The impact of ICTs and digitalization on productivity and labor share: Evidence from French firms

Gilbert Cette$^{1,2}$, Sandra Nevoux$^1$ and Loriane Py$^1$

1: Banque de France
2: University of Aix-Marseille (AMSE)

The views expressed in this document do not necessarily reflect those of the Banque de France or the Eurosystem.
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2. Data
3. Estimated model and identification
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1. Introduction

Average annual growth rate of labor productivity per hour
Smoothed indicator (HP filter, $\lambda = 500$) - Whole economy – 1891-2018 – In %
Source: Bergeaud, Cette and Lecat (2016) - See: www.longtermproductivity.com

- Productivity slowdown over recent decades
- Productivity growth rates now at the lowest in 150 years (outside WW periods)
- Where are productivity gains from digitalization? Risk of Secular Stagnation?
1. Introduction

Growth accounting decomposition – United States
Source: Cette, Devillard and Spieza (2020, Forthcoming)

<table>
<thead>
<tr>
<th>GDP growth (in %) and contributions (in pp)</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
<th>Period 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GDP (1)</td>
<td>3,66</td>
<td>3,16</td>
<td>3,39</td>
<td>1,76</td>
<td>2,99</td>
<td></td>
</tr>
<tr>
<td>Hours (2)</td>
<td>1,38</td>
<td>1,88</td>
<td>1,01</td>
<td>0,71</td>
<td>1,33</td>
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</tr>
<tr>
<td>Productivity (3) = (1)-(2)</td>
<td>2,28</td>
<td>1,29</td>
<td>2,38</td>
<td>1,05</td>
<td>1,67</td>
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</tr>
<tr>
<td>Capital deepening (4)</td>
<td>0,67</td>
<td>0,25</td>
<td>0,58</td>
<td>0,40</td>
<td>0,45</td>
<td></td>
</tr>
<tr>
<td>ICT capital total (5) = (6)+(7)+(8)</td>
<td>0,11</td>
<td>0,27</td>
<td>0,43</td>
<td>0,20</td>
<td>0,24</td>
<td></td>
</tr>
<tr>
<td>Hardware (6)</td>
<td>0,06</td>
<td>0,15</td>
<td>0,21</td>
<td>0,05</td>
<td>0,11</td>
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</tr>
<tr>
<td>Software and databases (7)</td>
<td>0,03</td>
<td>0,09</td>
<td>0,14</td>
<td>0,11</td>
<td>0,09</td>
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</tr>
<tr>
<td>Telecommunication eqpt (8)</td>
<td>0,03</td>
<td>0,04</td>
<td>0,07</td>
<td>0,04</td>
<td>0,04</td>
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<tr>
<td>Robots (9)</td>
<td>0,00</td>
<td>0,01</td>
<td>0,03</td>
<td>0,03</td>
<td>0,02</td>
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</tr>
<tr>
<td>Non ICT capital and non robots capital (10) = (4)-(5)-(9)</td>
<td>0,55</td>
<td>-0,03</td>
<td>0,13</td>
<td>0,16</td>
<td>0,19</td>
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</tr>
<tr>
<td>TFP (11) = (3)-(4)</td>
<td>1,61</td>
<td>1,03</td>
<td>1,79</td>
<td>0,65</td>
<td>1,22</td>
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<tr>
<td>Education (12)</td>
<td>0,45</td>
<td>0,27</td>
<td>0,20</td>
<td>0,17</td>
<td>0,28</td>
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<tr>
<td>Robotisation (13)</td>
<td>0,01</td>
<td>0,03</td>
<td>0,08</td>
<td>0,10</td>
<td>0,05</td>
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<tr>
<td>Residual (14) = (11)-(12)-(13)</td>
<td>1,15</td>
<td>0,73</td>
<td>1,51</td>
<td>0,38</td>
<td>0,89</td>
<td></td>
</tr>
</tbody>
</table>

- Decrease of ICT contribution, slight increase of robot contribution
- Large decrease of residual \( \text{TFP} \) contribution
- Where are productivity gains from digitalization? Risk of \textit{Secular Stagnation}?
## 1. Introduction

### Growth accounting decomposition – Euro Area

Source: Cette, Devillard and Spieza (2020, Forthcoming)

