Who Profits from Industry 4.0? Theory and Evidence from the Automotive Industry

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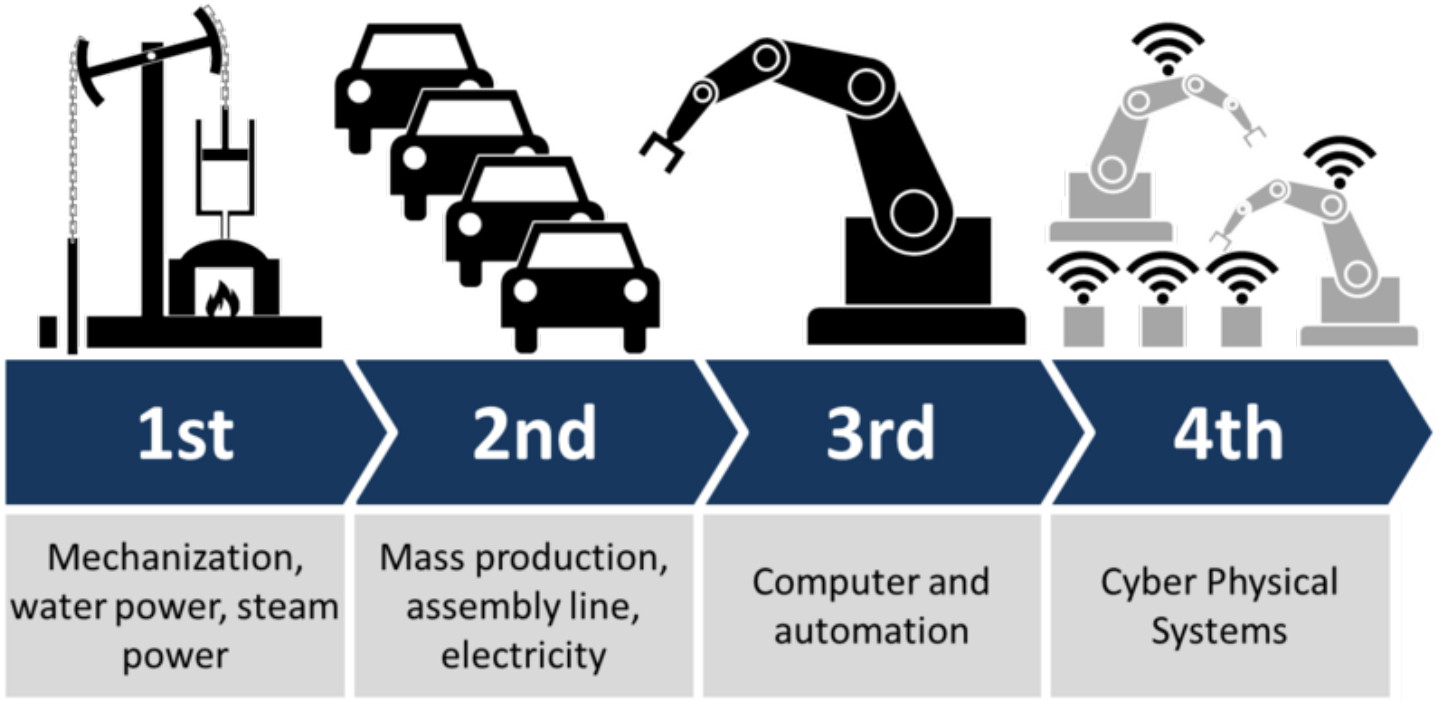
AI and Robots in Manufacturing: Industry 4.0

The Industry 4.0 Vision:

- Continuous collection and analysis of manufacturing data in real-time
- Allows managers (both at middle and upper levels) to remotely monitor operations and alter as needed
- More dramatically: machines that "think" – that can configure themselves and adapt to changes within the manufacturing process itself.

