Pathways to Innovation:
Policies, Products, and Processes
for Competitive Advantage in a Global Economy

20 – 21 May 2005, Tokyo

Impact of behavioral factors on innovation performance

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

Monika Friedrich-Nishio

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Aim and motivation

analysis of determinants of firms' innovation activities
- influence of behavioral factors
- "economy and culture cannot exist separately"

development of firms in a sector through time
with inclusion of historical and cultural factors

here: selected firms in Japan und Germany in the IT sector

My aim: a historically consistent trace (no forecast)
with one model for both countries
identifying the responsible parameters

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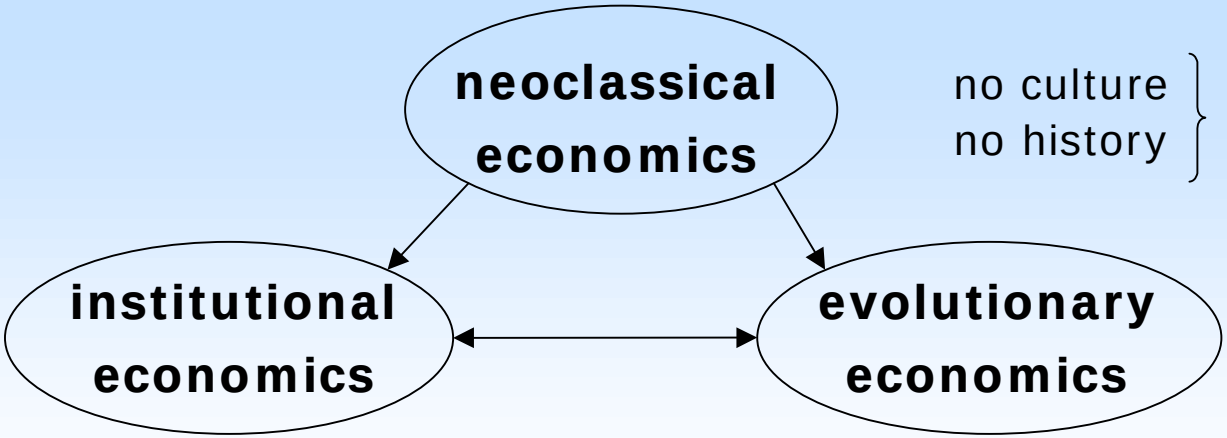
Theoretical framework



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- 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)
  (Nelson, Freeman. Lundvall)

Top 3

- concept of the irreversible, historical time
- VST-concept
- homo discens

Top 4

- technological paradigms and path dependencies

Top 5

- focus: development under given **cultural, social and political conditions**

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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

value, tradition, religion:

Country's / sector's behavioral characteristics

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Growth of IT sector world-wide

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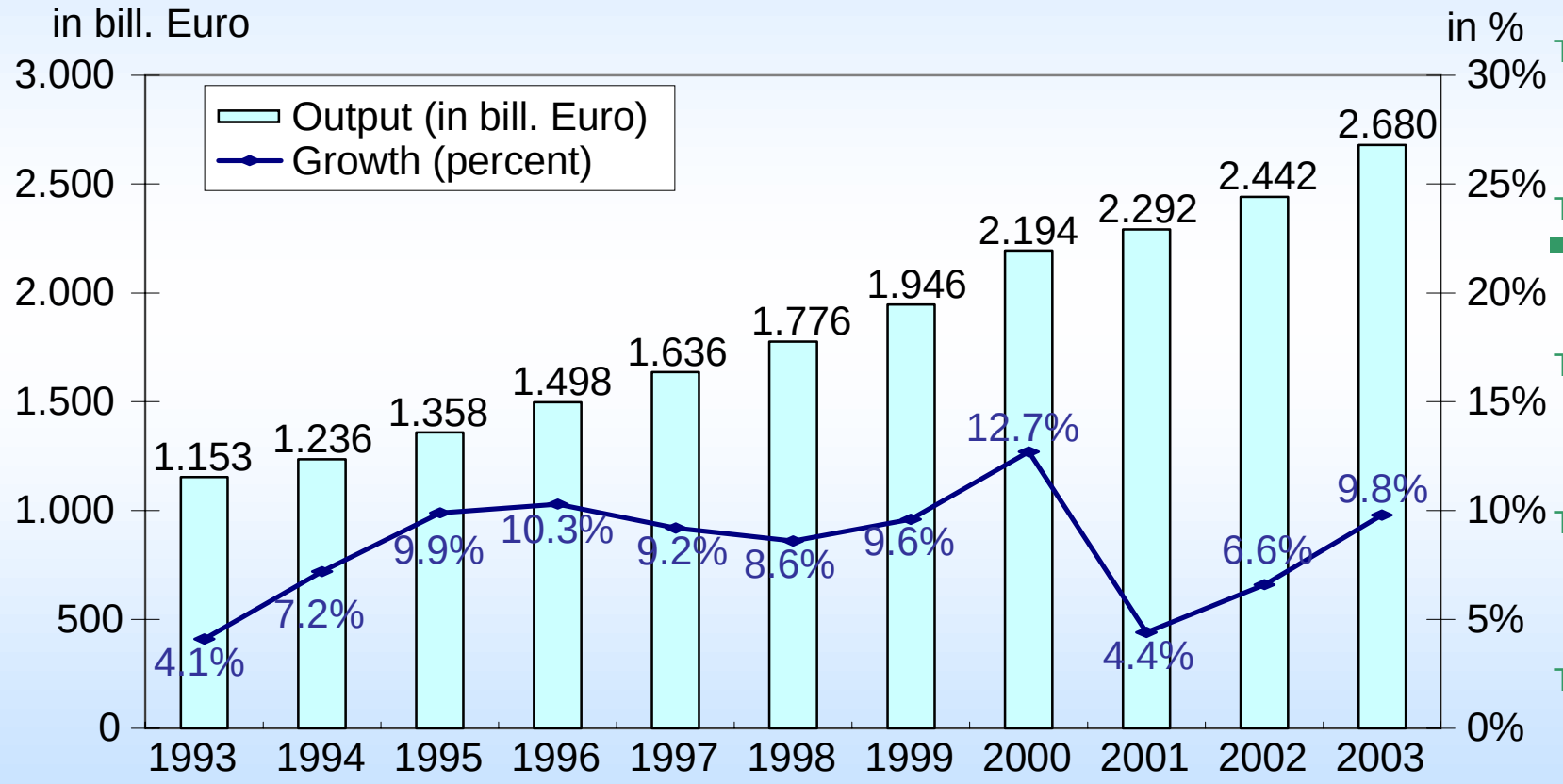