<table>
<thead>
<tr>
<th>GDP growth (in %) and contributions (in pp)</th>
<th>Period 1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>GDP (1)</td>
<td>4,60</td>
<td>2,44</td>
<td>2,12</td>
<td>1,09</td>
<td>2,61</td>
</tr>
<tr>
<td>Hours (2)</td>
<td>-0,71</td>
<td>-0,22</td>
<td>0,93</td>
<td>0,37</td>
<td>-0,01</td>
</tr>
<tr>
<td>Productivity (3) = (1)-(2)</td>
<td>5,31</td>
<td>2,66</td>
<td>1,19</td>
<td>0,72</td>
<td>2,63</td>
</tr>
<tr>
<td>Capital deepening (4)</td>
<td>2,03</td>
<td>0,97</td>
<td>0,43</td>
<td>0,42</td>
<td>1,02</td>
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<td>0,79</td>
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<td>TFP (11) = (3)-(4)</td>
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<td>1,69</td>
<td>0,77</td>
<td>0,30</td>
<td>1,61</td>
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<td>0,12</td>
</tr>
<tr>
<td>Residual (14) = (11)-(12)-(13)</td>
<td>2,68</td>
<td>1,23</td>
<td>0,32</td>
<td>-0,16</td>
<td>1,10</td>
</tr>
</tbody>
</table>

- Decrease of ICT contribution and of robot contribution
- Large decrease of residual TFP contribution
- Where are productivity gains from digitalization? Risk of *Secular Stagnation*?
1. Introduction: motivation and context

- In recent decades, simultaneously global productivity slowdown and firm level analyses indicate large impact from ICT and digitalization on productivity level/growth. For instance among others: Andrews et al. (2018), Gal et al. (2019a and 2019b)

**Same for modelized approaches**, mainly through DSGE models. For instance among others: Etro (2009), DeStefano et al. (2019), Tamegawa et al. (2014 and 2015), ...

- **Puzzling**
  It reminds us of the 1987 Solow paradox: “You can see the computer age everywhere, but in the productivity statistics”

- Higher consensus concerning the **impact of robotization and digitalization on labor share**

- Previous analyses find **negative impact on LS** through different types of mechanisms. For instance among others: Dinlersoz and Wolf (2018), Acemoglu and Restrepo (2018), Aghion et al. (2019), Acemoglu et al, (2020)
1. Introduction: aim of the paper

- Analyzes the impact of the employment of ICT specialists (in-house and external) and the use of digital technologies (cloud and big data) on productivity and labor share

- Uses a firm level dataset of French firms
  - 1065 firms with at least 20 employees in the manufacturing sector in 2018
  - From two BdF datasets: survey on factor utilization (FUD) and firm level annual financial statements (FIBEN)

- Estimates relations explaining Labor Productivity ($LP$), Total Factor Productivity ($TFP$), Labor Share ($LS$) by the use of ICT specialists or digital technologies

- OLS and IV methods
  - Instruments for the IV method: Bartik (1991) method
  - Leave-one-out mean at the industry level

- Between-firm approach
1. Introduction: main findings

- Empirical results:
  - **Use of ICT specialists** (through internal or external employment) and **use of digital technologies** (cloud and big data)
    - Improves *LP* and *TFP* by about 17 to 23%
    - Decreases *LS* by about 2.5 pp
  - **Means very large impact of ICTs and digitalization** on productivity and labor share
  - **Confirmation of previous literature results**
    - **With an original approach**: between firm estimates
    - **With an original dataset** on French firms
2. Data: two firm-level dataset

- **FIBEN**: Accounting data from fiscal documents
  - All French firms with annual turnover > €750,000 or with outstanding credit > €380,000
  - About 200,000 firms
  - Information on size, age, industry, … of the firm
  - Allow us to calculate \( LP, TFP \) and \( LS \) at the firm level

- **FUD**: Survey on Factor Utilisation Degrees
  - Manufacturing industries
  - Plants with more than 20 employees
  - Information on Capital Utilization Rate (CUR), Shiftwork, …
  - Specific questions in 2018 on the use of Internet, ICTs and Digitalization
    - “For how many years have you been using an internet connection?”
    - “Do you employ in-house ICT specialists? If yes, for how many years?”
    - “Do you employ external ICT specialists? If yes, for how many years?”
    - “Have you ever used cloud computing services? If yes, for how many years?”
    - “Have you ever analyzed big data? If yes, for how many years?”
  - →1,349 complete answers to these questions
2. Data: final sample

- **Final dataset used for estimates**
  - Merger and cleaning of these two datasets (FIBEN and FUD)
  - 1,065 French firms / obs
  - More than 20 employees
  - Manufacturing industries
  - 2018

- **Rich information at the firm-level**
  - Productivity: Labor productivity (LS) and Total factor productivity (TFP)
  - Labor share (LS)
  - Employment of inhouse and external ICT specialists
  - Use of cloud and use of big data
  - Age, Size, Industry, Use of shiftwork, Capital utilization rate
2. Data: descriptive statistics