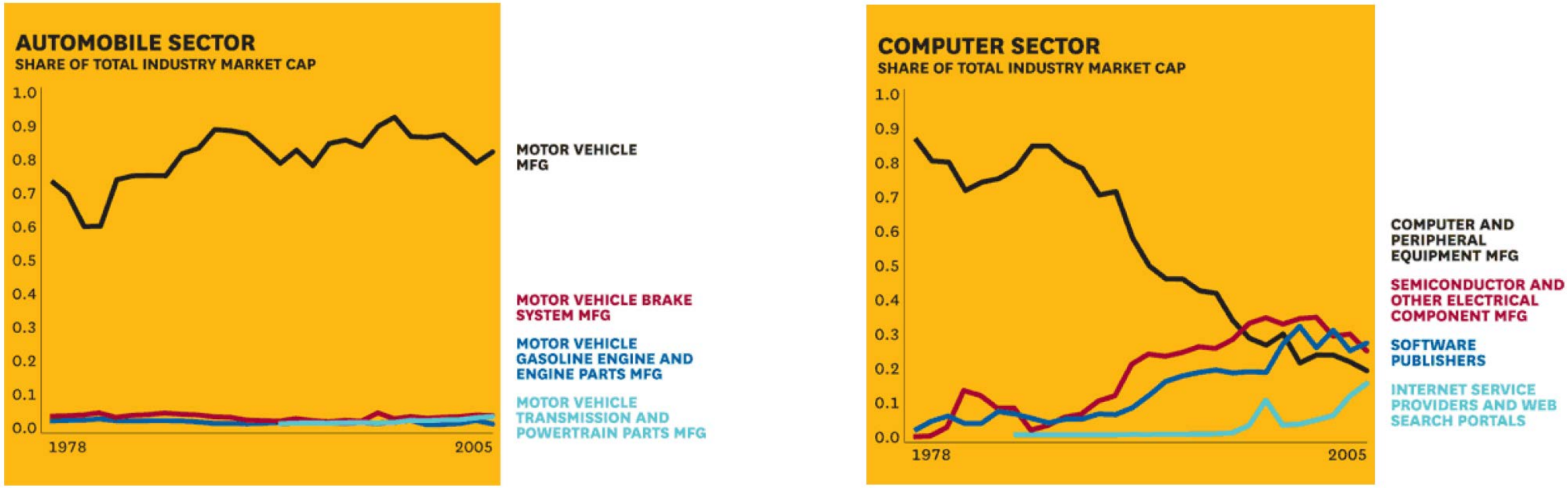


Christoph Roser at AllAboutLean.com

- This vision has important implications for the (lack of) role of labor in manufacturing

Industry 4.0 and value capture

- Industry 4.0 could affect (and be affected by) “industrial architecture”
  - “which firms do what” and “which firms take what”
    - Jacobides, MacDuffie and Tae, 2016
  - “Intel inside”
- Industry 4.0 could affect, be affected by “organizational architecture”
  - which occupations do what and which occupations take what



Jacobides, MacDuffie, Tae 2016

SOURCE: DATA FROM COMPUSTAT

- Value migration in other contexts
  - “Intel inside” shifted value in computer industry from box to chip maker
  - Firms introduced computer-controlled (CNC) machine tools in an effort to reduce power of shop-floor workers
  - Historically, machine tool specialization (Hounshell; Rosenberg)