Source: EITO in cooperation with IDC

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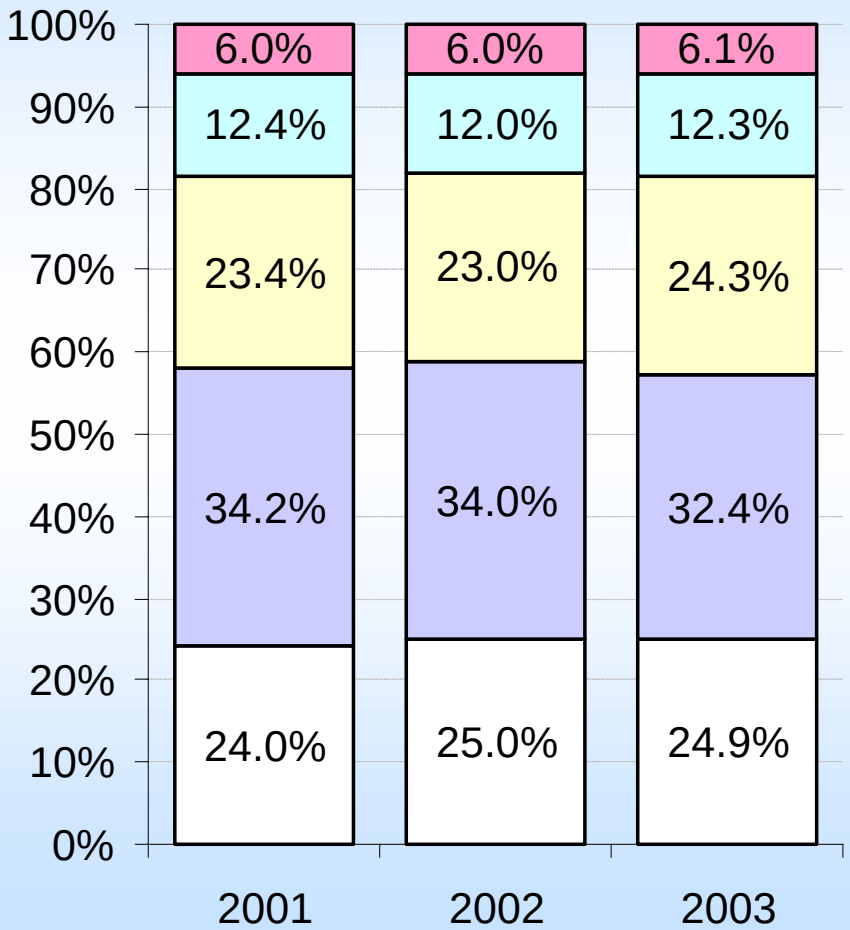
World-wide ICT market by region



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Source: EITO in cooperation with IDC

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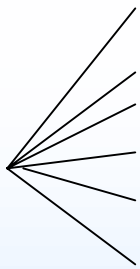
IT sector: empirical data

- data bases for firms (Hoppenstedt), patents, publications (SCI) etc.
- statistical key data from several different institutions
  (e.g. METI, MPT, NISTEP, Stifterverband, Stat.Bundesamt...)
- Data taken 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)

Top 1
Top 2
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period: 1960 until now

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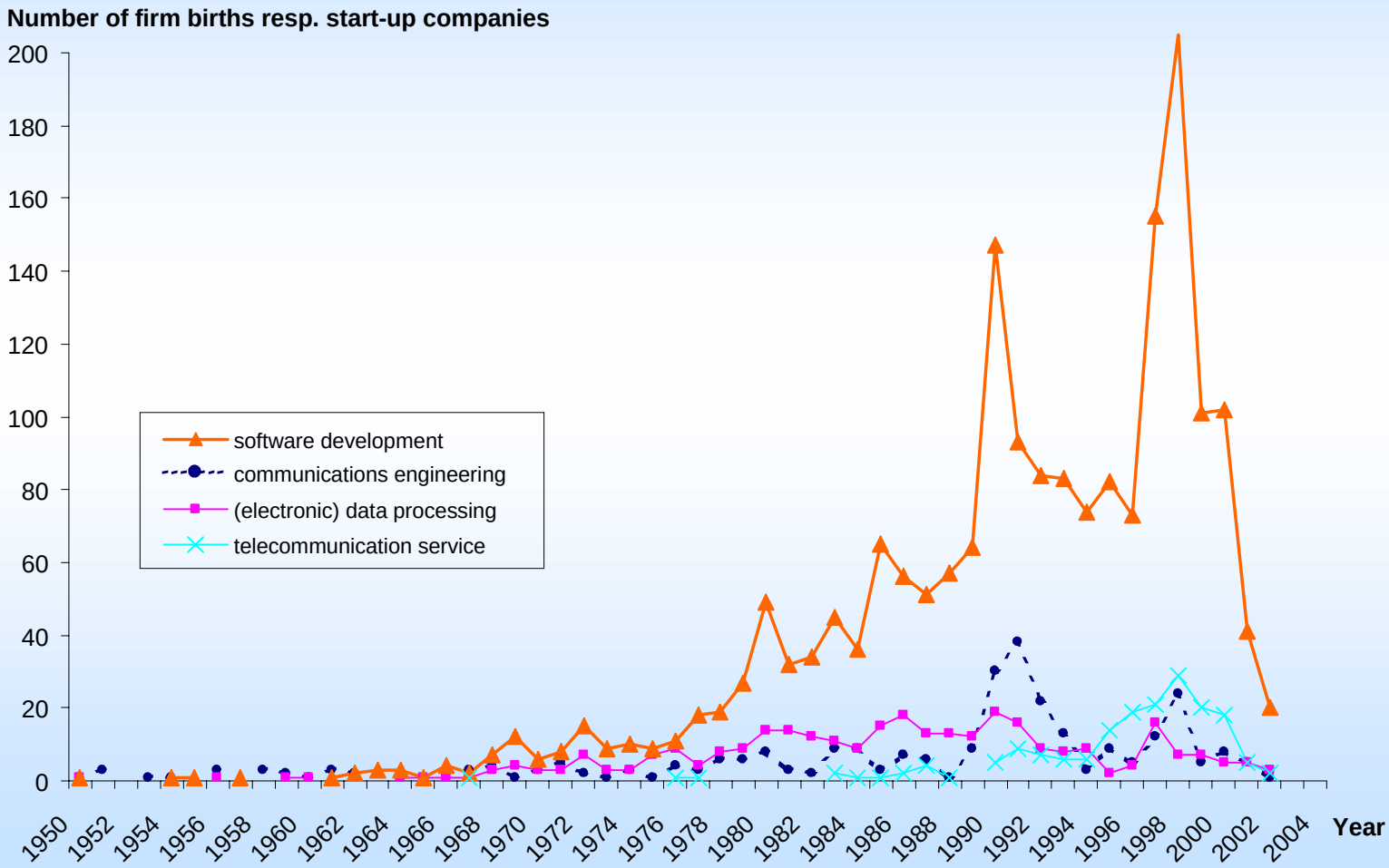
IT sector:

Boom of foundations in the IT sector



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IT sector:

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

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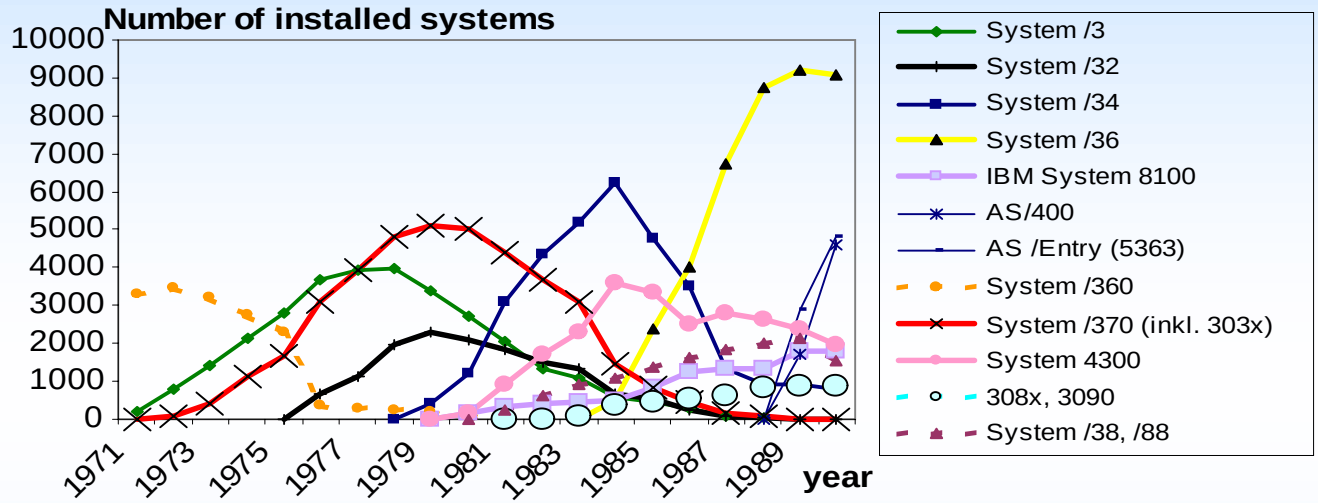