- **Average use of ICTs and digital technologies**

![Bar chart showing the average use of ICTs and digital technologies.](image)

Sources: FIBEN and FUD survey (Banque de France)

- **Consistent with results from Eurostat ICT survey**
2. Data: descriptive statistics

- These uses vary across size and sector

The use increases with the firm size

Sources: FIBEN and FUD survey (Banque de France)
2. Data: multiple correspondence analysis

- A multiple correspondence analysis:
  - **Over the four ICT and digital basic variables** (0 or 1 for each):
    ICT employment internal or external, Cloud, Big Data
  - **Comp1**: First principal component
    Explains 43% of the overall variation in the use of ICTs and Digital technologies
  - **Comp2**: Second principal component
    Explains 22% of the overall variation in the use of ICTs and Digital technologies
  - → We use only *Comp1* in estimates
3. Estimated model and identification

Estimated model

\[ Y_i = \beta_1 . DIG_i + \beta_2 . CUR_i + \beta_3 . Shiftwork_i + \beta_4 + \delta_{Si} + \delta_{Ai} + \delta_{Ii} + \varepsilon_i \]

- \( i \): Index of the firm
- \( Y \): Log of the variable of interest, \( LP, TFP \) or \( LS \)
- \( DIG \): ICT or digital variable
  - \( Comp1 \), continuous
  - \( Int. ICT, Ext. ICT, Cloud \) or \( Big Data \), originally 0 or 1
  - For some estimates, we distinguish \( \leq 5 \) years and \( > 5 \) years
- \( CUR \): Continuous variable
- \( Shiftwork \): 0 or 1
- \( \delta_{Si} \): Size fixed effects
  - 4 size categories: 20 to 49 employees, 50 to 249 employees, 250 to 499 employees, 500 employees or more
- \( \delta_{Ai} \): Age fixed effects
  - 5 age categories: 20 years or less, 21 to 35 years, 36 to 50 years, 51 to 70 years, 71 years and above
- \( \delta_{Ii} \): Industry fixed effects
  - 11 categories of manufacturing industries
3. Estimated model and identification

- Estimated model

\[ Y_i = \beta_1.DIG_i + \beta_2.CUR_i + \beta_3.Shiftwork_i + \beta_4 + \delta_{S_i} + \delta_{A_i} + \delta_{I_i} + \epsilon_i \]

- \( \beta_1 \): Expected \( >0 \) for LP and TFP and \( <0 \) for LS (see literature previously mentioned)

- \( \beta_2 \): Expected \( >0 \) for LP and TFP and \( <0 \) for LS (see Cette et al. 2016a and 2016b)

- \( \beta_3 \): Expected \( >0 \) for LP and LS as Shiftwork more frequent when capital to labor ratio is high, \( <0 \) for TFP as working time is shorter when Shiftwork is used (see Anxo et al. eds. 1995)

- \( \beta_2 \) and \( \beta_3 \): Significant estimated values, expected estimated sign, not reported below

- \( \beta_4 \): not reported either
3. Estimated model and identification

- **Potential endogeneity issues**
  - Reverse causality: firms with higher productivity are more likely to adopt digital technologies
  - Omitted variable bias: many other firm and industry characteristics are likely to influence firm productivity

- **Identification**
  - OLS and IV estimates
    - We report below only IV estimates
  - For IV estimates, instruments inspired by Bartik (1991)
    - Instruments: leave-one-out mean in the sector
  - Include a large set of controls in the estimates
4. Results: Impact on productivity

Impact on productivity

Table 1: Impact on LP and TFP (in log) of Comp1

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explained Var.</td>
<td>Log(LP)</td>
<td>Log(TFP)</td>
</tr>
<tr>
<td>Comp1</td>
<td>0.00823***</td>
<td>0.00546***</td>
</tr>
<tr>
<td></td>
<td>(0.00166)</td>
<td>(0.00138)</td>
</tr>
</tbody>
</table>

Significant positive impact of Comp1 synthetic index on productivity, on both LP and TFP
An increase by 1 SD of Comp1 would increase LP and TFP by 5.9% and 3.9% respectively