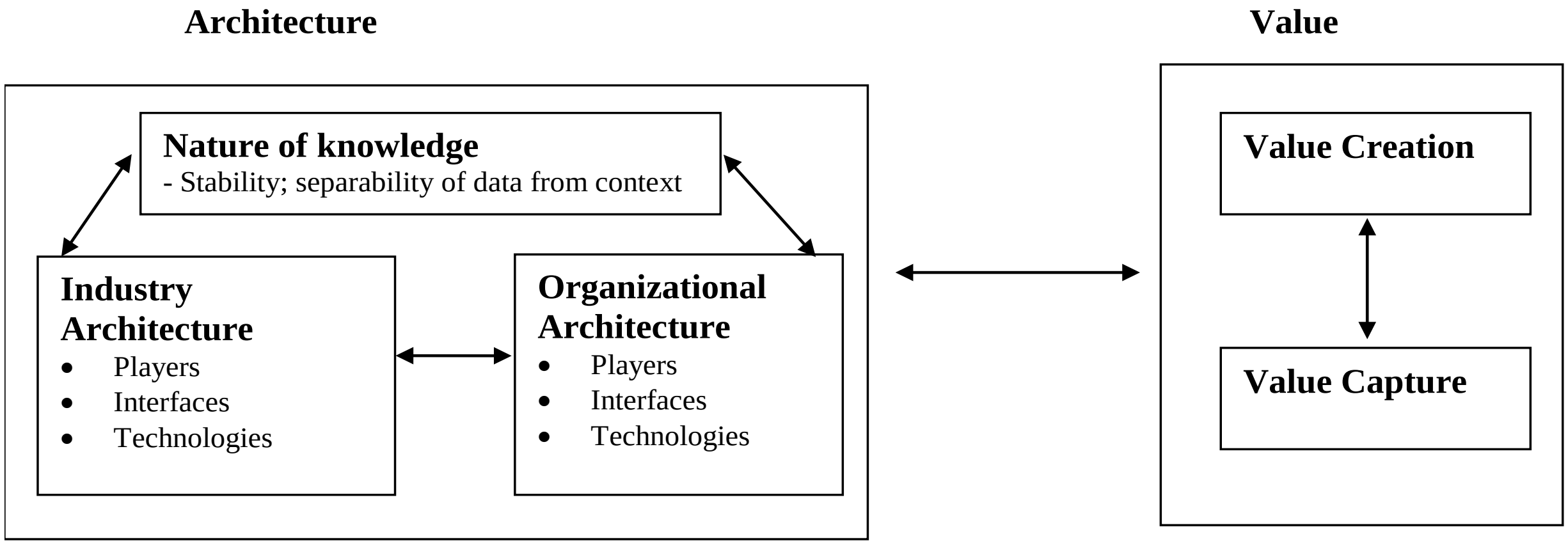
Will “digital entrants” be the new Intel inside?

- Key question: can data can be separated from its operational context?
- Much automation theory and practice says yes:
  - “Industry 4.0 means I can manage factories anywhere in the world from my i-phone”
- This separability is a cause and consequence of industrial architecture, organizational architecture, and management paradigms
  - Digital entrants (data analytics firms, integrators, equipment suppliers), have more ability to create and capture value if data is separable.
  - Similar to entry of machine tool-makers, IT consultants

Potential value of production context

- Data generation:
  - Auto plant with skylights: on cloudy days machine vision systems record false positives
  - “Sometimes the sensors go bad – about once a week a sensor will tell us the product is defective when it really isn’t. Then we have to check things out manually –it’s really great if you have an experienced operator who’s seen this before”. -- *large equipment manufacturer*
- Data interpretation:
  - “We do workshops with our suppliers to improve their process. We always start with having the production associate describe the process, because they know it best. There’s stuff that is not obvious to the engineer, like this machine heats up and then it makes the hole too big, or this machine gets condensation dripped on it.”-*automaker*

Management paradigms link Industry Architecture and Organizational Architecture



“Taylorist” Industry 4.0

- It is efficient to separate “brain work” and “hand work”
- Vision:
  - Executives control a firm’s equipment remotely, from their i-phone
  - Automation allows engineers’ conception to be implemented directly
    - Robots are seen as ideal workers: do things the same way every time, don’t complain or get tired
    - Programming of robots and analysis of data is done by engineers away from the shop floor
- Potential consequences:
  - Worker skill not valued
  - Manufacturers lose power to new data analytics firms

“Pragmatist” Industry 4.0

- Automation and big data should be designed to build on worker skills – they should not substitute for these skills
- Vision
  - The person closest to production has expertise that no one else has
    - Therefore, design equipment and jobs to help frontline workers analyze what they see; build information systems to enable collaborative problem-solving
  - Sensor data not useful unless analysis is guided by theory or experience
- Consequences
  - Marrying data, automation, and worker insights increases the economic pie
    - Faster problem-solving speeds de-bugging, increases uptime
  - Workers may gain a share of this larger pie, because their skills are integral

Management paradigms affect value capture

- “Taylorist”
  - IA: Integrators/data analytics firms specialize in data analysis across industries
  - OA: Automation is a substitute for shop-floor workers
  - Contracts: boundaries/duties can/should be codified
- “Pragmatist”
  - IA: Manufacturers combine analytics with understanding of process
  - OA: Manufacturers depend on shop-floor workers to provide this understanding and do preliminary analysis
  - Contracts: Problem-solving is best governed by RCs, given the difficulty of specifying in advance which activities will solve a problem; also key that participants not fear that if they provide information they may be punished for causing the problem

Manufacturers can protect favorable IA if they move to Pragmatist OA

- If factory owners develop automation methods that capitalize on their greater access to the context in which production data is generated, they will be better able to prevent value from migrating to “digital entrants” that offer automation consulting and data analytics.
- Manufacturers can do this by adopting an organizational architecture that empowers shop-floor workers to combine their local knowledge with digital tools.
- Manufacturers’ advantage is their closer access to the shop floor
  - Worker-complementing strategies help them retain bargaining power with integrators and data analytics firms
  - Conversely, to the extent that digital entrants develop a more abstract version of these tools that they spread across industries, they will capture more value.

