Impact of behavioral factors on innovation performance

An evolutionary approach with a simulation model for IT-companies in Japan and Germany

Dr. Monika Friedrich-Nishio
Structure

Top 1 Aim and Motivation
Top 2 Theoretical framework
Top 3 Object of analysis
Top 4 Simulation model: structure
Top 5 Simulation model: results
Top 6 Conclusion
Aim and motivation

analysis of determinants of firms’ innovation activity
- influence of behavioral factors
- “economy and culture cannot exist separately”

development of firms and branches through time
with inclusion of historical and cultural factors
here: selected firms in Japan und Germany in the IT sector

AIM: historically consistent trace (no forecast)
with one model for both countries
identifying the responsible parameters
<table>
<thead>
<tr>
<th>Top 1</th>
<th>Aim and motivation</th>
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<tr>
<td>Top 2</td>
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</tbody>
</table>
Theoretical framework

- Institutions = rules / systems of rules
- “Institutions and history have a decisive influence on the performance of innovation systems“
  (“History matters!” D. North)
- level of satisfaction
  (model of the “Satisficing Man”, H. Simon, 1957)
- concept of national innovation systems (NIS)

\[ \text{neoclassical economics} \]
\[ \text{institutional economics} \]
\[ \text{evolutionary economics} \]
\[ \text{no culture, no history} \] \ \{ \text{paths} \}

- concept of the irreversible, historical time
- VSB-concept
- homo dissent
- technological paradigms and path dependencies
- focus: development under given cultural, societal and political frameworks
  \[ \rightarrow \text{theory of the firm} \]
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Before modeling

Identifying the characteristics

1. IT sector
   • consideration/analysis of several market members
   • collection of empirical data
   • whole market development (key figures)
   • special incidents

2. Culture
   Ethical value, tradition, religion:
   Country’s / sector’s behavioral characteristics
Growth of IT sector world-wide

Source: EITO in cooperation with IDC
Object of analysis: IT sector: key data (2)

World-wide ICT market by region

<table>
<thead>
<tr>
<th>Region</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>6.0%</td>
<td>6.0%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Japan</td>
<td>12.4%</td>
<td>12.0%</td>
<td>12.3%</td>
</tr>
<tr>
<td>Europe (without Germany)</td>
<td>23.4%</td>
<td>23.0%</td>
<td>24.3%</td>
</tr>
<tr>
<td>USA</td>
<td>34.2%</td>
<td>34.0%</td>
<td>32.4%</td>
</tr>
<tr>
<td>rest of the world</td>
<td>24.0%</td>
<td>25.0%</td>
<td>24.9%</td>
</tr>
</tbody>
</table>

Source: EITO in cooperation with IDC
IT sector: collecting empirical data

- **IT sector** = hardware, software and telecommunication
- data bases for firms, patents, publications etc.
- statistical key data from several different institutions (e.g. METI, MPT, NISTEP, Stifterverband, Stat.Bundesamt...)
- from firms of IT sector:
  - Fujitsu
  - Hitachi
  - NEC
  - NTT
  - Toshiba
  - Ahead
  - MAXDATA
  - Nixdorf
  - SAP
  - Siemens
  - VOBIS
  - IBM Deutschland

  interviews and analysis of business reports

  - number of employees
  - R&D personnel
  - R&D-expenditures
  - array of products
  - turnover/ benefit
  - qualitative data (firm strategy, -philosophy)

**period**: 1960 until now: What are the characteristics?

→ development and change of **platforms**
  1) mainframe systems
  2) minicomputer / small und middle-sized systems
  3) microcomputer / PC
  4) client/server platform
Object of analysis: IT sector

IT sector:

Boom of foundations in the IT sector

Number of firm births resp. start-up companies

- software development
- communications engineering
- (electronic) data processing
- telecommunication service

Year

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IT sector:

Product cycles: Shape, length, number... Example: IBM vs. Nixdorf

Object of analysis: IT sector
Before modeling

Identifying the characteristics

1. IT sector
   • consideration/analysis of several market members
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   • whole market development (key figures)
   • special incidents

2. Culture
   Ethical value, tradition, religion:
   Country’s / sector’s behavioral characteristics
Culture and Behavior

- **religious influences**
  Origins: religions (Shintoism, Confuzianism, Buddhism, Christianity)

- **historically developed influence factors**
  (e.g. "Keiretsu" 系列: fusion of firms to a "family")

- differences in behavior and attitudes of employees and managers from different countries → Hofstede (1980)
  → no change over time (Adler 1997)

- Harmony vs. Individualism

- Status (in society, in firms)
  → meaning of contracts
  → hierarchy in firms

- business relationship and shareholding
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Idea of the evolutionary innovation model

- Theory of decision-making in firms
- Firm: active seek for **profit**
- **Strategy**: innovation, imitation or remaining, depends on:
  - own experiences and abilities
  - already used rules of decision making
  - known processes of problem solving
  - random incidences
  → **ROUTINES**

- **Market’s selection process**: controls surviving / dying of firms
- Program in VENSIM