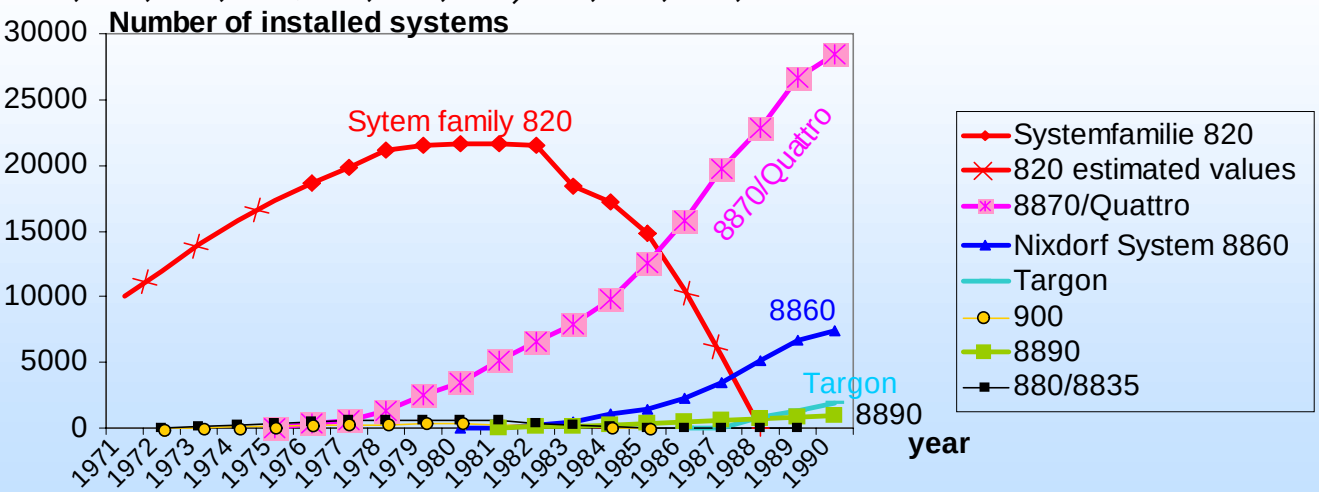

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Culture and Behavior

Top 1

- religious influences?
  Origins: religions (Shintoism, Konfuzianism, Buddhism, Christianity)

Top 2

- historically developed influence factors?
  (e.g. „Keiretsu“ 系列: fusion of firms to a “family“)

Top 3

- differences in behavior and attitudes of employees and managers from different countries → Hofstede (1980)

  → no change over time (Adler 1997)

Top 4

- Harmony vs. Individualism

Top 5

- Status (in society, in firms)

  → meaning of contracts

  → hierarchy in firms

Top 6

- business relationships

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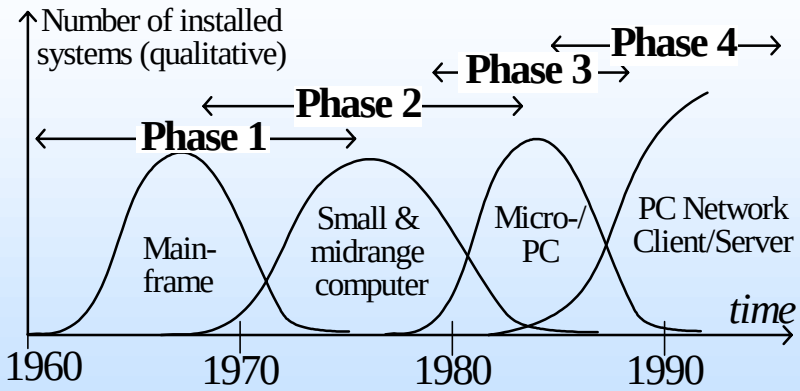
Idea of the evolutionary innovation model

- Theory of decision-making in firms
- Firm: active seek for **profit**
- **Strategy**: innovation, imitation or remaining; depend 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,...



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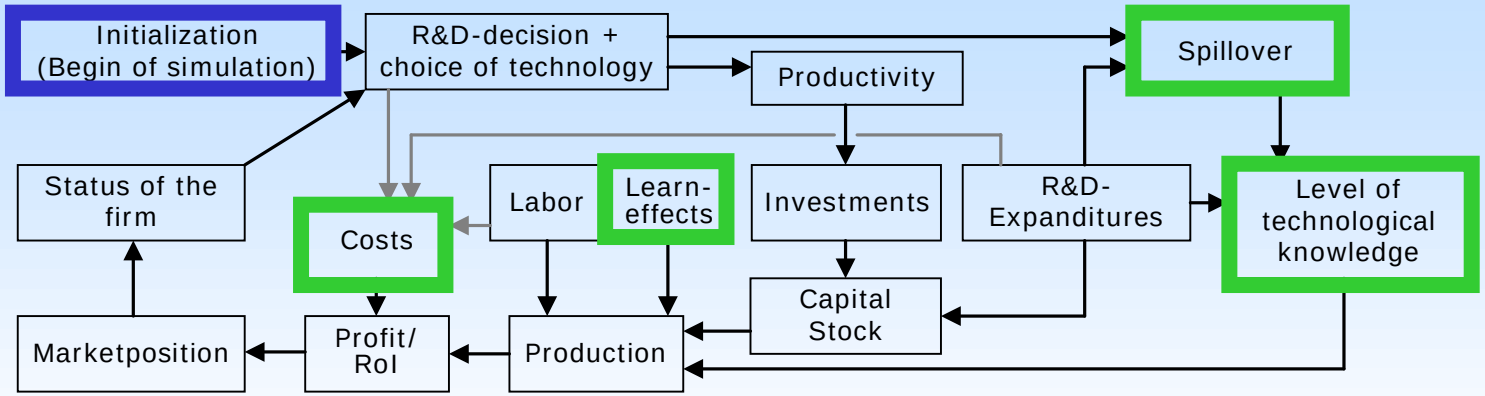
Model: Initialization



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Initialization: Firm's equipment with:

Capital, labor, starting productivity: (K_{it}, L_{it}, A_{it})

and ideas + behavior/attitude

→ individual

also cultural?

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

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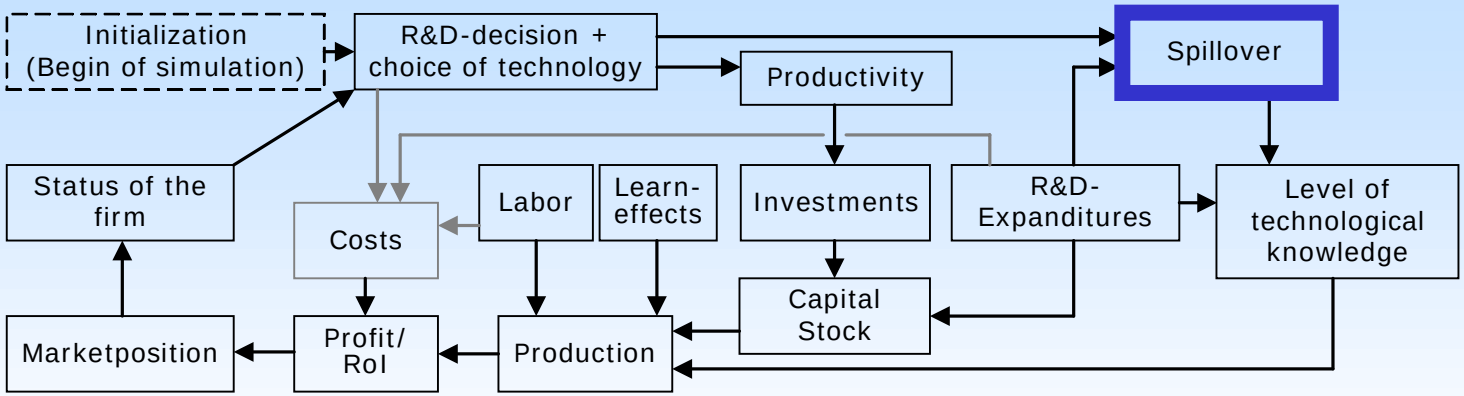

