasses several dimensions. Such dimensions include the share of ICT tangible and intangible (i.e., software) investment; share of purchases of intermediate ICT goods and services; the stock of robots per hundreds of employees; share of ICT specialists in total employment; and the share of turnover from online sales. According to the proposed indicator, we were able to classify sectors into four categories of digital intensity, namely: Low, Medium-low, Medium-high, and High<sup>4</sup>.

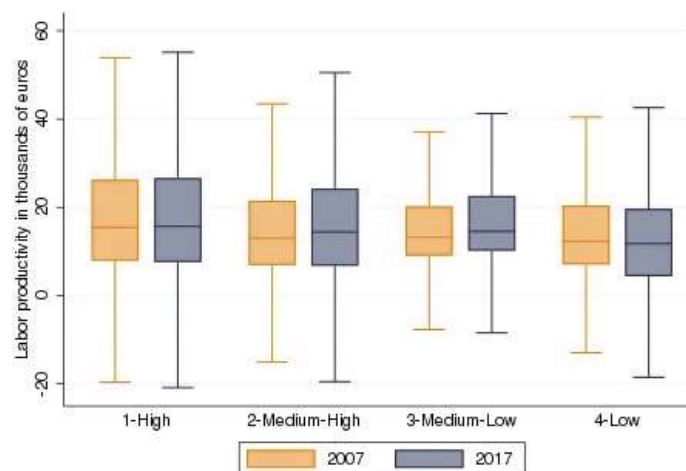
In Figure 10, we present the distribution of productivity by digital intensity status of firms in 2017. Although all distributions are strongly skewed to the left, a noticeable feature comes from the fact that there seems to be a monotonic relation between digital intensity and productivity. Another striking feature stems from the fact that productivity distributions of firms with higher digital intensity are heavy tailed, hinting towards a more significant degree of heterogeneity among them.

<sup>4</sup> Table 11 in annex 2 provides further details about the classification of sectors in the categories mentioned above.

**Figure 10: Labor Productivity Distribution 2017 by digital intensity**

Source: IES and authors calculations

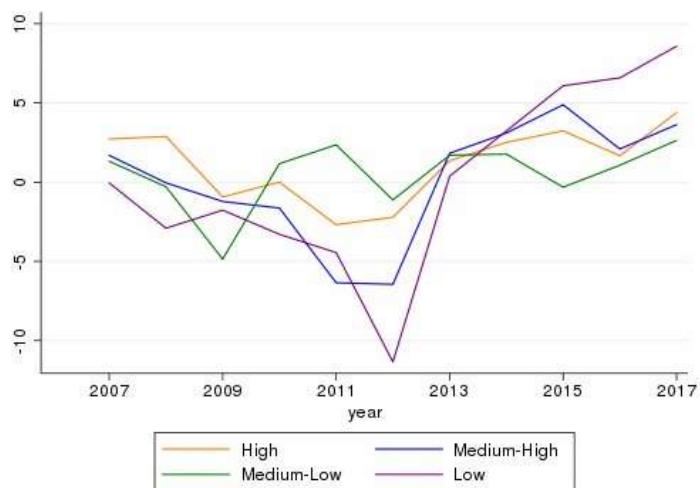
This feature of the distribution is, to some extent, confirmed in Figure 11, as the interquartile range of labor productivity, in 2017, increases with the degree of digital intensity of firms (the exception being the medium-low group). Furthermore, within-group heterogeneity in productivity increased during the last decade for all groups except for low digital intensity firms. Notwithstanding, Figure 11 highlights the fact that despite the productivity gains observed in the upper quartiles of each group, median productivity remained rather unchanged during the last decade.

**Figure 11: Labor Productivity Distribution 2007-2017 by digital intensity**

Source: IES and author's calculations

Moreover, Figure 12 depicts productivity growth by digital intensity categories, for the median firms during the last decade. There are at least three features that stand out. First, median labor productivity growth of firms with low digital intensity had been consistently negative since 2007, well before the global financial crisis. Second, median productivity growth of firms with medium-low digital uptake showed to be far more resilient than their medium-high and high digital intensity counterparts during the crisis. Lastly, median productivity growth of high digital intense firms experienced far less volatility during the period.

**Figure 12: Median Productivity Growth 2007-2017: by digital intensity**



Source: IES and authors calculations.