- (Model)-World with **exogenous conditions**:
  - technology phases
  - development of demand
  - political frame
  - exogenous “Shocks”: Oil crisis, Bubble Economy (J), structural change, Globalisation,...
Initialization: Firm’s equipment with:
Capital, labor, starting productivity: \((Kit, Lit, Ait)\)
and ideas + behavior/attitude

- learning behaviour
- risk attitude
- aims / image / expectations
- experience knowledge
- techn. knowledge (what kind? where from?)
- absorption (will, speed)

\(\rightarrow\) individual
also cultural?
Spillover-effects: Collective Know-How-potential

\[ S_{it} = \sum_{j=1, j \neq i}^{n} W_{jt} \cdot R\text{CAP}_{jt} \]

with

\[ R\text{CAP}_{it} = R\text{CAP}_{i, t-1} \cdot (g^{R&D} - \delta_R) + R_{it} \cdot g^{R&D} \]

- \( R\text{CAP}_{it} \): R&D Capital of firm \( i \) at time \( t \)
- \( \delta_R \): amortization rate of R&D-capital
- \( R_{it} \): R&D-expenditures of firm \( i \) at time \( t \)
- \( g^{R&D} \): expansion rate of R&D-capital
- \( W_{jt} \): weighting factor of firm \( j \) at \( t \) from view \( i \)
Level of technological knowledge: $T_{it}$

$$T_{it} = \sum_{j=1}^{\Lambda} \frac{1}{\Lambda!} \cdot (\Lambda - j + 1) \cdot R_{i,t-1} + (1 - \rho_T) \cdot T_{i,t-1} + S_{it}$$

$$TL_{it} = \frac{T_{it}}{\sum_i T_{it}}$$

- $S_{it}$: spillover-effects, received by firm $i$ at time $t$
- $R_{it}$: R&D-expenditures of firm $i$ at time $t$
- $\rho_T$: obsolescence rate of a technology
- $\Lambda$: "Lead Time" of R&D
- $TL_{it}$: comparative level of knowledge of firm $i$ at $t$
Place of influence of behavioral factors

- **imitation**: where do firms search for existing technology?
- **innovation**: depends on risk attitude, technological orientation etc.
- **level of satisfaction**: when are firms “satisfied”?
  - duration of the searching process
- **adjustment of R&D-expenditure rates** to:
  1. (R&D-)personnel
  2. economical framework (factor F)
  3. innovative behavior of the previous period (factor $\epsilon$)

- **“Keiretsu”-variable**
  - place of search for technology
  - learning speed
  - spillover + technological knowledge
  - pool of the resource “Human Capital”
Selection

- performance-indicator (depends on innovation output of the firm: “patents” and “publications”)
- market entry and market exit

Scenario

- scenario A: Japanese firms’ data
- scenario B: German firms’ data

with 4 further scenarios:

- scenario 1: basic scenario (“reality” simulation)
- scenario 2: low innovation efficiency
- scenario 3: high innovation efficiency
- “what if“-scenario: equipment of several firm parameter with other firms’ ones

→ Model calibration, optimization and specific questions
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<tr>
<td><strong>Top 6</strong></td>
</tr>
</tbody>
</table>
**Result 1: Tracing the real historical development: Basic scenario**

**Scenario A: Variable “R&D share in exchange” and “capital”**

**R&D Ratio to Net Sales**

**Capital**
## Comparison scenario A and B

<table>
<thead>
<tr>
<th></th>
<th>Scenario A</th>
<th>Scenario B</th>
</tr>
</thead>
<tbody>
<tr>
<td>“keiretsu” (Acting in own firm family)</td>
<td>search for technology restricted to firm family</td>
<td>search for technology in whole industry</td>
</tr>
<tr>
<td>“Spillover”</td>
<td>spillover of knowledge not from all firms of industry</td>
<td>technological knowledge of all firms relevant</td>
</tr>
<tr>
<td>“Priority own technology”</td>
<td>rarely chosen aim: adopt technology direction given by the firm</td>
<td>often chosen aim: technological leadership by own standards</td>
</tr>
<tr>
<td>“Market leadership” (= “Priority own technology“ + “Innovation“)</td>
<td>not primary intention level of satisfaction is lower than in scenario B</td>
<td>often chosen market leadership is aim</td>
</tr>
<tr>
<td>Market entrance</td>
<td>no market entrance in all scenarios</td>
<td>the more open the market considering innovations the more market entrances</td>
</tr>
</tbody>
</table>
• **Result 1:** Tracing the real historical development is possible

• **Result 2:** Learning and relevance of history and accumulated knowledge

• **Result 3:** Incremental innovation and acting in family in scenario A (the Japanese case)

• **Result 4:** Persistence of the structure in scenario A (the Japanese case)

• **Result 5:** Spillover and industry knowledge in scenario B (the German case)

• **Result 6 + 7:** The case of Nixdorf: a contra factual historiography

• **Result 8:** Firm size: determining factor for success (i.d. positive performance) is whether firm size nor duration of market membership
Result 6: the case of the company Nixdorf

Scenario B: Variable “employment”

![Graph showing employment over time for different firms.]