Top 1

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Spillover-effects: Collective Know-How-potential

Top 3

$$S_{it} = \sum_{j=1,\, j \neq i}^{n} w_{jt} \cdot RCAP_{jt}$$

with

Top 4

$$RCAP_{it} = RCAP_{i,\,t-1} \cdot (g^{R\&D} - \delta_R) + R_{it} \cdot g^{R\&D}$$

Top 5

$RCAP_{it}$: R&D Capital of firm *i* at time *t*

δ_R: amortization rate of R&D-capital

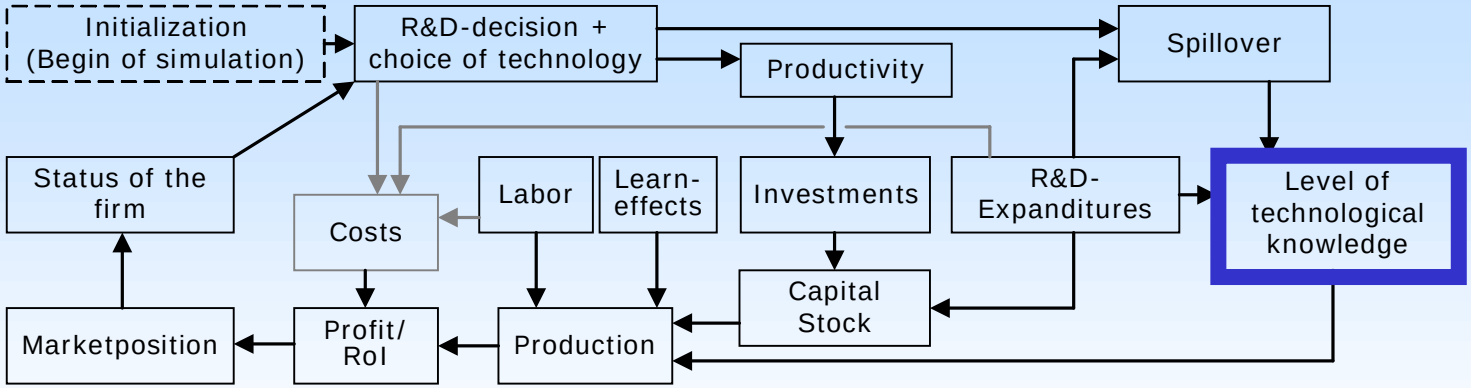
R_{it}: R&D-expenditure of firm *i* at time *t*

Top 6

$g^{R\&D}$: growth rate of R&D-capital

w_{jt}: weight factor of firm *j* at *t* from view *i*

Model: Technological knowledge



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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*
ρ_T : obsolescence rate of a technology
Λ : "Lead Time" of R&D
TL_{it} : comparative level: technological level of knowledge of firm *i* at *t*

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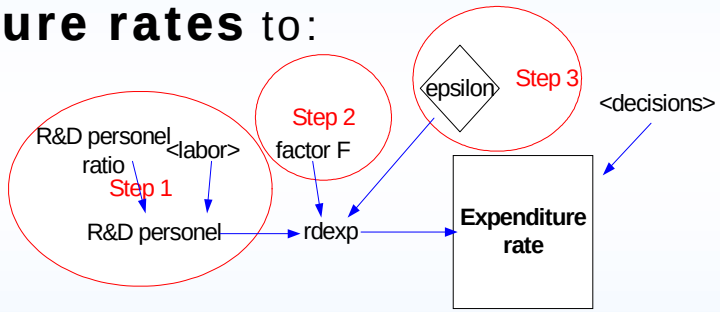
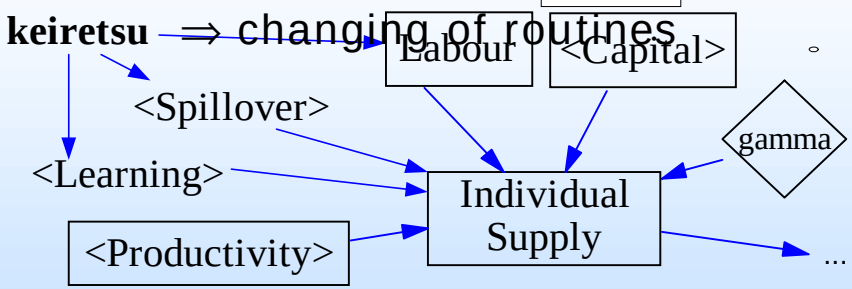
influence of behavioral factors

- **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 ε)



- **Variable for behavior**
  (so-called "Keiretsu")
  - place of search for technology
  - learning speed
  - spillover + technological knowledge
  - pool of the resource "Human Capital"



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Market Selection

- performance-indicator
  (depends on innovation output of the firm like "patents" and "publications")
- rules for market entry and market exit

Top 1

Top 2

Scenario

- scenario **A**: **Japanese** firms' data
- scenario **B**: **German** firms' data

Top 3

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

Top 4

Top 5

Top 6

→ Model calibration, optimization and specific questions

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Tracing the real historical development: Basic scenario

Scenario A: Variable “R&D ration to net sales“ and “capital“

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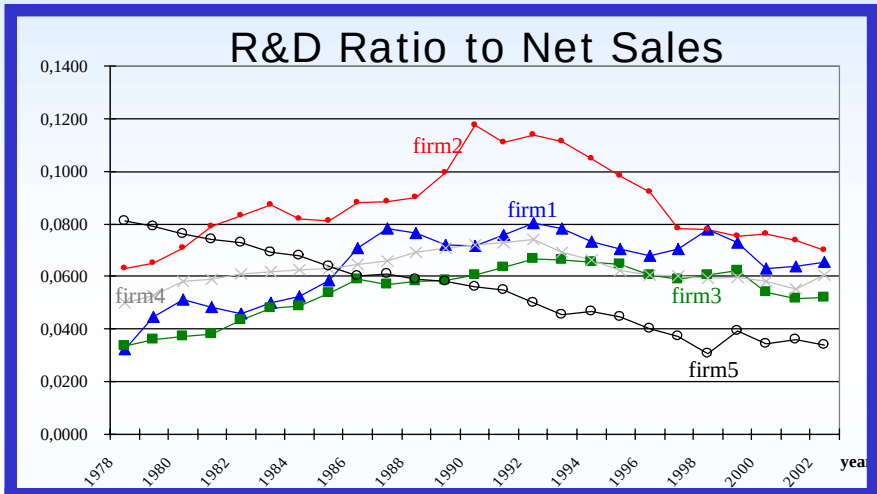