#### 4. Annex 1 – Descriptive Statistics

Table 1: Labor Productivity by R&D intensity (thousands of euros) | All firms

year	R&D Intensity	Observations	Mean	sd	Percentiles		
					25	50	75
2007	High	440	29,94	50,90	8,97	21,08	40,24
	Medium-High	6.705	27,11	104,93	10,18	19,16	31,60
	Medium	6.230	20,08	29,29	10,45	16,29	24,79
	Medium-Low	48.720	18,83	69,74	8,80	13,92	22,07
	Low	178.478	19,86	124,85	6,70	12,49	20,93
	<b>Total</b>	<b>240.573</b>	<b>19,88</b>	<b>113,51</b>	<b>7,32</b>	<b>13,03</b>	<b>21,64</b>
2017	High	625	23,18	36,67	4,27	18,44	34,73
	Medium-High	9.311	24,95	59,43	8,44	19,00	31,56
	Medium	6.150	21,51	24,79	10,75	17,78	27,05
	Medium-Low	57.301	21,03	75,14	8,96	14,79	23,80
	Low	183.809	18,86	105,70	5,18	12,75	21,87
	<b>Total</b>	<b>257.196</b>	<b>19,64</b>	<b>96,90</b>	<b>6,28</b>	<b>13,52</b>	<b>22,88</b>

Source: IES and author calculations.

Table 2: Labor Productivity by R&amp;D intensity (thousands of euros) | Manufacturing

year	R&D Intensity	Observations	Mean	sd	Percentiles		
					25	50	75
2007	High	303	34,78	56,46	11,91	25,18	46,01
	Medium-High	2.832	25,97	58,95	12,94	19,95	29,89
	Medium	4.920	19,38	28,03	10,20	15,81	23,71
	Medium-Low	24.621	15,59	23,09	8,86	12,88	19,48
	<b>Total</b>	<b>32.676</b>	<b>17,24</b>	<b>29,37</b>	<b>9,17</b>	<b>13,81</b>	<b>21,26</b>
2017	High	287	28,37	40,30	9,42	23,63	41,73
	Medium-High	2.488	26,37	58,21	12,89	21,04	32,59
	Medium	4.173	20,80	23,43	10,74	17,31	26,13
	Medium-Low	22.925	18,32	80,41	9,52	13,90	21,40
	<b>Total</b>	<b>29.873</b>	<b>19,43</b>	<b>73,09</b>	<b>9,75</b>	<b>14,79</b>	<b>23,24</b>

Source: IES and author calculations.

Table 3: Labor Productivity by R&amp;D intensity (thousands of euros) | Non manufacturing

year	R&D Intensity	Observations	Mean	sd	Percentiles		
					25	50	75
2007	High	137	19,26	33,43	2,39	13,74	28,13
	Medium-High	3.873	27,95	128,53	7,61	18,50	33,03
	Medium-Low	22.471	22,80	99,56	8,57	15,81	26,15
	Low	178.478	19,86	124,85	6,70	12,49	20,93
	<b>Total</b>	<b>204.959</b>	<b>20,34</b>	<b>122,38</b>	<b>6,88</b>	<b>12,88</b>	<b>21,73</b>
2017	High	338	18,77	32,70	0,00	13,41	29,01
	Medium-High	6.823	24,43	59,86	6,77	17,99	31,17
	Medium-Low	32.426	23,34	73,34	8,19	15,98	26,32
	Low	183.809	18,86	105,70	5,18	12,75	21,87
	<b>Total</b>	<b>223.396</b>	<b>19,68</b>	<b>100,44</b>	<b>5,62</b>	<b>13,29</b>	<b>22,83</b>

Source: IES and author calculations.

Table 4: Median Productivity Growth, by R&amp;D intensity (%) | All

year	R&D Intensity					Total
	High	Medium-High	Medium	Medium-Low	Low	
2007	5,22	2,72	0,76	1,68	0,88	1,15
2008	-2,26	3,20	-0,06	1,35	-1,59	-0,07
2009	2,57	-3,86	-4,68	-2,27	-1,34	-1,74
2010	6,28	1,34	-1,24	-0,10	-2,43	-1,70
2011	0,66	-0,12	-0,21	-0,77	-5,86	-4,25
2012	-2,32	-1,33	-3,75	-2,78	-8,82	-6,82
2013	-1,03	2,35	-0,20	1,42	1,17	1,24
2014	5,73	1,90	1,67	1,80	3,48	2,88
2015	-2,55	-0,09	1,56	1,63	6,00	4,40
2016	0,64	0,48	0,50	1,35	4,52	3,32
2017	5,01	3,67	3,99	3,78	6,03	5,26

Source: IES and author's calculations.

