Building the layers of a manufacturing taxonomy: how 3D printing is creating a new landscape of production eco-systems and competitive dynamics

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Building the layers of a manufacturing taxonomy

How 3D printing is creating a new landscape of production ecosystems and competitive dynamics

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The problem

• Recent innovations in 3D printing technologies and processes have influenced how products are designed, built and delivered.

• However, there is a significant gap in our knowledge of how 3D printing is impacting on manufacturing eco-systems and competitive dynamics in different industries and contexts
  • “a granular understanding of the socioeconomic consequences of 3D printing lags activity” (Ford et al., 2016).

• This paper addresses this by developing a taxonomy of firms based on their use of 3D printing
Methodology

- Based on systematic review of secondary data
  - Newspaper articles, websites, industry commentaries, academic papers
- 20 Illuminatory cases
3D printing

• Process of joining materials to make objects using digitised model data
• Original use for prototyping and model making
• Now more widely used in manufacturing of end products
• Benefits include:
  • Supply chain efficiencies
  • Shorter design processes
  • Reduced time to market
  • Move from mass manufacturing to mass customization
  • Monetizing of the long tail
  • Sustainability benefits
    • Reduction of waste
3D’s potentially disruptive effect on manufacturing ecosystems

• Potentially transforming many manufacturing sectors’ business models
  • location of manufacturing,
  • new materials,
  • new supply chains,
  • new cost and pricing structures,
  • much greater potential for co-development
    • disintermediation
    • Maker movement
Current generic limitations of 3D printing technologies

- Raw materials’ reliability
  - new suppliers who are inventing the materials as they go along
- Limitations in the size of products possible
- Problems in scaling up production
Use of 3D printing in different sectors (Wohlers 2014, p.18)
Industrial taxonomies

• Pavitt (1984)
• Castellacci (2008)
  • Help to conceptualise typical behaviours in different sectors
  • Draw out implications for competitive strategies and dynamics
• Pavitt
  • Focused on innovation and dominance
  • Castellacci added to this service- manufacturing sectors external sources and open business models
Pavitt’s taxonomy showing technological linkages
## Pavitt Taxonomy of Innovation Patterns (adapted from Kristensen 1999)

<table>
<thead>
<tr>
<th>Sector type/variables</th>
<th>Supplier-dominated (SD)</th>
<th>Scale-Intensive (SI)</th>
<th>Science-Based (SB)</th>
<th>Specialised suppliers (SS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Firm size</strong></td>
<td>Small firms</td>
<td>Large firms</td>
<td>Large firms</td>
<td>Small firms</td>
</tr>
<tr>
<td><strong>Type of innovation</strong></td>
<td>Processes</td>
<td>Processes</td>
<td>Mixed products and processes</td>
<td>Products</td>
</tr>
<tr>
<td><strong>Locus of innovation</strong></td>
<td>External</td>
<td>Production</td>
<td>R&amp;D departments</td>
<td>Decentralised</td>
</tr>
<tr>
<td><strong>Means of appropriability</strong></td>
<td>Tacit knowledge</td>
<td>Tacit knowledge and entry barriers</td>
<td>Patents and entry barriers</td>
<td>Tacit knowledge/reputation</td>
</tr>
<tr>
<td><strong>Competitive parameter</strong></td>
<td>Price</td>
<td>Price/quality</td>
<td>Performance/quality/price</td>
<td>Quality/ performance</td>
</tr>
</tbody>
</table>
Castellacci’s taxonomy

Vertical chain

Personal goods and services
- Supplier-dominated goods
- Supplier-dominated services

Mass production goods
- Scale-intensive
  - Science-based

Infrastructural services
- Physical infrastructure
- Network infrastructure

Advanced knowledge providers
- Specialised suppliers
- Knowledge-intensive business services

Technological content
Three major components of the new taxonomy

- inductive approach enabled 3 categories to emerge from the data
  1. the uses and applications of 3D printing
  2. the level of customisation
  3. the level of competitive turbulence.
Our results: the main users of 3D printing

• consumer products,
  • clothing/textiles
  • artistic products such as jewellery
• consumer electronics,
• automotive,
• aerospace,
• medical/dental,
• industrial/business machines,
• material suppliers
• Knowledge Intensive Business Services (KIBS)
  • software development, design, and online platforms for the application of 3D printing
<table>
<thead>
<tr>
<th>Industry</th>
<th>Sector</th>
<th>Uses and applications of 3D printing</th>
<th>Customisation</th>
<th>Competitive Turbulence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier-Dominated</td>
<td>Wearing apparel</td>
<td>Customised Products</td>
<td>Co-creation and Personalisation</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Jewellery, bijouterie and related articles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Footwear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale-Intensive</td>
<td>Motor vehicles</td>
<td>Specialised components for production</td>
<td>Mass Customisation</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spare parts and components</td>
<td>None</td>
<td>Medium</td>
</tr>
<tr>
<td>Science-Based</td>
<td>Air and spacecraft and related machinery</td>
<td>Approved components</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prototype jet engine parts</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specialised components for production</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Medical and dental instruments and supplies</td>
<td>Customised orthopedic implants and prosthetics</td>
<td>Personalisation</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Pharmaceutical products</td>
<td>Approved drugs</td>
<td>Personalisation</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumer electronics</td>
<td>Production tooling</td>
<td>Personalisation</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low volume customized products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Knowledge Providers</td>
<td>Knowledge Intensive Business Services</td>
<td>Consulting, Software, Design</td>
<td>Enabling opportunities</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Specialized suppliers</td>
<td>3D printing materials and equipment</td>
<td>Enabling opportunities</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Supplier dominated

• Implement technologies developed outside the firm
• May not invest themselves in R&D
• Improvement rather than radical change
• Rapid prototyping ethos applied to end products

• Current challenges
• Standard of materials and supplies
• Lack of choice of suppliers
  • Supplier power likely to increase
Scale-intensive firms

• Invest heavily in R&D
• Close cooperation with specialized suppliers
• Not yet achieved scalability in end products
• Using 3D printing to create tools and components
• Large potential cost savings
  • But loss of profits from spare parts as they can be produced by other printers

Current challenges
• 3d printing not yet able to speed up mass production times
Science-Based firms

• Internally-generated new knowledge
• Collaboration with institutions such as universities
• 3d printing opened up new possibilities
  • Aerospace, defence, shipping etc
  • Huge cost and performance possibilities
  • Geographical benefits
    • Bypass international import duties
    • Parts for ships can be made at sea
  • Customizable products

• Current challenges
  • Unreliability of raw materials
    • 3D printers inability to cope with this (as normal manufacturing techniques can)
  • Size limitations
  • Lock-in to certain suppliers
  • Certification and reputation risk problems
Advanced Knowledge Providers and Knowledge Intensive Business Services (KIBS)

• Heterodox sector
• 3D developers as well as 3D users (architects etc)
• Significant technological capability
  • Suppliers of know-how to other firms
• Provision of online design libraries

• Current concerns
• IPR issues
• Crowd customisation
  • Co-development
  • Maker movement
Final thoughts

• 3D printing will not fulfil the hype in all sectors
  • How many 3D printing shops do you have on your high street?
  • Too many intermediary roles and supply standards to be resolved
  • Scale-intensive industries likely to use 3D printing selectively

• 3D printing allows (in theory) co-creation in most sectors
  • But the role of designer, IPR and skills of end users is yet to be resolved

• 3D printing more disruptive in some industries than others
  • Supplier-dominated firms likely to be worse affected
THANK YOU