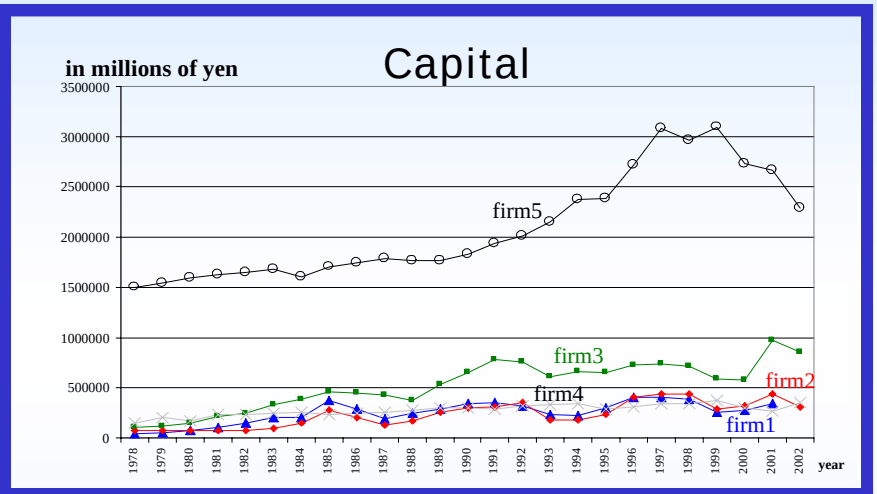

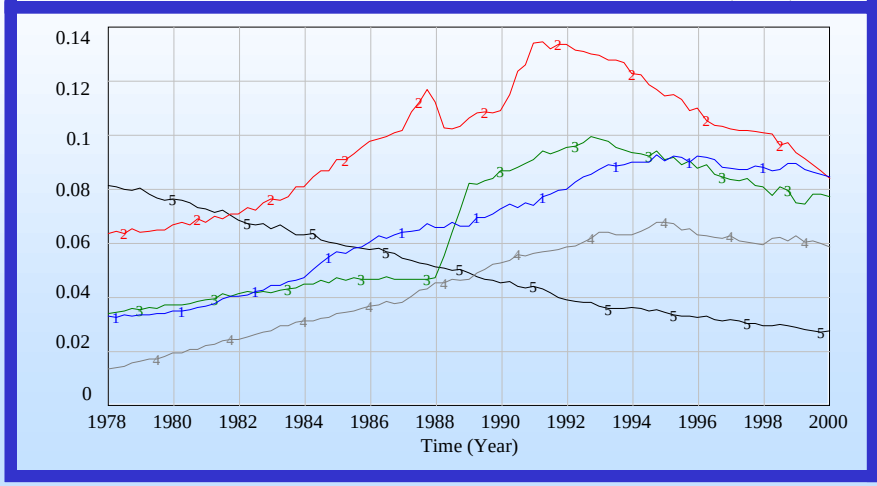

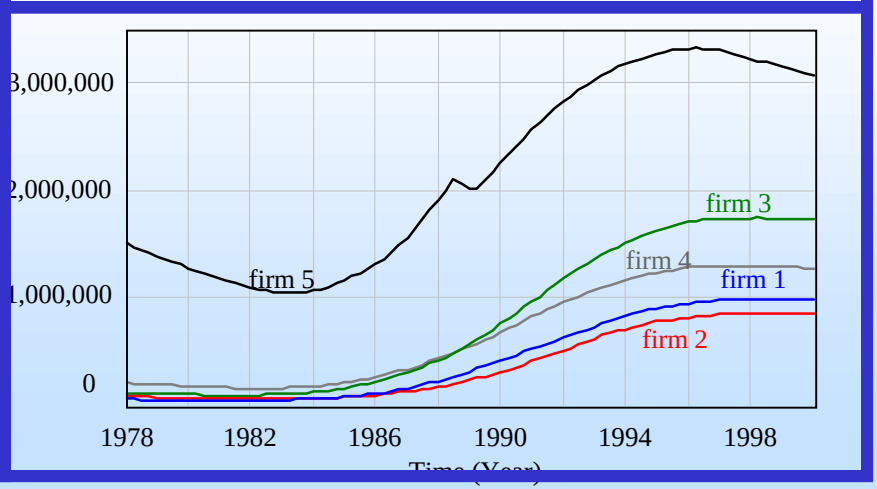

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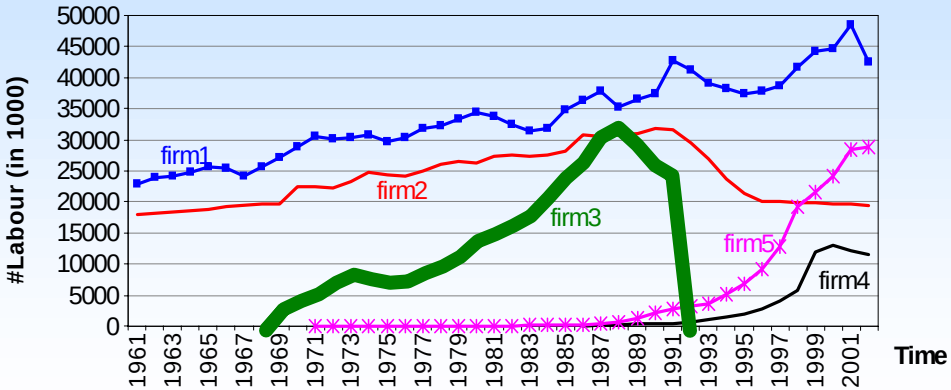
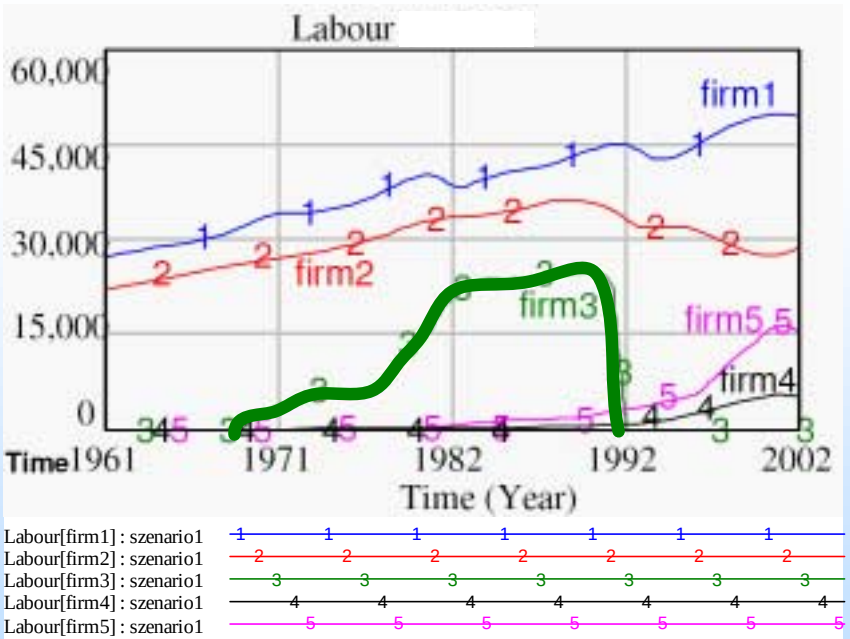
The case of the company Nixdorf

