Industry 4.0 and Productivity

UNIDO EQuIP Presentation
Pretoria, December 2019

Juergen Amann
Outline

• **Introduction**
  
  *What do we mean by industry 4.0 and new technology?*

• **Technology adoption**
  
  *To what degree is a country integrated in the adoption of new technologies?*

• **Robotization**
  
  *Are jobs at risk of being replaced by new technology?*

• **Runner industries**
  
  *Will new technologies inevitably lead to ‘jobless’ growth?*
Introduction

What do we mean by industry 4.0 and new technology?
Innovations and their consequences.

• 1956: Hard Drive
• 1958: Jet Airliner
• 1959: Integrated Circuit
• 1962: Communications Satellite
• 1968: Integrated Computer Systems
• 1970: Fiber Optics
• 1974: Barcode
• 1976: Supercomputer
• 1977: Personal Computer
• 1978: GPS

• 1983: Microsoft Word
• 1986: Electronic Mailing List
• 1989: World Wide Web
• ...
• Industry 4.0
• ...
• Future technologies
Innovation and their consequences

- They can be beneficial as they might generate new jobs and boost economic performance (e.g. value added and productivity).

- Not all countries/sectors/individuals adapt (to) new technology equally fast or successfully. This may have many reasons (e.g. political or ‘structural’, ...).

- Innovative changes are rarely unambiguously positive. Negative effects may occur on the level of the individual, sector, country.
In the context of Industry 4.0

- Policy makers are eager to adopt industry 4.0 technologies to ‘jump on the bandwagon’ of the unfolding industrial revolution ...
  - ...in the hopes of boosting economic performance (productivity).
  - ...in the fear of otherwise falling behind in this inevitable process.

- There is widespread fear that the adoption of industry 4.0 technology will do very little to boost employment (‘jobless growth’).
  - We will see in the next session that industry 4.0 is new, but it’s not a stand-alone technology.
  - In simple terms: We have had machines already; now with 4.0 we make them smart.
  - Have new technologies negatively affected manufacturing (particularly employment)?
New technologies
Productivity
New technologies will only be adopted if they ‘pay off’, i.e. increase productivity.

Adoption of new technologies will affect macroeconomic variables (value added and employment).
Development patterns inform new technology.

Pursuit of productivity growth leads to the development of new technologies.

Industry 4.0

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Industry 4.0

Capabilities and Prerequisites

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Industry 4.0

Capabilities and Prerequisites

Productivity

• What do we mean by Industry 4.0 in this tool?  
• How is a country adopting these technologies?  
• Do the patterns vary across countries?
Development patterns inform new technology.

Pursuit of productivity growth leads to the development of new technologies.

Industry 4.0

Capabilities and Prerequisites

Productivity

New technologies will only be adopted if they ‘pay off’, i.e. increase productivity.

Adoption of new technologies will affect macroeconomic variables (value added and employment).

What do we mean by Industry 4.0 in this tool?
How is a country adopting these technologies?
Do the patterns vary across countries?

What are the consequences of technology adoption?
How have manufacturing industries reacted?
Data

• As for all EQuIP tools the data should
  • Be freely available
  • Have good cross-country coverage
  • Be comparable

• For what remains, we focus on the tangible aspect of modern production technology (because of the above reasons).

• The proposed concepts may however also be suited to a more specific question to which you may wish to apply your own data.
New technologies

- New materials
  - Carbon graphene
  - Functional materials
  - ... [Invis. sun blockers, Nano-composites]

- Biotechnologies
  - Tissue engineering
  - Biochips

- Nano-technologies

- Digital & Production-technology
  - Big data analytics
  - Machine learning
  - Artificial intelligence
  - Internet of Things (IoT)
  - ...
New technologies

- Biotechnologies
  - Tissue engineering
  - Biochips
- Nano-technologies
  - Invis. sun blockers
  - Nano-composites
- New materials
  - Carbon graphene
  - Functional materials
- Advanced Manufacturing
- Digital & Production-technology
  - Big data analytics
  - Machine learning
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New technologies

- New materials
  - Carbon graphene
  - Functional materials

- Biotechnologies
  - Tissue engineering
  - Biochips

- Advanced Manufacturing
  - Invis. sun blockers
  - Nano-composites

- Digital & Production-technology

- Big data analytics
- Machine learning
- Artificial intelligence
- Internet of Things (IoT)
- ...
New technologies

Advanced Manufacturing

Biotechnologies

Digital & Production technology

Smart Factory:
- 3D printing/additive manufacturing
- CAD-CAM
- Robotics
- Industrial IoT
- etc.