Will digital entrants capture profits that used to go to manufacturers?

- Some integrators are beginning to offer data management, monitoring, or other digital services.
  - “Who controls the data that automation throws off is going to be an important discussion. You could imagine the integrator or the robot manufacturer owning the data, doing predictive analytics, and making a guarantee that if the process is run a certain way that there will be a certain amount of uptime.” -- trade association staffer

Industry 4.0 ← → Relational Contracts

- **Past RCs affect current implementation of Industry 4.0**
- ***Past RCs could affect current *development* of Industry 4.0**
- **Industry 4.0 is likely to affect the scope and nature of future RCs**
- ***RCs between manufacturers and digital entrants may evolve as data becomes more valuable**
  - **(particularly in their clarity around data use)**

“Pragmatist” industry 4.0: Examples

- Equipment, software design focuses on intuitive user interfaces
  - heat maps, cobots
- Frontline workers’ jobs are designed to include participation in sensor data collection and analysis
  - At some UAW-GM plants, some workers displaced by automation have become data analysts
  - Tradespeople run 3D printing room

Industry 4.0 and data in RCs

- Many RC's lack clarity about who may use for what purpose the data that automated equipment provides.
- Data is non-rival, but the profits to be made from it are not.
  - As these profits rise, manufacturers may revisit their contracts (both relational and explicit) with equipment manufacturers.
- The robots that GM buys from Fanuc send a stream of data to Fanuc, about the rate at which the robot is producing output, moment-by-moment energy use, etc.
  - Fanuc uses this data to improve its products, but does not otherwise compensate GM.
- Some equipment providers (Komatsu) now provide advice to their customers about how to use their equipment more efficiently, but don't charge extra for it.
- In contrast, other equipment makers (Kuka) are setting up "Manufacturing as a service" business models. These models monetize data analytics, because Kuka provides guarantees about uptime if manufacturers operate in accordance with instructions based on such analytics.
- A Firm that is both a user of robots and a maker of equipment complementary to robots wanted a share of data-derived profits
  - so has set up a joint venture with its robotics supplier to consult to other manufacturers on the basis of this production data.

Conclusion

- "Industry 4.0" proposes a substantial reorganization of industry
  - Sensors and data everywhere & centralized use of the information created
- An alternative “pragmatist” paradigm proposes that data analysis is most effective when done close to where the data is generated.
  - Automation should thus be designed to promote shop-floor experimentation
- These paradigms imply different Industry and Organizational Architectures
  - The efficient solution is not guaranteed
- Interactions between IAs and OAs will affect:
  - Nature, amount, and distribution value created
  - How automation is developed
- Next steps:
  - Collect more field evidence
  - Survey auto suppliers to understand patterns of adoption

Interview evidence: role of context

Taylorism

- “This big data stuff is really exciting! New companies like Beet can use data analytics – you [a manufacturer] could give them data from 20,000 sensors and they could figure out why you’re having quality problems, where the bottlenecks are. With machine learning, soon machines can fix themselves, change out their own tools just before the old one is likely to break.”

Pragmatism

- “I’m not so sure about this. You can’t just take the data by itself—you have to see where it came from. … Maybe the sensor is reacting to something that’s happening to the machine next to it – you won’t know that unless you’re there. There’s a saying … “machines can’t learn, only people can.” “

Interview evidence: how does learning occur?

Taylorism

- “But you could put heat sensors on the machine -- with machine learning, machines can now learn.”