Scenario B: Variable “labour“





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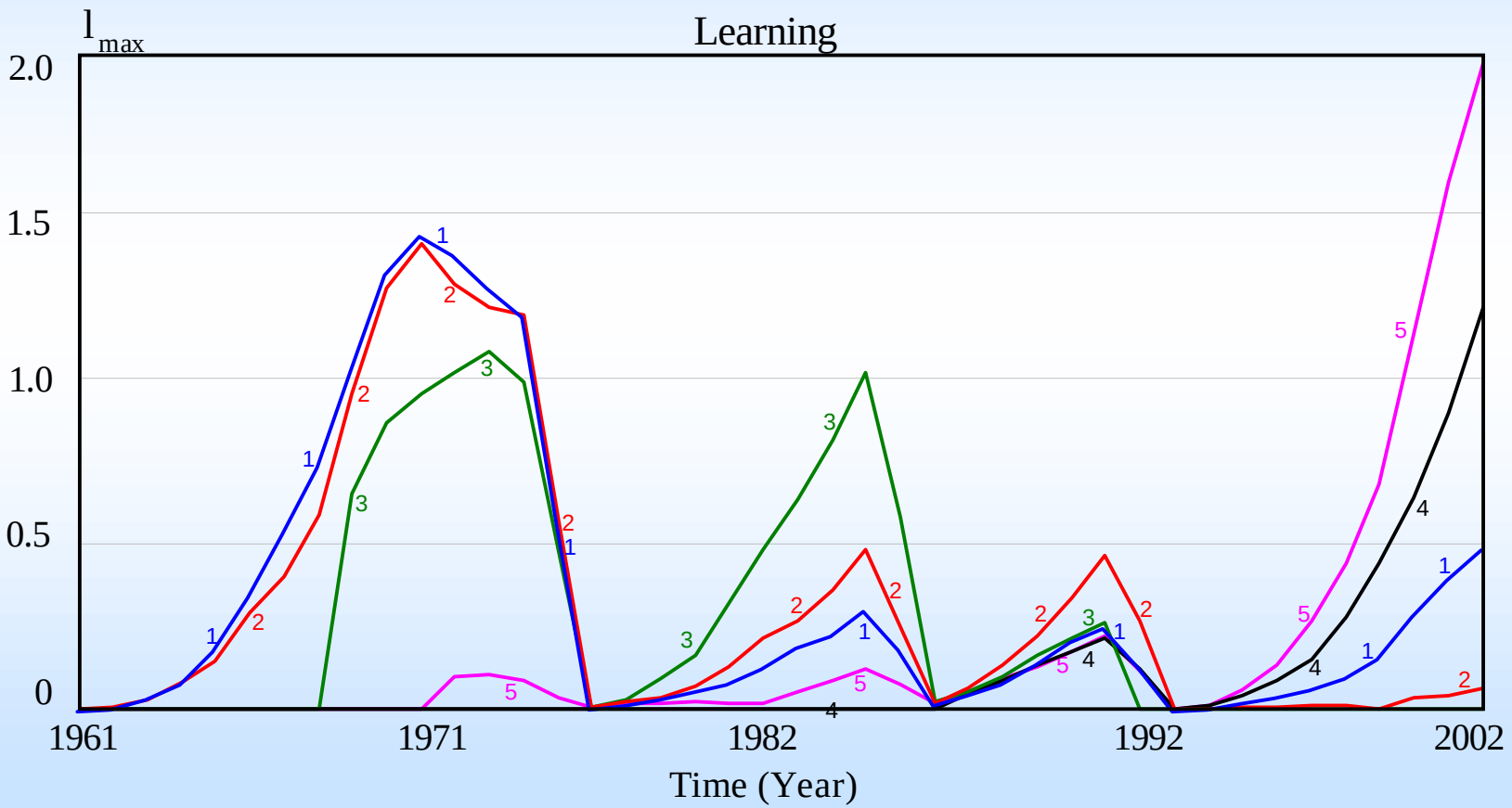
The case of the company Nixdorf

Scenario B: Variable “Learning“



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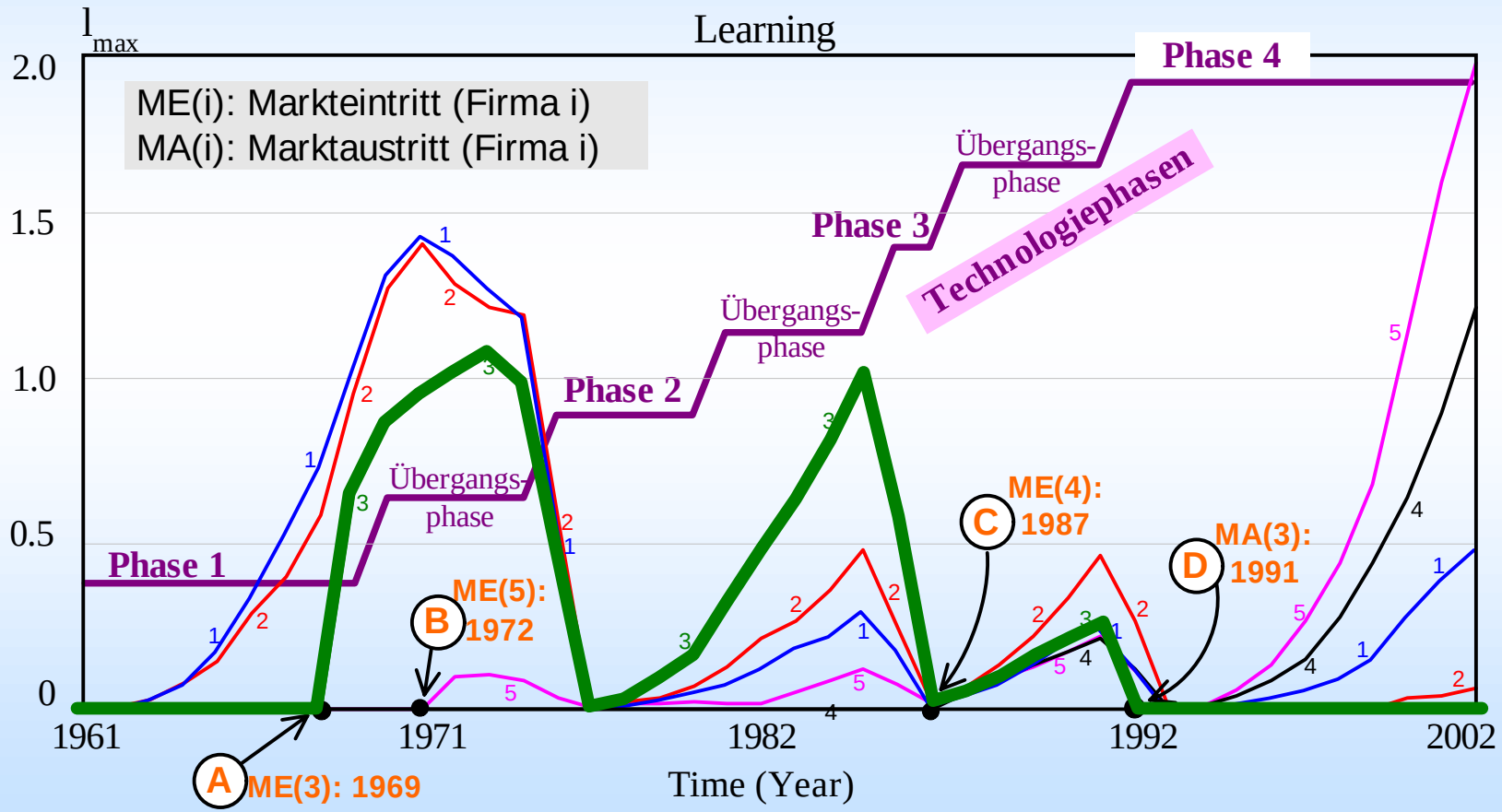
The case of the company Nixdorf

Scenario B: Variable “Learning“



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A contra-factual scenario

Top 1

in scenario B for firm 3

Top 2

Firm 3 has equal starting equipment like before

Top 3

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

Top 4

⇒ instead of "own technology" and
"focus on previous success"

Top 5

now more often: "focus on new technology",
"acquisition of new technology" and
"imitation"

Top 6

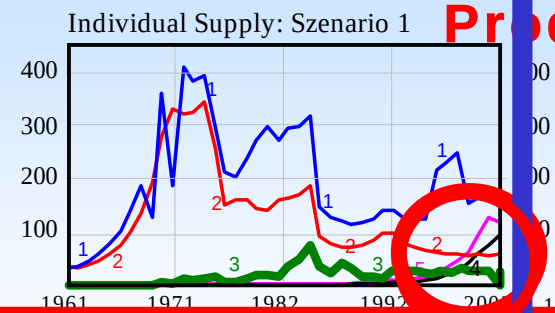
Model: results

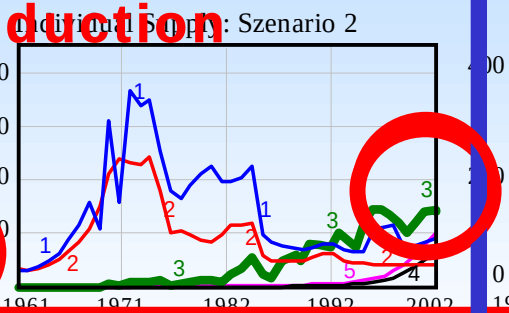
Scenario 1 (Basic scenario)

