Impact of behavioural factors on innovation performance. An evolutionary simulation model

Monika Friedrich-Nishio*†

Institute for Economic Policy Research
Section System Dynamics and Innovation
University of Karlsruhe (TH)

ABSTRACT
This paper takes an integral look at the main determinants of innovation processes. Specifically, it examines from an evolutionary perspective how innovation arises in individual firms and in the economy. In the line with the evolutionary theory firms’ innovative performance is based on their portfolio of skills, behaviour, and core competencies. A simulation model is developed, based on analysis of IT firms in Japan and Germany and their development in the last four decades. For this purpose statistical and firm data are collected to describe the IT development in Japan and Germany as a whole, then to create the background frame for a simulation model. Local interviews in these firms are conducted in order to obtain a detailed view of firms’ individual strategy in R&D and innovation policy. The interview results obtained were used in the simulation model as behavioural factors. The model can help to examine how entrepreneurial behaviour, influenced by cultural factors, has an impact on innovation performance.

KEY WORDS
Technological innovation and R&D, evolutionary economics, simulation, Japan, Germany, IT sector.

JEL Codes
O33, D21, C88, L86

*Waldhornstr. 27, Geb. 01.96, D-76131 Karlsruhe, Germany. Tel.: +49(0)721 608-7694, Fax: +49(0)721 608-8429, email: friedrich-nishio@iww.uni-karlsruhe.de
†With this paper I wish to qualify for the Young Economists Award.
1 Introduction

The present study examines how entrepreneurial behaviour, influenced by cultural factors, has an impact on innovation performance. The cultural factors exert direct effects on the attitudes and values of the entrepreneurs, but also an indirect influence through their impact on legal systems and public administration. The proposition is that a culturally-based factor will have similar influence on the attitudes of entrepreneurs coming from different social groups. However, these common traits are modified as soon as the entrepreneur participates in training programs and has some business experience.

These propositions are investigated in the IT case study in Japan and in Germany. In each case companies with different historical backgrounds and different start-up conditions show attitudes concerning their innovative behaviour, especially their R&D decisions.

Then, an evolutionary simulation model is developed, following a system dynamics approach. The use of simulation modeling techniques in studies of technological innovation dates back to Nelson and Winter’s 1982 book ”An Evolutionary Theory of Economic Change” and is an area which has been steadily expanding ever since. The objective of the study in this paper will be to trace the development on the one hand, and on the other hand to determine the impact of behavioural factors on innovation performance.

2 Theoretical background

2.1 Innovation as a driving force

When we consider the subject of innovation and the firm, we have to think about several points. First, what is meant by innovation? Second, what is meant by an innovative firm? And third, what are the characteristics that make a firm innovative? If we take the definition by Schumpeter (1934 [22]) innovation is:

- introduction of a new product or a qualitative change in and already existing product
- introduction of a new process, not known in the industry
- opening of a new market
- development of new sources of the supply of raw materials or inputs
- introduction of changes in industrial organization

An innovative firm is more difficult to define. A review of the literature shows that there is no single criteria on that. But the essential point is the methodological advances made by the OECD. According to this, firms are considered to be innovative when the have introduced innovations of product and/or process in the last three years (OECD). The characteristics that make a firm more or less innovative depend on a set of factors including the technological opportunities that a firm seeks. The main point is that a technologically trained labour force is an essential element for
the use of new technologies in the firm. In addition, the pressure and the quality of the compensation, the capacity to relate to other firms and research centers, and the financial availability and the structure are important factors for innovation. The innovation process is usually not a result of inspired ideas of some of the managers or engineers but more often comes from a simpler and more inherent process. The firm has a specific problem, and if this can’t be solved by the existing knowledge research will be needed. The research and development section of a firm is a very important element in the innovation process.

2.2 Evolutionary economics

In evolutionary economics the level of analysis is normally the firm, where tacit and explicit forms of knowledge interact and are selected in the basis of choice made by individuals, according to some utility emerging from the historical and economic context. Evolutionary economics extend the behavioural theory of firm (Nelson/Winter 1982 [16], Cyert/March 1963 [5]) and draws on the Schumpeterian idea of capitalism as an evolutionary process, which regards industry structure as constantly evolving and firms as adapting over time in a "process of creative destruction" (Schumpeter 1934 [22]).