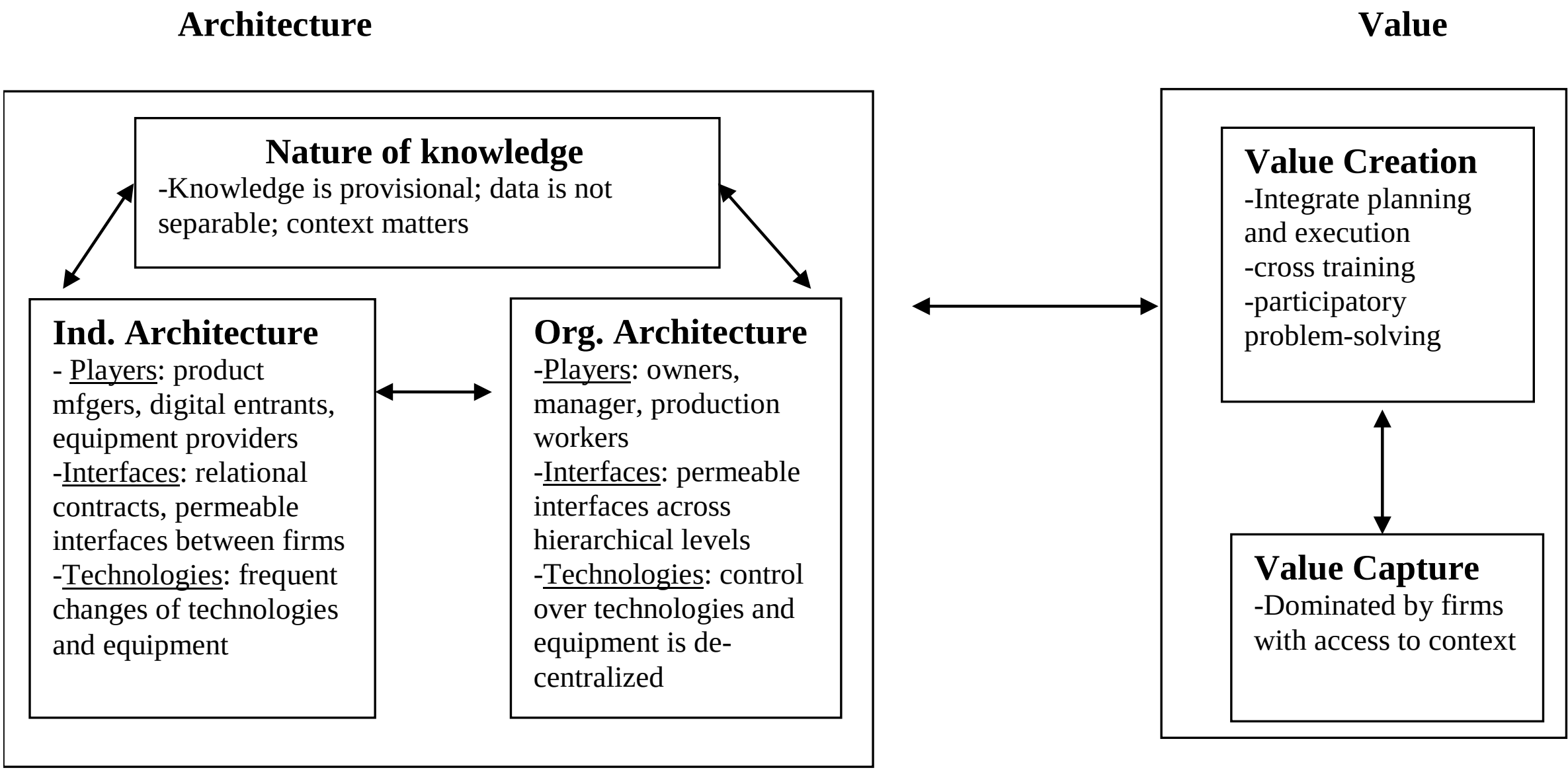
Pragmatism

- “Yes, that’s a good idea. But if you wait until the whole set up is perfect, you’re going to have a lot of idle time, a lot of dollars sitting around. It’s better to start with something and then improve it later, and you can always learn more about the process.”
- “How can you know how close you can get the robots to each other without being there? Even when they’re setting up a line, our engineers will be out there with old refrigerator boxes to create a cheap mock-up of how things are going to look — you see a lot more than with CAD.”

Integration of worker knowledge increases the economic pie if hard to separate data from context

- Humans can diagnose a new problem that sensors have not (yet) been designed to collect data on (eg, a new contaminant)
- Familiarity with equipment helps diagnose false positives
- Problem that appears in one station may have been caused in a previous station

Pragmatist case -- automation



Taylorist case -- Automation