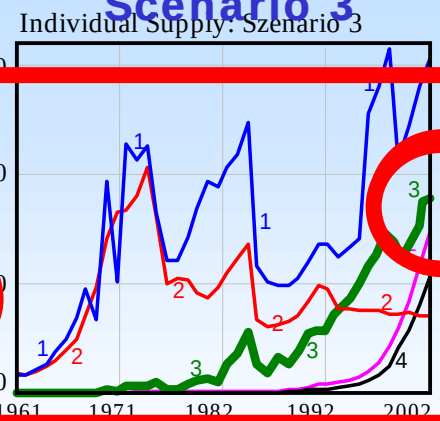
Scenario 2

Scenario 3

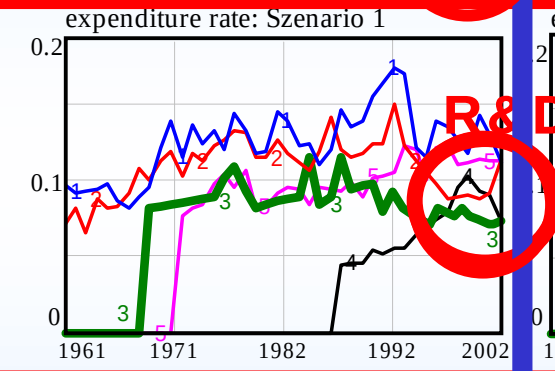
Production

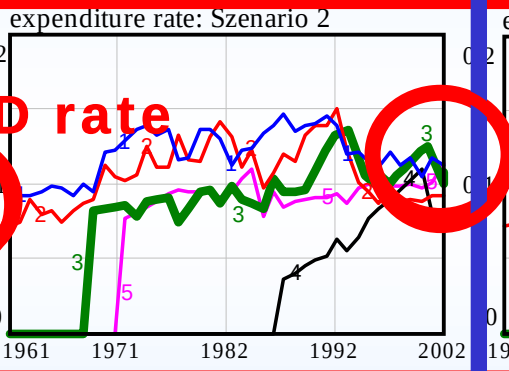


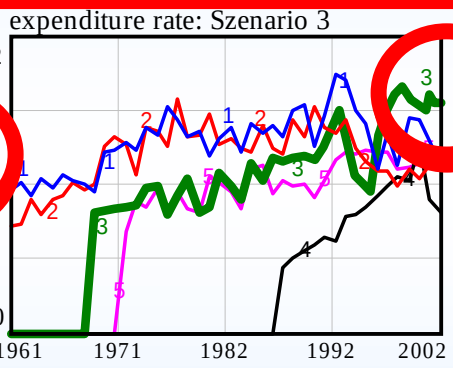




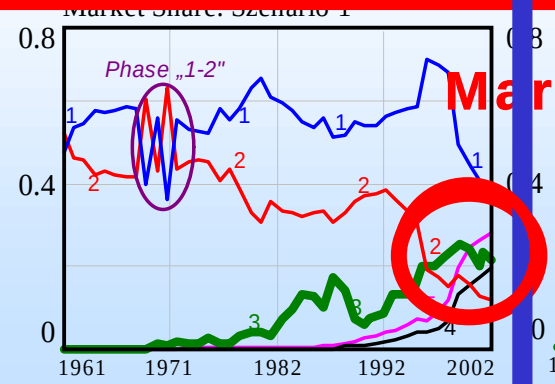
R&D rate

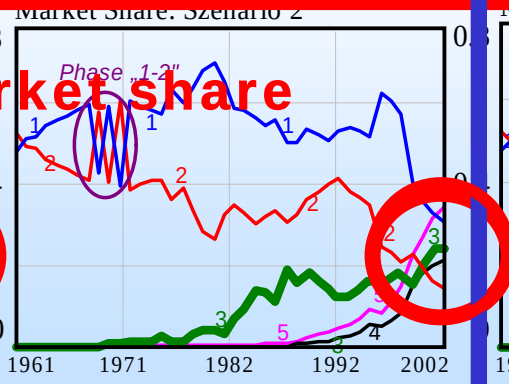


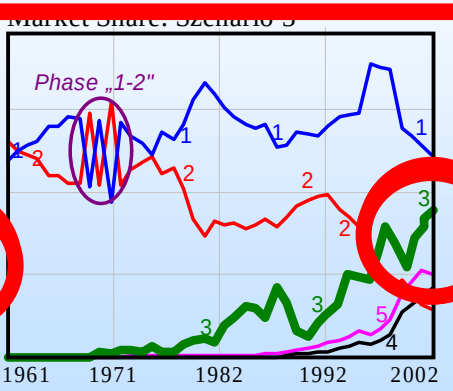




Market share







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Comparison scenario A and B

	Scenario A	Scenario B
Behavior by "keiretsu" (Acting in own firm family)	search for technology restricted to firm family	search for technology in whole industry
"Spillover"	spillover of knowledge not from all firms of industry	technological knowledge of all firms relevant
"Priority own technology"	rarely chosen aim: adopt technology direction given by the firm	often chosen aim: technological leadership by own standards
"Market leadership" (= "Priority own technology" + "Innovation")	not primary intention level of satisfaction is lower than in scenario B	often chosen market leadership is aim
Market entrances?	no market entrance in all scenarios	the more open the market considering innovations the more market entrances

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The simulation model shows...

- Market entrances and exits are possible, but not in all cases

Top 1

- What does a firm need to survive?
  Strategy "Market leadership"? Can help, but no garantee
  Political framework? necessary, but not enough

Top 2

- **Differences Japan-Germany**
  - subjective cognition of competition / success

Top 3

  - Differences due to: not technical components or production functions, but behavioral parameters

Top 4

- **Factors for success**
  not firm size, not duration of market membership, not production methods

Top 5

  but: Behavioral variables
  ⇒ essential for R&D resp. innovation strategy
  and **learning behavior**
  ⇒ decisive for innovation performance

Top 6

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ρ_T and Λ :

Top 1

ρ_T = rate of obsolescence of a technology
= reciprocal value of product-life time

here for the IT-case

Top 2

average life time of an IT technology: ca. 4.9 years

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

Top 3

Top 4

Λ = Lead-Time: average time from R&D beginning of the technology until bringing onto the market

Top 5

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

here for the IT-case

Top 6

ca. 2.8 years $\Rightarrow \Lambda = 3$

therefore R&D expenditure rates of the last 3 years!

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Model calibration, optimization and questions

Model calibration:

- fixing: real (historical) data of capital, employment and R&D-expenditures
- estimation of the remaining parameters
  $\rightarrow$ 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?