New materials

Nano-technologies

Carbon graphene
Functional materials

Invis. sun blockers
Nano-composites

Tissue engineering
Biochips

Digital & Production technology

- Big data analytics
- Machine learning
- Artificial intelligence
- Internet of Things (IoT)
- ...

Digital & production technology applied to manufacturing
Manufacturing technologies

- **0.0: Analog production**
  - Use of pre-digital technologies

- **1.0: Rigid production**
  - Rigid and isolated automation using digital technologies and ICT in a punctual way (e.g. CAD)

- **2.0: Lean production**
  - Flexible and semi-flexible automation without (partial) integration between areas

- **3.0: Integrated Production**
  - Full integration between areas and activities

- **4.0: Smart Factory**

**Robots**

**3D printing/additive manufacturing**

**CAD-CAM**
How can we quantify a country’s performance?

3D printing/additive manufacturing

CAD-CAM

Robots
How can we quantify a country’s performance?

• The main idea:
  • Analyse certain components of a particular set of goods

- 3D printing/additive manufacturing
- CAD-CAM
- Robots
How can we quantify a country’s performance?

• The main idea:
  • Analyse certain components of a particular set of goods
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  - Analyse certain components of a particular set of goods
How can we quantify a country’s performance?

• The main idea:
  • Analyse certain components of a particular set of goods

• Derive indicators to
  • quantify the degree of adoption of industry 4.0-ready technologies;
  • identify and differentiate countries through their adoption strategy;
  • monitor employment creation/displacement effects.
Technology Adoption

To what degree is a country integrated in the adoption of advanced technologies?
Motivation

• Question(s)
  • Is my country adopting advanced technologies

• These technologies can be
  • Developed and produced domestically
  • Imported (embodied in machines)

• Data
  • National firm level (ideally)
  • Trade data to capture cross-country dimension
  • Here: focus on capital goods and I4.0 goods
Imports of capita goods (share of total) 1/2
Imports of capita goods (share of total) 2/2
Export of capita goods (share of total) 1/2
Export of capita goods (share of total) 2/2

The graph shows the share of total export of capita goods for South Africa, Namibia, Mozambique, Zimbabwe, Botswana, and Nigeria from 2005 to 2015. The data indicates fluctuations in the share percentages for each country during this period.
Import/Export of capita goods

- Can we put this into perspective?

- We consider the imports and export relative to the world average.
  - The Revealed Comparative Advantage (RCA) considers import/export performance in relation to the global trend.
  - If RCA > 1 performance is above world average.
  - IF RCA < 1 performance is below world average.
Empirical regularity: RCA by income group

- The higher a country’s income, the more they export capital goods.
- Countries average import of capital goods is highest for the lower middle income group.
Generalisation

• This approach can easily be generalised.

• Granular goods classification allows for a detailed analysis:
  • Analysis of Industry 4.0 ready goods;
  • Or components thereof.
Empirical regularity: RCA by income group

- A similar yet more skewed picture emerges.
- The higher a country’s income, the more they export Industry 4.0 goods.
- Exports are highly concentrated.
Technology adoption: summary

- Analysis of relative and absolute import and export performance across countries.
- Different types of goods and categorisation allow for the comprehensive cross-country analysis.
- Analysis may be conducted on very specific sub-classification on Industry 4.0 goods as well.
  - ‘What is the performance in 3D printing?’
- Flexible framework that can easily be extended by domestic firm-level data on goods groups of interest.
  - Cross-country comparability subject to data availability.
Robotization

Are jobs at risk of being replaced by new technology?
What is one of the biggest fears for employees and policy makers when they think about robots?
What is one of the biggest fears for employees and policy makers when they think about robots?

That this (5 cars, 9 people)....
What is one of the biggest fears for employees and policy makers when they think about robots?

That this (5 cars, 9 people)…. 

…turns into this (7 cars, 0 people).
What kind of robots are we talking about?

• Industrial robots as defined by the International Federation of Robotics:
  • An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications
  • See ifr.org/industrial-robots for more information.
  • Selected examples on the right.
Industrial robots: what and why?

- How is this different to industry 4.0 technology?
  - Robots cover a **broader range of manufacturing production**.
  - We use **stock data** on the level of manufacturing industries.
  - We can identify the number of **robots per worker**, changes over time and **differences across industries**.

- **Analysis also goes one step further in terms of technology adoption:**
  - If we only look at the number of imported robots we don’t know if/how firms use them.
  - Provides insights into how robotization changes the composition of **production input factors**.
  - This is of high relevance for developing countries.