Evolutionary economics focuses on intensity, direction, and strategy of search activity and their causal factor. Organizational search leads to dynamic environmental changes and selection, and changes in business strategies and search activities lead to dynamic changes at the aggregate firm level, since profitability, investments and rates of expansion are affected. These changes in turn affect to dynamic changes at the industry level. Firms behave differently concerning their strategies, and these differences are assumed to result in performance outcome variations. Less successful firms tend to imitate strategies of other firms by reducing their strategic diversity. Only a few successful firms will be able to find pioneering new technologies in order to generate innovations. They can obtain above average returns until the imitators dissipate away these temporarily high returns. Firms, unable to overcome internal structural inertia, might fail to adapt to the environmental changes, so that they eventually will not survive: a selection process through the market (Schumpeter 1934 [22]).

2.3 National Innovation Systems

The concept of National Innovation System (NIS) has been the center of interest in a lot of works. But we cannot talk of the existence of a single concept of National Innovation System, because this concept covers different realities, and the interpretations differ depending on the author. ¹) These concepts differ in their methodological point of view (micro- or macro-economical), the conceptualization of the technology, and the role of institutional frameworks.

Freeman (1987) emphasizes that economic success is often related to major institutional changes in the national system of innovation, as well as to big increases in the scale of professional research and inventive activities and new clusters of radical innovations.

If we talk about the main players in an innovation system, we have to look for the characteristics of the innovation systems in terms of science and technology activities. For this we are using indicators of innovation processes, like indicators of input into research and development (R&D expenditures, human resources), indicators of output (number of patents, number of scientific papers), indicators of results of innovations (technology trade and exports of high-tech products, including the relationships between universities and companies).

Apart from the difficulties in measuring these indicators, we also have difficulties regarding the interpretation, for we don’t have a well-defined and unambiguous definition of the relationship between input, output and performance. The NIS concept points out that within an innovation system there are a lot of elements, i.e. institutions, involved in different levels. Ultimately the mode, way and quality of these relationship between the elements within a NIS, which naturally differ from country to country, determine the quality and performance of an innovation system.

### 2.4 Institutional and behavioural factors

Hofstede (1980 [10]) investigated workers of IBM in different countries and could find highly significant differences in the behaviour and attitudes of employees and managers from different countries. He also analyzed that these differences did not change over time (Adler 1997 [1]).

**Harmony versus Individualism:** In Germany the identifying feature of firm strategies is individualism: the behaviour of Germans is strongly individualistic. According to interviews with the firms they mostly aim at individual success, i.e. to accomplish innovations through own technology instead of imitations. Characteristically German firms are not satisfied with the second-best-solutions, e.g. the
company Nixdorf. Heinz Nixdorf, founder and president of the Nixdorf Company, had developed all products himself and aimed for setting own standards, disinterested whether in imitations nor cooperations (he refused the conclusion of a contract with Apple in 1982). Individualism like we have in the western culture does not exist in Japan. Japanese people must behave harmoniously with other people in a society established by traditional social hierarchy. According to the Japanese religions, Shintoism, Buddhism and Confucianism, Japanese people are expected to consider their relationship with the others before considering their own wishes. So harmony is also a synonym of conformism.

Status Society (The meaning of contracts): Purportedly, titles are very important to Germans, and age takes precedence over youth. Nevertheless, in business not age but qualification and skills determines the ”status” of a person. Hence, the state of dependence established in contracts attach importance to the relationship between the parties and groups. In Japan this relationship is not based on contracts but on a person’s status in the multilayered hierarchy. The Japanese ”status” is defined in terms of employer, title, seniority/age, and so on. This status is not absolute but relative, i.e. it’ll be changed when these people are transferred or leave the firm. The order of the people is usually decided on their seniority in the society, i.e. even a difference of one year is important for the so-called 'Sempai-Kohai’ relationship. According to this the meaning of entering into a contract is quite different in Japan compared to Western countries. Written contracts are often considered to be just a symbol of a deal. So it is difficult to define the ”fixed” strategy of a firm. Management methods are often based on loose verbal and informal conditions.

Keiretsu: Keiretsu is a Japanese term for a set of companies with interlocking business relationships and shareholdings. They are conglomerates, some emerged out of former Zaibatsus but others are just new groupings of companies. The ”Big Six” keiretsu are Mitsui, Mitsubishi, Sumitomo, Fuyo, Sanwa, and Dai-Ichi Kangyo, all led by their respective banks, which are the largest in Japan. Technological innovation and Internet-business growth continue to be strong in Japan because of this keiretsu-system. The Japanese keiretsu system (closely knit, long-standing associations of manufacturers, suppliers, and distributors) also continues to pose a challenge to outside companies seeking to enter the marketplace. For decades, supply-chain partners have bonded in horizontal and vertical keiretsus to protect their mutual interests and fend off foreign-business threats. Although this practice is now waning (Nissan is a notable example), the keiretsu tradition still exists in many business sectors including banking, insurance, steel, manufacturing, chemicals, and also in IT industry. There, a strong holding together can be observed, whereas in the German case this kind of coacting couldn’t be found. So, dealing and acting in a ”strategic group” is to be considered as a typical Japanese firms’ attribute.