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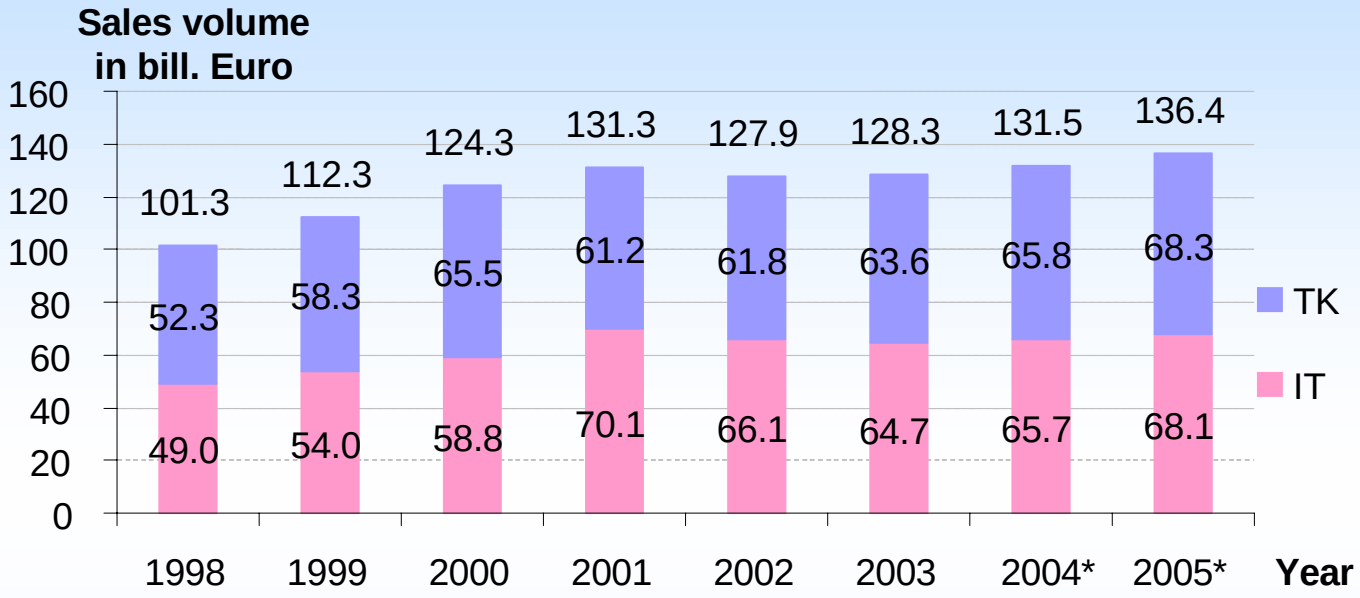
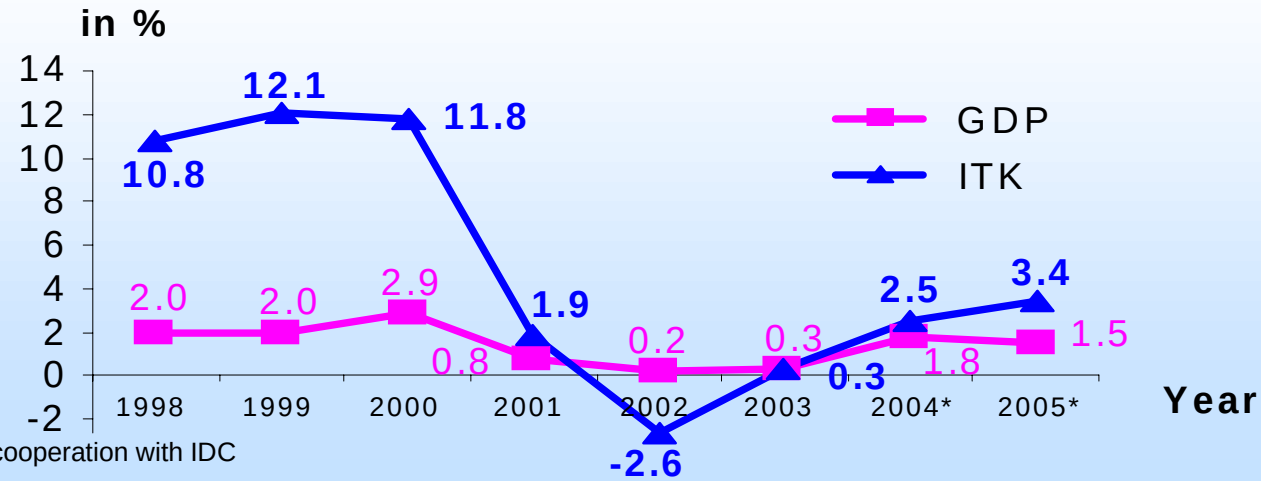
IT sector development in Germany





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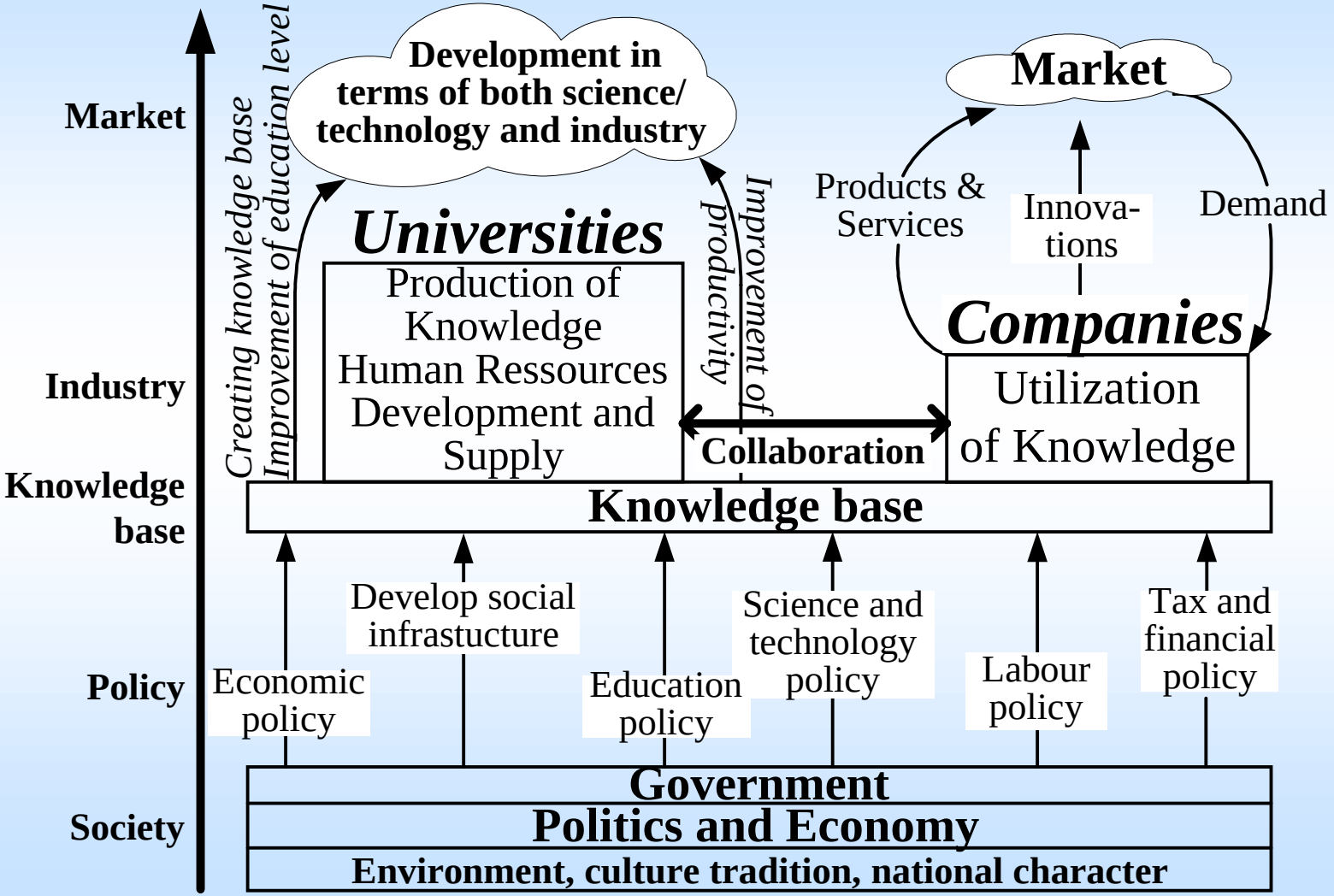
Institute for Economic Policy Research
Section System Dynamics and Innovation

NIS-concept



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We remember…

- identification of the for success of firms responsible parameters Top 1
- construction of a simulation model for both countries with equal basic structure
  but with individual behavioral parameters Top 2
- calibration with Japanese and German firm data Top 3
- aim: Historically consistent tracing (basic scenario)
- alternative scenarios:
  "what if"-scenario: changing of the firm's behavior
  without changing of the initial equipment Top 4

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Model: results

- **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**

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