- **Disclaimer**
  - No data for African countries on industrial robots: analysis lacks one dimension (see next slide).
  - Data set currently not free of charge.
Robotisation: capacity and job loss

Size of manufacturing sector (manufacturing share)
- ‘How many people are potentially affected?’

Degree of automation (robot intensity)
- ‘How intensely are robots used in an industry?’
- Not available for Africa because of lack of data.

Size of ‘risk industries’ as part of manufacturing
- Defined by Mayer (2018) as:

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Rubber and Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Appliances</td>
<td>Automobiles</td>
</tr>
</tbody>
</table>
Maturity in robotisation
Robotisation: summary

• The risk of job loss due to robotization may be higher
  • The larger the manufacturing sector is
  • The larger the share of activities is robots can perform (with the latest, smartest generation of robots this share naturally increases)
  • The higher the growth rate of the number of robots per employee (active replacement)

• Robotisation (as most new technologies) will also lead to the creation of new jobs; however, they
  • Will probably not allow for a 1-to-1 job transitioning for the same worker(s)
  • May be at least temporarily socio-economically costly (e.g. re-training, involuntary unemployment)
Runner industries

Will new technologies inevitably lead to ‘jobless’ growth?
Runner industries

• Question(s)
  • What are the productivity growth dynamics of a particular industry and what do they depend on?
  • Are positive productivity growth rates always good?
  • Is ‘jobless growth’ in manufacturing inevitable?

• Policy relevance
  • There is always a growth trade-off:
    • \( \text{growth(productivity)} \approx \text{growth(value added)} - \text{growth(employment)} \)
  • We define industries with a positive productivity and employment (and therefore value added growth) growth rate as runner industries.
Runner industries visualized

- Employment growth
- Value added growth

Jobless growth
Declining growth
Runners
Employment led growth
Employment led downturn
### Global runners

- Consider the overlap with ‘high risk’ industries identified in the previous part!

<table>
<thead>
<tr>
<th>Manufacturing Industries</th>
<th>Productivity CAGR</th>
<th>VA CAGR</th>
<th>Employment CAGR</th>
<th>Global runner</th>
</tr>
</thead>
<tbody>
<tr>
<td>15: Food and beverages</td>
<td>0.39</td>
<td>1.07</td>
<td>0.46</td>
<td>Yes</td>
</tr>
<tr>
<td>16: Tobacco</td>
<td>1.50</td>
<td>-1.63</td>
<td>-3.68</td>
<td></td>
</tr>
<tr>
<td>17: Textiles</td>
<td>1.19</td>
<td>-2.72</td>
<td>-4.18</td>
<td></td>
</tr>
<tr>
<td>18A: Wearing apparel</td>
<td>-0.03</td>
<td>-2.29</td>
<td>-2.57</td>
<td></td>
</tr>
<tr>
<td>20: Wood products</td>
<td>0.16</td>
<td>-0.56</td>
<td>-0.93</td>
<td></td>
</tr>
<tr>
<td>21: Paper</td>
<td>1.29</td>
<td>0.65</td>
<td>-0.75</td>
<td></td>
</tr>
<tr>
<td>22: Printing and publishing</td>
<td>2.68</td>
<td>-0.51</td>
<td>-3.30</td>
<td></td>
</tr>
<tr>
<td>23: Coke and refined petroleum</td>
<td>-1.74</td>
<td>-2.06</td>
<td>-0.23</td>
<td></td>
</tr>
<tr>
<td>24: Chemicals</td>
<td>2.05</td>
<td>2.46</td>
<td>0.15</td>
<td>Yes</td>
</tr>
<tr>
<td>25: Rubber and plastic</td>
<td>0.90</td>
<td>2.03</td>
<td>1.06</td>
<td>Yes</td>
</tr>
<tr>
<td>26: Minerals</td>
<td>1.13</td>
<td>0.99</td>
<td>-0.68</td>
<td></td>
</tr>
<tr>
<td>27: Basic metals</td>
<td>0.30</td>
<td>-0.51</td>
<td>-1.11</td>
<td></td>
</tr>
<tr>
<td>28: Fabricated metals</td>
<td>0.31</td>
<td>1.37</td>
<td>0.75</td>
<td>Yes</td>
</tr>
<tr>
<td>29C: Machinery</td>
<td>3.32</td>
<td>3.39</td>
<td>-1.55</td>
<td></td>
</tr>
<tr>
<td>31A: Electrical machinery</td>
<td>1.14</td>
<td>3.96</td>
<td>1.35</td>
<td>Yes</td>
</tr>
<tr>
<td>33: Precision instruments</td>
<td>3.15</td>
<td>4.86</td>
<td>0.97</td>
<td>Yes</td>
</tr>
<tr>
<td>34A: Motor vehicles</td>
<td>1.36</td>
<td>2.90</td>
<td>1.64</td>
<td>Yes</td>
</tr>
<tr>
<td>36: Furniture, n.e.c</td>
<td>-0.20</td>
<td>0.13</td>
<td>0.26</td>
<td></td>
</tr>
</tbody>
</table>
### South Africa Runners