Model: results (4)

Result 6: the case of the company Nixdorf

Scenario B: Variable “employment”

![Graph showing employment over time for different firms.]

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Result 6: the case of the company Nixdorf

Scenario B: Variable “Learning curve”

![Diagram showing the learning curve over time for different companies. The x-axis represents time in years, ranging from 1961 to 2002, and the y-axis represents the maximum learning factor (Lmax). The diagram includes lines for different companies, labeled Top 1 to Top 6, indicating their performance over the years.](image-url)
Result 6: the case of the company Nixdorf

Scenario B: Variable "Learning curve"

Model: results (6)
Result 7: a counterfactual scenario B

in scenario B for firm 3

Firm 3 has equal starting equipment like before

BUT: modification/change of behavioral parameters → like firm 1

⇒ instead of “own technology” and “focus on previous success”

now more often: “focus on new technology”, “acquisition of new technology” and “imitation”
Structure

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Top 6  Conclusion
• identification of the factors responsible for the success of firms
• construction of a simulation model for both countries with equal basic structure but with individual behavioral parameters
• calibration with Japanese and German firm data
• aim: Historically consistent tracing (basic scenario)
• alternative scenarios:
  “what if“-scenario: changing of the firm’s behavior without changing of the initial equipment
The model shows...

- Market entrance and exit
- Strategy “Market leadership”
  Political framework necessary, but not enough
- **Differences Japan-Germany**
  - subjective cognition of competition / success
  - Differences due to: **not** technical components or production functions, but behavioral parameters
- **Factors for success**
  not firm size, not duration of market membership, not production methods but:
  Behavioral variables
  ⇒ essential for R&D respectively innovation strategy and learning behavior
  ⇒ decisive for innovation performance
Impact of behavioral factors on innovation performance

An evolutionary approach with a simulation model for IT-companies in Japan and Germany

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Institute for Economic Policy Research
Section System Dynamics and Innovation
\( \rho_T \) and \( \Lambda \):

- \( \rho_T \) = rate of obsolescence of a technology
- \( \rho_T \) = reciprocal value of product-life time

Here for the IT-case

- Average life time of an IT technology: ca. 4.9 years

\[
\frac{1}{4.9 \text{ years}} = 0.2041 = 20.4\% \text{ per year} \quad \Rightarrow \quad \rho = 0.2041
\]

\( \Lambda \) = Lead-Time: average time from R&D beginning of the technology until bringing onto the market

\[
T_{it} = \sum_{j=1}^{\Lambda} \frac{1}{\Lambda!} \cdot (\Lambda - j + 1) \cdot R_{i,t-1} + \ldots
\]

Here for the IT-case

- Ca. 2.8 years \( \Rightarrow \Lambda = 3 \)
- Therefore R&D expenditure rates of the last 3 years!
Model calibration, optimization and questions

Model calibration:

• fixing: real (historical) data of capital, employment and R&D-expenditures

• estimation of the remaining parameters
  → realization of sufficient consensus between simulated and real time series. Optimization method: OLS

Questions:

• tracing near reality (concerning basis variables) $K_{it}, L_{it}$ und $r_{it}$ for both scenarios possible?

• market entrance and exit of firms possible in model?

• responsible variables?

• development of alternatives?
Object of analysis: IT sector: key data (3)

IT sector development in Germany

Sales volume in bill. Euro

<table>
<thead>
<tr>
<th>Year</th>
<th>TK</th>
<th>IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>49.0</td>
<td>101.3</td>
</tr>
<tr>
<td>1999</td>
<td>54.0</td>
<td>112.3</td>
</tr>
<tr>
<td>2000</td>
<td>58.8</td>
<td>124.3</td>
</tr>
<tr>
<td>2001</td>
<td>70.1</td>
<td>131.3</td>
</tr>
<tr>
<td>2002</td>
<td>66.1</td>
<td>127.9</td>
</tr>
<tr>
<td>2003</td>
<td>63.6</td>
<td>128.3</td>
</tr>
<tr>
<td>2004*</td>
<td>65.8</td>
<td>131.5</td>
</tr>
<tr>
<td>2005*</td>
<td>68.1</td>
<td>136.4</td>
</tr>
</tbody>
</table>

Sales volume in %

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP</th>
<th>ITK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>10.8</td>
<td>12.1</td>
</tr>
<tr>
<td>1999</td>
<td>11.8</td>
<td>12.1</td>
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<tr>
<td>2000</td>
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Source: EITO in cooperation with IDC
NIS-concept

Universities
- Production of Knowledge
- Human Resources
- Development and Supply

Imagery: NIS-concept

Knowledge base

Development in terms of both science/technology and industry

Improvement of productivity

Collaboration

Companys
- Utilization of Knowledge
- Products & Services
- Innovations

Demand

Market

Society

Politics and Economy
- Environment, culture tradition, national character
- Labor policy
- Tax and financial policy
- Science and technology policy
- Education policy
- Economic policy

Creating knowledge base

Improvement of education level

Policy

Knowledge base

Industries

Demand

Market

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