The interaction of a number of firms with different characteristics in terms of their propensities to innovate, imitate and invest in R&D, implies a modeling of a system, which is characterized by a high level of complexity. Since the degree of complexity of this stochastic modeling makes it difficult or even impossible to solve it analytically, computer simulations and agent based modeling are used in the analysis of emerging properties in such an environment.
3 The model

We consider an industry evolving in discrete time \( t = 0, 1, 2, \cdots, T \). At time \( t = 0 \) there are no firms ready to manufacture, but a random number of firms are drawn which will start to manufacture at \( t = 1 \). At time \( t = 1 \) the industry consists of \( n_t \) firms which are involved in manufacturing. At each time \( t \) the economy is endowed with two factors of production: labour, which is provided by the employees of firms, and physical capital. At the beginning of each period the firm \( i \) is characterized by the productivity of its technology \( (A_{it}) \), its labour employed in production \( (L_{it}) \) and its capital stock \( (K_{it}) \). The production technology is characterized by fixed input coefficient and constant scale economies. Each firm produces the same homogenous good. We have constant returns to scale and the productivities are modified by technical progress. A technology of a firm can never be degraded but only improved. An improvement is possible either through successful innovations or through adopting a better technology of another firm (imitation).

The main elements conform to the traditional evolutionary models.\(^2\) The most interesting and new element in this model is the inclusion of the following three elements into the production-function:

- the individual learning processes,\(^3\)
- the technology knowledge of a firm,\(^4\)
- the spillover-effects.\(^5\)

3.1 Productive efficiency level and learning process

Firms learn different from the past. The capacity of changing the organizational routines varies across firms, and the relative position of a given firm is unstable. The variable \( u_{it} \) indicates the productive efficiency level at time \( t \). Changes in \( A_{it} \) are a function of technical progress via R&D strategy. Firms can also change their total factor productivity by improving the efficiency of their organizational routine \( l_{it} \).\(^6\) This is possible through learning and adopting over time. But routines are very hard to change, so they are responsible for inflexibility and inertia in organizational behavior. The learning process has two characteristics:

1. learning effects are limited, and
2. the organizational knowledge is technology-specific: If a new technology is introduced, a new learning process begins and the firm enters into a different "learning curve".

\(^3\)following the ideas of Cohendet 1999 [4] and Possas 2001 [20], p. 10
\(^4\)according to Watanabe 2001 [23], p. 283
\(^5\)in the style of Aiello 2003 [2]
\(^6\)Cohendet 1999 [4]
The firm’s efficiency at time $t$ is

$$ l_{it} = \left(1 + \omega_i \cdot e^{z_i(t - \tau_{ei})}\right)^{-1} \cdot \left(l_{max} - e^{-\nu_k^k(t - \tau_{ki}) - k}\right) $$

with $0 < l_{min} \leq l_{max} \leq \infty$

$z_i, \nu_k^k$: learning speed, the higher the value, the faster the learning process

$\tau_{ei}$: period, where firm $i$ enters in the industry

$\tau_{ki}$: period, where technology $k$ is selected

$t - \tau_{ei}$: age of the firm $i$, number of periods, during which firm $i$ uses technology $k$

$k \in \mathbb{R}$: position of the learning curve

The first term $(1 + \omega_i \cdot e^{z_i(t - \tau_{ei})})^{-1}$ is a logistic function and expresses the learning process associated with the age of the firm $i$. The second term $(l_{max} - e^{-\nu_k^k(t - \tau_{ki}) - k})$ is a modified exponential function. It characterizes the specific learning process of technology $k$. The production cost per unit of output of firm $i$ at time $t$ (unit costs of this technology) is given by

$$ c_{it} = \frac{1}{l_{it}} \cdot \frac{v}{A_{it}} $$

where $v$ is variable costs per unit of output, assumed constant over time, and for a given plant or technology, the efficiency of input utilization is kept unchanged with the amount produced. Differences in firms’ unit costs arise from improvements in efficiency $l_{it}$ and from technical progress $A_{it}$. When the total productivity $A_{it}$ increases, the unit costs decrease. Each technology has a specific design, and according to the usual assumptions in economic studies concerning the behavior of learning curves, the productivity increase of a given technology tends progressively to exhaust.\(^7\)

As a new technology is introduced, lagging or handicapped firms have the opportunity to catch up or even to go beyond the leaders in the former technology or in the old equipment. This can be imagined as a firm’s sudden jump to a new learning curve, bringing itself in a position of equality or even superiority to others.\(^8\)

### 3.2 Market behavior

The individual supply for firm $i$ at time $t$ is then according to a Cobb-Douglas-production-function:

$$ Q_{it} = A_{it} \cdot K_{it}^\gamma \cdot L_{it}^{1-\gamma} \cdot l_{it} \cdot TL_{it} $$

with $0 < \gamma < 1$. The total supply for the whole industry is $Q_t = \sum_{i=1}^{n_t} Q_{it}$.