- No runner industries identified.
- Productivity increases result of negative employment growth.
- **Chemicals:**
  - More productive than the global average.
  - The only industry with positive VA growth
  - Characterised by jobless growth.

<table>
<thead>
<tr>
<th>Manufacturing industry</th>
<th>Productivity CAGR</th>
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<th>Employment CAGR</th>
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<td>-0.27</td>
<td>-2.93</td>
<td></td>
</tr>
<tr>
<td>21: Paper</td>
<td>-0.16</td>
<td>-2.43</td>
<td>-2.28</td>
<td></td>
</tr>
<tr>
<td>23: Coke and refined petroleum</td>
<td>-1.41</td>
<td>-1.86</td>
<td>-0.46</td>
<td></td>
</tr>
<tr>
<td><strong>24: Chemicals</strong></td>
<td><strong>2.65</strong></td>
<td><strong>0.49</strong></td>
<td><strong>-2.10</strong></td>
<td></td>
</tr>
<tr>
<td>25: Rubber and plastic</td>
<td>1.64</td>
<td>-0.55</td>
<td>-2.15</td>
<td></td>
</tr>
<tr>
<td>26: Minerals</td>
<td>0.44</td>
<td>-2.17</td>
<td>-2.60</td>
<td></td>
</tr>
<tr>
<td>27: Basic metals</td>
<td>1.83</td>
<td>-3.33</td>
<td>-5.07</td>
<td></td>
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<td>-1.34</td>
<td>-1.60</td>
<td>-0.26</td>
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<td>1.94</td>
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<tr>
<td>33: Precision instruments</td>
<td>-2.68</td>
<td>-2.31</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>34A: Motor vehicles</td>
<td>-0.77</td>
<td>-1.45</td>
<td>-0.68</td>
<td></td>
</tr>
</tbody>
</table>
Industry profiling: Chemicals

Sector 24: Chemicals.

Productivity
Value added
Employment

Red vertical lines illustrate mean CAGRs of the income group runners.
Linking back to Industry 4.0 adoption

• Through the time dimension of the runner industry analysis one can identify the effect of technology adoption:
  
  • How and when does country engages with (what kind of) new technology?
  
  • Is this leading to displacement of workers?
  
  • Do industries qualify as runners?
    • Does adoption increase productivity and generate employment?
    • How pronounced is this effect relative to benchmarking countries? (quasi-control trial)
Runner industries: summary

• Not all forms of productivity growth are equally desirable
  • Productivity growth itself is not necessarily good (e.g. jobless growth)
  • Not all forms of productivity decline are equally bad (e.g. employment led growth)
• Industry profiling can help understand structural dynamics of an industry in absolute and relative terms
  • It can help assess how similar growth dynamics of (a) particular industry/(ies) across countries
• Time-trajectory can help connect back to adoption process.
• Runner industries are typically medium- to high-technology: They are strongly driven by technological progress.
• Economic growth and the adoption of new technology do not necessarily entail a toll in terms of growth/employment trade-off.
Thank you for your attention

www.equip-project.org

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Appendix
Appendix:
Capital Goods Classification
Classification of capital goods types

System of National Accounts (SNA)

- Consumer Goods
- Intermediate Goods
- Capital Goods
Classification of capital goods types

System of National Accounts (SNA)

- Consumer Goods
- Intermediate Goods
- Capital Goods

Capital Goods

- [41] + [521]

COMTRADEBE C Classification
Classification of capital goods types

System of National Accounts (SNA)

- Consumer Goods
- Intermediate Goods
- Capital Goods
  - Capital Goods
    - COMTRADEBE C Classification
  - Capital Goods
    - [41] + [521]
  - 4.0 ready goods
  - Non 4.0 Goods
    - COMTRADE HS Classification
Classification of capital goods types

System of National Accounts (SNA)

- Consumer Goods
- Intermediate Goods

Capital Goods

- Capital Goods [41] + [521]