Table 2, Impact on LP (in log) of ICT and Digital variables

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. ICT</td>
<td>0.157***</td>
<td>0.132***</td>
<td>(0.0213)</td>
<td>(0.0225)</td>
<td></td>
</tr>
<tr>
<td>Ext. ICT</td>
<td>0.0464***</td>
<td>0.0216</td>
<td>(0.0177)</td>
<td>(0.0197)</td>
<td></td>
</tr>
<tr>
<td>Cloud</td>
<td>0.0678***</td>
<td>0.0239</td>
<td>(0.0167)</td>
<td>(0.0152)</td>
<td></td>
</tr>
<tr>
<td>Big data</td>
<td>0.141***</td>
<td>0.104***</td>
<td>(0.0346)</td>
<td>(0.0339)</td>
<td></td>
</tr>
</tbody>
</table>

High impact of ICT and digital technologies on LP
The employment of ICT specialists and the use of digital technologies could improve LP by about 23%

Table 3: Impact on TFP (in log) of ICT and Digital variables

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. ICT</td>
<td>0.102***</td>
<td>0.0797***</td>
<td>(0.0244)</td>
<td>(0.0262)</td>
<td></td>
</tr>
<tr>
<td>Ext. ICT</td>
<td>0.0483***</td>
<td>0.0309*</td>
<td>(0.0166)</td>
<td>(0.0184)</td>
<td></td>
</tr>
<tr>
<td>Cloud</td>
<td>0.0606**</td>
<td>0.0314</td>
<td>(0.0246)</td>
<td>(0.0242)</td>
<td></td>
</tr>
<tr>
<td>Big data</td>
<td>0.0894***</td>
<td>0.0617***</td>
<td>(0.0241)</td>
<td>(0.0231)</td>
<td></td>
</tr>
</tbody>
</table>

High impact of ICT and digital technologies on TFP
The employment of ICT specialists and the use of digital technologies could improve TFP by about 17%

Robust standard errors clustered at the sector level (11 categories of industries) are reported between parentheses
The t statistics are reported as follows:
* p<0.10, ** p<0.05, *** p<0.01.
4. Results: Impact on productivity

- Learning by doing effect (LDE) or Second-mover advantage (SMA)

Table 4: Impact on LP (in log)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
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<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. ICT ≤ 5</td>
<td>0.140*** (0.0379)</td>
<td>0.139*** (0.0361)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Int. ICT &gt; 5</td>
<td>0.160*** (0.0237)</td>
<td>0.126*** (0.0259)</td>
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</tr>
<tr>
<td>Ext. ICT ≤ 5</td>
<td>-0.0428 (0.0414)</td>
<td>-0.0491 (0.0350)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ext. ICT &gt; 5</td>
<td>0.0654*** (0.0162)</td>
<td>0.0370* (0.0194)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud ≤ 5</td>
<td>0.0548*** (0.0191)</td>
<td>0.0172 (0.0175)</td>
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</tr>
<tr>
<td>Cloud &gt; 5</td>
<td>0.104*** (0.0243)</td>
<td>0.0455* (0.0245)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Big data ≤ 5</td>
<td>0.154*** (0.0459)</td>
<td>0.117*** (0.0454)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big data &gt; 5</td>
<td>0.118*** (0.0337)</td>
<td>0.0644 (0.0395)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerning LP,
- ICT:
  Nothing clear for INT. ICT and
  Clear LDE for the use of Ext. ICT
- Digital:
  Clear LDE for the use of Cloud and clear SMA for the use of Big Data

Table 5: Impact on TFP (in log)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
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<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. ICT ≤ 5</td>
<td>0.124*** (0.0318)</td>
<td>0.118*** (0.0301)</td>
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<td></td>
</tr>
<tr>
<td>Int. ICT &gt; 5</td>
<td>0.0972*** (0.0316)</td>
<td>0.0698* (0.0358)</td>
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</tr>
<tr>
<td>Ext. ICT ≤ 5</td>
<td>0.00227 (0.0323)</td>
<td>-0.00847 (0.0270)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ext. ICT &gt; 5</td>
<td>0.0581*** (0.0179)</td>
<td>0.0394** (0.0187)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud ≤ 5</td>
<td>0.0495* (0.0274)</td>
<td>0.0205 (0.0268)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud &gt; 5</td>
<td>0.0920*** (0.0241)</td>
<td>0.0609** (0.0296)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big data ≤ 5</td>
<td>0.120*** (0.0382)</td>
<td>0.0933** (0.0386)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Big data &gt; 5</td>
<td>0.0336 (0.0243)</td>
<td>-0.00785 (0.0251)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerning TFP,
- ICT:
  Clear SMA for the use of Int. ICT and
  As for LP, clear LDE for the use of Ext. ICT
- Digital:
  As for LP, clear LDE for the use of Cloud and clear SMA for the use of Big data