Table 5: Median Productivity Growth, by R&amp;D intensity (%) | Manufacturing

year	R&D Intensity				Total
	High	Medium-High	Medium	Medium-Low	
2007	3,35	3,05	0,60	0,75	0,94
2008	-2,37	0,17	-0,68	0,11	-0,04
2009	0,83	-5,21	-4,60	-4,16	-4,26
2010	6,62	0,69	-1,68	-0,10	-0,18
2011	2,82	-0,55	-0,16	0,94	0,67
2012	-1,11	-3,21	-4,49	-2,32	-2,65
2013	-0,94	3,17	-0,53	1,18	1,07
2014	4,31	2,37	1,14	1,20	1,33
2015	-2,58	-0,67	1,89	0,39	0,41
2016	-1,55	0,51	0,96	1,13	1,04
2017	3,60	1,75	4,28	3,09	3,17

Source: IES and authors calculations.



Table 6: Median Productivity Growth, by R&amp;D intensity (%) | Non manufacturing

year	R&D Intensity				Total
	High	Medium-High	Medium-Low	Low	
2007	6,26	2,52	3,29	0,88	1,19
2008	-1,57	6,69	3,04	-1,59	-0,90
2009	12,31	-2,60	0,08	-1,34	-1,18
2010	4,88	1,83	-0,81	-2,43	-2,15
2011	-2,04	0,13	-3,37	-5,86	-5,39
2012	-5,61	-0,20	-3,86	-8,82	-7,89
2013	-1,75	1,78	1,50	1,17	1,24
2014	11,03	1,62	2,33	3,48	3,23
2015	-2,46	0,43	3,39	6,00	5,41
2016	4,44	-1,07	1,91	4,52	3,93
2017	6,83	4,66	4,70	6,03	5,75

Source: IES and author's calculations.

Table 7: Labor Productivity by digital intensity (thousands of euros)

year	Digital Intensity	Observations	Mean	sd	Percentiles		
					25	50	75
2007	High	33.648	23,40	115,82	7,90	15,46	26,30
	Medium-High	93.366	17,22	84,32	6,91	13,06	21,53
	Medium-Low	18.398	16,63	24,50	9,06	13,19	20,25
	Low	95.161	21,88	143,95	7,07	12,31	20,42
	<b>Total</b>	<b>240.573</b>	<b>19,88</b>	<b>113,51</b>	<b>7,33</b>	<b>13,03</b>	<b>21,64</b>
2017	High	49.314	23,34	76,12	7,60	15,68	26,63
	Medium-High	92.732	19,36	72,32	6,74	14,45	24,26
	Medium-Low	16.959	18,60	23,30	10,17	14,55	22,60
	Low	98.191	18,21	129,01	4,39	11,78	19,68
	<b>Total</b>	<b>257.196</b>	<b>19,64</b>	<b>96,90</b>	<b>6,28</b>	<b>13,52</b>	<b>22,88</b>

Source: IES and author's calculations.

Table 8: Median Productivity Growth, by digital intensity (%)

year	Digital Intensity				Total
	High	Medium-High	Medium-Low	Low	
2007	2,72	1,69	1,32	-0,05	1,15
2008	2,88	-0,04	-0,29	-2,90	-0,71
2009	-0,94	-1,22	-4,85	-1,77	-1,74
2010	0,00	-1,63	1,17	-3,29	-1,70
2011	-2,69	-6,35	2,36	-4,45	-4,25
2012	-2,22	-6,44	-1,12	-11,34	-6,82
2013	1,35	1,82	1,70	0,37	1,24
2014	2,51	3,10	1,77	3,23	2,88
2015	3,24	4,88	-0,32	6,08	4,40
2016	1,66	2,09	1,07	6,58	3,32
2017	4,38	3,63	2,64	8,58	5,26

Source: IES and author's calculations.