4.0 ready goods

- 3D Printing
- CAD-CAM
- Robotics

Non 4.0 Goods

- COMTRADEBE C Classification
- COMTRADE HS Classification
- UNIDO Classification
Appendix:
Centralisation of I4.0 Exports
Concentration of I4.0 Exports

Based on UNIDO (2020) and Foster-McGregor, Nomaler, and Verspagen (2019), Industrial Robots (IR), Computer-aided design and manufacturing (CAD-CAM) and Additive Manufacturing (AD) are core industry 4.0 technologies for which there is available data on trade.
## Classification

<table>
<thead>
<tr>
<th>Industry 4.0 goods cluster</th>
<th>HS 2002 capital goods classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive Manufacturing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>847710 (&quot;Injection-moulding machines&quot;);</td>
</tr>
<tr>
<td></td>
<td>847720 (&quot;Extruders&quot;);</td>
</tr>
<tr>
<td></td>
<td>847730 (&quot;Blow moulding machines&quot;);</td>
</tr>
<tr>
<td></td>
<td>847740 (&quot;Vacuum moulding machines and other thermoforming machines&quot;);</td>
</tr>
<tr>
<td></td>
<td>847761 (&quot;Other machinery for moulding or otherwise forming. For moulding or rethreading pneumatic tires or for moulding or otherwise forming inner tubes&quot;);</td>
</tr>
<tr>
<td></td>
<td>847769 (&quot;Other machinery for moulding or otherwise forming&quot;); and</td>
</tr>
<tr>
<td></td>
<td>847799 (&quot;Parts&quot;);</td>
</tr>
<tr>
<td>CAD-CAM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>845811 (&quot;Horizontal lathes. Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845819 (&quot;Other lathes. Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845921 (&quot;Other drilling machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845931 (&quot;Other boring-milling machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845961 (&quot;Milling machines, knee-type. Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845961 (&quot;Other milling machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845011 (&quot;Flat-surface grinding machines, in which the positioning in any one axis can be set up to an accuracy of at least 0.01 mm: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>846021 (&quot;Other grinding machines, in which the positioning in any one axis can be set up to an accuracy of at least 0.01 mm: Numerically controlled&quot;);</td>
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<td></td>
<td>846031 (&quot;Sharpening (tool or cutter grinding) machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>845221 (&quot;Bending, folding, straightening or flattening machines (including presses): Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>846231 (&quot;Shearing machines (including presses), other than combined punching and shearing machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td></td>
<td>846241 (&quot;Punching or notching machines (including presses), including combined punching and shearing machines: Numerically controlled&quot;);</td>
</tr>
<tr>
<td>Robotics</td>
<td>847969 (&quot;Industrial robots, not elsewhere specified or included&quot;)</td>
</tr>
</tbody>
</table>
Appendix: Runner Industry Decomposition
<table>
<thead>
<tr>
<th>Rank (of 57)</th>
<th>Country</th>
<th>Runner value added share</th>
<th>Runner employment share</th>
<th>Income group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Switzerland</td>
<td>0.89</td>
<td>0.82</td>
<td>High-income</td>
</tr>
<tr>
<td>2</td>
<td>Luxembourg</td>
<td>0.87</td>
<td>0.90</td>
<td>High-income</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>0.80</td>
<td>0.79</td>
<td>High-income</td>
</tr>
<tr>
<td>6</td>
<td>France</td>
<td>0.79</td>
<td>0.79</td>
<td>High-income</td>
</tr>
<tr>
<td>7</td>
<td>Philippines</td>
<td>0.78</td>
<td>0.66</td>
<td>Lower middle-income</td>
</tr>
<tr>
<td>8</td>
<td>Hungary</td>
<td>0.77</td>
<td>0.74</td>
<td>High-income</td>
</tr>
<tr>
<td>9</td>
<td>Netherlands</td>
<td>0.76</td>
<td>0.77</td>
<td>High-income</td>
</tr>
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Note:
INDSTAT 2 rev.3, 2000-2017, runner exposure shares shown for 2016. Ranking based on a total of 57 countries.
Runner industry shares

Distribution of runner value added shares over time, full sample.

Percentile

1990 2000 2010
Year

Aggregate Developed economies Developing economies
Runner industry shares

Distribution of runner value added shares over time, post-2000.

Percentile

Year

Aggregate  Developed economies  Developing economies

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Note: INDSTAT 2 rev.3.

To this end, Table C.3 summarizes the number of countries that reported positive productivity, value-added as well as employment growth rates.