Robust standard errors clustered at the sector level (11 categories of industries) are reported between parentheses. The t statistics are reported as follows:
* p<0.10, ** p<0.05, *** p<0.01.
5. Results: Impact on labor share

Table 6: Impact of Comp1

<table>
<thead>
<tr>
<th>Comp1</th>
<th>-0.00147***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.000542)</td>
</tr>
</tbody>
</table>

- Significant negative impact of Comp1 synthetic index on LS
  An increase by 1 SD of Comp1 would decrease LS by 1.1pp

Table 7: Impact of ICT and Digital variables

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Int. ICT</td>
<td>-0.0315***</td>
<td>-0.0292**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0100)</td>
<td>(0.0118)</td>
<td></td>
<td></td>
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<tr>
<td>Ext. ICT</td>
<td>-0.00719</td>
<td>-0.00351</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.00877)</td>
<td>(0.00964)</td>
<td></td>
<td></td>
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<tr>
<td>Cloud</td>
<td>-0.00227</td>
<td>0.00742</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00744)</td>
<td>(0.00733)</td>
<td></td>
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<tr>
<td>Big data</td>
<td>-0.0299***</td>
<td>-0.0248**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0116)</td>
<td>(0.0125)</td>
<td></td>
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</tr>
</tbody>
</table>

- High impact of ICT, through Int. ICT, and digital technologies through Big data, on LS
  The use of in house ICT specialists and the use of big data would decrease the LS by 2.9pp and 2.5pp respectively

Robust standard errors clustered at the sector level
(11 categories of industries) are reported between parentheses
The t statistics are reported as follows:
* p<0.10, ** p<0.05, *** p<0.01.
6. Conclusion

- **Method**
  - Use of an original dataset of 1,065 French firms for the year 2018
  - Data on the use of ICT specialists (in house or external) and digital technologies (Cloud and Big data)
  - Identification through IV approach, instruments inspired by Bartik (1991)
    - Instruments: leave-one-out mean in the sector
6. Conclusion

➢ Results
  o Productivity
    • Large positive impact of ICT specialists (in house or external) and digital technologies (*Cloud* and *Big data*) on productivity, on both *LP* and *TFP*
    • Use of ICT specialists and digital technologies could improve productivity level by 23% for *LP* and 17% for *TFP*
    • Learning by doing mechanisms for the use of *Ext.ICT* and the use of *Cloud*
    • Second mover advantage for the use of *Big data*
  o Labor share
    • Large negative impact of *Int.ICT* and *Big data* on the *LS*
    • Use of *Int.ICT* and *Big data* could decrease *LS* by 2.9pp and 2.5pp respectively
6. Conclusion

➢ Results

○ Productivity
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○ Labor share
  • Large negative impact of Int.ICT and Big data on the LS
  • Use of Int.ICT and Big data could decrease LS by 2.9pp and 2.5pp respectively

➢ Consistent with the literature highlighting the role of TIC and digital
  • Provide new evidence on impact of TIC and digital at the firm-level, positive for productivity (LP and TFP), negative for LS
  • Using French firms of more than 20 employees in the manufacturing industry
  • Such orders of magnitude need to be confirmed by other firm-level studies
6. Conclusion

➢ How to reconcile these results with the observed global productivity slowdown?
  o Large impact on productivity level
  o Need of other continuous Digital innovations to benefit from a large impact on growth rate over a long period
6. Conclusion

- How to reconcile these results with the observed global productivity slowdown?
  - Large impact on productivity level
  - Need of other continuous Digital innovations to benefit from a large impact on growth rate over a long period

- Where are we in Digital revolution?
  - As Van Ark (2016) said, the current pause in the productivity gains from the Third Industrial Revolution could in fact be a period of transition between the creation and installation of new technologies and their full deployment
  - Same as with previous technological revolutions, see David (1990): 50 to 60 years passed between the invention of a working electric dynamo in 1868 and its full exploitation in production
  - Need time and will require major changes to our institutions and to our methods of production and of management
  - Need of common explanations of the general productivity slowdown
    For instance, circular relation between real interest rates and productivity gains (see Aghion et al., 2019, Bergeaud et al., 2020)
6. Conclusion

- Risks and positive prospects
  - **Need of a global productivity revival** to finance the sustainability of the economic organization, the social system and possibly the institutions of developed countries
  - The **context of the COVID-19 threat** has boosted the use of digital technologies by firms and households
  - Starting point for an acceleration of ICT and digital diffusion?
  - This is one possible positive impact of the pandemic event: **to open the door more widely to the third industrial revolution**