Towards the decentralisation of food manufacture: effect of scale production on economics, carbon footprint and energy demand

A.Almena, E. Lopez-Quiroga, P.J. Fryer, S. Bakalis

University of Birmingham / The University of Nottingham

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Evolution of Manufacturing Paradigms

Craft Production
- Small scale
- Local demand
- Close to consumers
- Freshness
- Customization

Mass Production
- Large scale
- Off-shoring
- Long Supply Chain
- Long Shelf life
- Standardisation

Industrial Revolution
18th – 19th Centuries

- Factory Model

• Off-shoring
• Long Supply Chain
• Long Shelf life
• Standardisation
Evolution of Manufacturing Paradigms

Centralised Manufacturing

Drawbacks
- Standard Product
- Economy of scale
- Low-cost product
- and emissions
- Development of Technology
- 1\textsuperscript{st} and 2\textsuperscript{nd} World War

Mass Customisation

- Late 20\textsuperscript{th} Century
- • Economy of Scope
- • Flexibility on Supply chains (final assembly)
- • Product Differentiation
- • Example: automotive industry

Supply chain

- Farming
- Wholesale
- Manufacture
- Product Wholesale
- Retailing
- Consumer
Evolution of Manufacturing Paradigms

- **Craft Production**
  - Very high customisation
  - Democratization of design
  - Low start-up and capital cost
  - Shorten delivery time
  - Sustainability (eco-demand)
  - Reduce cost in transportation

- **Mass Production**
  - Maximize the shareholder value

- **Mass Customisation**
  - Flexibility in manufacturing

- **Next Paradigm**
  - Flexibility and agility in supply chains
Examples.

- **Additive Manufacturing**
  - 3D printing
  - Aircraft, Medical and food industries

- **Modular Manufacturing**
  - Small scale modular facilities
  - Process intensification
  - Chemical engineering

- **Distributed Manufacturing**
  - Small (micro) scale, close to end user
  - Healthcare (ACBTs), brewery.
## Distributed Manufacturing

**Features**

- **Small** (and micro) scale
- **Localisation** of production
- **Flexibility** in manufacturing
- **Just in time** delivery (no additives)
- **Sustainability**:  
  - Energy saving (storage and distribution)
  - Reduce food miles (emissions and transport cost)
  - Social benefits: e.g. employment creation

**Horizontal relationship:**

- Short food supply chains
- Alternative food supply chains

**Requirements**

- Development of **ICT technologies**
- **Naturalness** demand on products
- **Ethical** relationship among actors
What is the main purpose of this work?

Assess theoretical Distributed Manufacturing scenarios in the food sector and compare to Centralised scenarios.

- Food Process Design
- Economic Evaluation
- Carbon footprint

Long shelf life and cheap transport

High transport cost

High distribution and storage cost

Short shelf life
Scaling Down Problem

- **Unitary Cost**: cost of each unit of product manufactured.

- **Breakeven point**: set the lower bound for the profitability of a plant. Operating cost = Sales Revenue.
Methodology

Artisanal Manufacturing Process

- Batch Process
- Developed in a kitchen

Industrial Manufacturing Process

- Semi-Continuous Process.
- Developed in an industrial plant
Methodology

Artisanal Production | Industrial Production
---|---
HM | FI | DM | MP | SP | CENTRALISATION

(i) On-demand Economy – Home manufacture (HM)

(ii) Sharing Economy – Food Incubator (FI)

(iii) Distributed Manufacturing (DM)

(iv) Centralised Manufacture: Single Plant Production (SP)

(v) Centralised Manufacture: Multiple-Plant Production (MP)
Results – Throughput variable range

- Baby cereal porridge
- Sandwich bread

- Management cost at DM is important.
- FI and DM perform worse for bread.
Results – UK demand Scenario. Unitary Cost.

- Baby cereal porridge (428 kg/h)
  - HM = 334 facilities
  - FI = 219 facilities
  - DM = 41 facilities

- Sandwich bread (23,560 kg/h)
  - HM = 13,089 facilities
  - FI = 7854 facilities
  - DM = 491 facilities
Results – UK demand Scenario. Total Capital.

- Baby cereal porridge (428 kg/h)
  - HM = 334 facilities
  - FI = 219 facilities
  - DM = 41 facilities

- Sandwich bread (23,560 kg/h)
  - HM = 13,089 facilities
  - FI = 7854 facilities
  - DM = 491 facilities
Results – UK demand Scenario. Energy Demand and Carbon footprint

- Baby cereal porridge (428 kg/h)
- Sandwich bread (23,560 kg/h)

### Energy Demand

![Energy Demand Graph]

### Carbon Footprint

![Carbon Footprint Graph]

Contact email: axa1122@student.bham.ac.uk
Results – UK demand Scenario. Net Profit.

- **Cereal porridge** provides **acceptable profitability** per facility at **any scale**.

- Despite **unit cost is lower** for HM, the higher productivity per facility gives **higher profitability** for FI and DM.

- **Bread manufacturing** shows **lower** values. Market price should increase.

- **FI is less profitable** than HM for bread.

- **DM at high management** assumptions is a **non profitable scenario** for bread, at this selling price.
Conclusions

- A **modelling platform** is developed for **processing design, cost estimation** and energy and cost optimisation.

- The model is **flexible** to parameter inputs, so **different products** can be assessed.

- **HM** is profitable at **very low throughputs** and remains competitive to industrial at **national demands**. Artisan manufacturing requires **far less capital**.

- **Bread** resulted in **lower energy consumption** and carbon load per kg produced.

- Decentralisation works **better** for **higher value added** products (cereal porridge).

Further work

- The **entire supply chain** should be evaluated.

- Applying the model to **other food products** to check the most suitable one for DM.
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