## 5. Annex 2 – Taxonomies

Table 9: Sectoral classification of R&amp;D intensity | Manufacturing

Sector	ISIC rev4	R&D Intensity
Pharmaceutical products	21	High
Computer, electronic and optical products	26	High
Other transport equipment	30	Medium-High
Motor vehicles, trailers, and semi-trailers	29	Medium-High
Machinery and equipment n.e.c.	28	Medium-High
Chemicals and chemical products	20	Medium-High
Electrical equipment	27	Medium-High
Rubber and plastics products	22	Medium
Other manufacturing	32	Medium
Other non-metallic mineral products	23	Medium
Basic metals	24	Medium
Repair and installation of machinery and equipment	33	Medium
Textiles	13	Medium-Low
Fabricated metal products, except machinery and equipment	25	Medium-Low
Leather and related products	15	Medium-Low
Paper and paper products	17	Medium-Low
Food products, beverages, and tobacco	10-12	Medium-Low
Wearing apparel	14	Medium-Low
Coke and refined petroleum products	19	Medium-Low
Furniture	31	Medium-Low
Wood and products of wood and cork	16	Medium-Low
Printing and reproduction of recorded media	18	Medium-Low

Source: Adapted from Galindo-Rueda and Verger (2016)

Table 10: Sectoral classification of R&amp;D intensity | Non manufacturing

Sector	ISIC rev4	R&D Intensity
Scientific research and development	72	High
Publishing activities	58	Medium-High
IT and other information services	62-63	Medium-High
Professional, scientific, and technical activities (except 72)	69-75	Medium-Low
Telecommunications	61	Medium-Low
Mining and quarrying	5-9	Medium-Low
Financial and insurance activities	64-66	Low
Electricity, gas and water supply, waste management and remediation	35-39	Low
Audiovisual and broadcasting activities	59-60	Low
Wholesale and retail trade	45-47	Low
Agriculture, forestry, and fishing	1-3	Low
Construction	41-43	Low
Administrative and support service activities	77-82	Low
Arts, entertainment, repair of household goods and other services	90-99	Low
Transportation and storage	49-53	Low
Accommodation and food service activities	55-56	Low
Real estate activities	68	Low

Source: Adapted from Galindo-Rueda and Verger (2016)

Table 11: Sectoral classification of digital intensity

Sector	ISIC rev4	Digital Intensity
Transport equipment	29-30	High
Telecommunications	61	High
IT and other information services	62-63	High
Finance and insurance	64-66	High
Legal and accounting activities, etc.	69-71	High
Scientific research and development	72	High
Advertising and market research; other business services	73-75	High
Administrative and support service activities	77-82	High
Wood and paper products, and printing	16-18	Medium-High
Computer, electronic and optical products	26	Medium-High
Electrical equipment	27	Medium-High
Machinery and equipment n.e.c.	28	Medium-High
Furniture; other manufacturing; repairs of computers	31-33	Medium-High
Wholesale and retail trade, repair	45-47	Medium-High
Publishing, audiovisual and broadcasting	58-60	Medium-High
Arts, entertainment, and recreation	90-93	Medium-High
Other service activities	94-96	Medium-High
Textiles, wearing apparel, leather	13-15	Medium-Low
Coke and refined petroleum products	19	Medium-Low
Chemicals and chemical products	20	Medium-Low
Pharmaceutical products	21	Medium-Low
Rubber and plastics products	22-23	Medium-Low
Basic metals and fabricated metal products	24-25	Medium-Low
Education	85	Medium-Low
Human health activities	86	Medium-Low
Residential care and social work activities	87-88	Medium-Low
Agriculture, forestry, fishing	01-03	Low
Mining and quarrying	05-09	Low
Food products, beverages, and tobacco	10-12	Low
Electricity, gas, steam, and air cond.	35	Low
Water supply; sewerage, waste management	36-39	Low
Construction	41-43	Low
Transportation and storage	49-53	Low
Accommodation and food service activities	55-56	Low
Real estate	68	Low

Source: Adapted from Calvino et al. (2018)

## 6. References

Calvino, F., C. Criscuolo, L. Marcolin, and M. Squicciarini (2018). A taxonomy of digital intensive sectors.

Galindo-Rueda, F., and F. Verger (2016). OECD Taxonomy of economic activities based on R&D intensity.