\(^7\)Possas 2001 \[20\]

\(^8\)This phenomenon can be seen e.g. in sectors like semiconductors, aircraft, and especially computers (rapid technological obsolescence of product design), Scherer and Ross 1990 \[21\]
The demand and short term equilibrium price is

\[ p_t = \frac{D}{Q_t^\eta} \]  

(4)

with \( D(Q_t) \): demand, and \( \eta \): demand elasticity. The demand function \( D(Q_t) \) denotes the quantity demanded at time \( t \), with \( \lim_{Q(t) \to 0} D(Q_t) < \infty \) and \( \lim_{Q(t) \to \infty} D(Q_t) = 0 \).

The capital stock depreciates at rate \( \delta \) at each period. Unit using cost of capital is \( m \) with

\[ m = \delta + r_{nat} \]  

(5)

where \( r_{nat} \) is the natural interest rate.

\( l_{it} \) is the productive efficiency level obtained through learning at time \( t \), \( 0 < l_{min} \leq l_{max} \leq \infty \) (see section 3.1), and \( TL_{it} \) the Technology knowledge stock Level of the firm, which is introduced in the next section.

The profit of firm \( i \) at time \( t \) is equal to total sales minus production and non-production (R&D) costs. Hence, the gross profit on capital of the firm \( i \) at time \( t \) is given by:

\[ \Pi_{it} = p_t \cdot Q_{it} - (m + c_{it}) \cdot K_{it} - R_{it} - C_{it} \]  

(6)

where \( R_{it} \) indicates the R&D expenditures (more in section 3.4) and \( C_{it} \) indicates the costs additional to the variable costs.

The state of each firm will change from one period to another in consequence of the R&D decisions, which modify its technology and hence its productivity, and the investment behavior, which modifies its capital stock. The market share \( (MS) \) of each firm is given by

\[ MS_{it} = \frac{Q_{it}}{Q_t} \]  

(7)

### 3.3 Technology knowledge stock and spillover-effects

\( TL_{it} \) is the Technology knowledge stock Level of firm \( i \) at time \( t \), which can be measured in the following way:

\[ TL_{it} = \frac{T_{it}}{\sum_j T_{jt}} \]  

(8)

and

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

(9)

with \( R_{it} \) indicating firm \( i \)'s R&D expenditure in time \( t \), \( \Lambda \) for Lead time (time lag between R&D and commercialization), and \( \rho_T \) for the rate of obsolescence of technology \( T \).
TL it comprises spillover-effects in the following manner: With respect to the calculation of a proxy of R&D spillovers, the identification of the amount of indirect R&D available to a firm is the starting point for the analysis. The external technology used by a firm depends on the stock of knowledge determined by the accumulation process in R&D followed by other firms. Thus, at time \( t \), the knowledge spillovers of firm \( i \) are, at a first glance, the weighted sum of R&D stock of other \( n - 1 \) firms, that is

\[
S_{it} = \sum_{j=1, j \neq i}^{n} w_{jt} \cdot RC_{jt}
\]  

(10)

with \( j = 1, 2, \cdots, n \) and \( w_{jt} \) indicating the weight of firm \( i \) at time \( t \) with \( \sum_j w_{jt} = 1 \).

\( RC_{it} \) denotes the R&D capital of firm \( i \) in time \( t \).

For modeling R&D spillovers in a production function, R&D Capital is viewed as a measure of present state of technological knowledge determined by current and past investments in R&D. Therefore, R&D capital can be derived by applying the perpetual inventory method to R&D investment. Then we have

\[
RC_{it} = RC_{i,t-1} \cdot (g^R - \delta_R) + R_{it} \cdot g^R
\]  

(11)

with \( \delta_R \) indicating the rate of depreciation and \( g^R \) indicating the growth rate of investment in R&D over this given span period.

### 3.4 Technical progress and R&D

Due to the technical progress firms are able to modify their productivity. In each period firms invest an amount of resources: They have R&D expenditure and capital expenditure, so there are two stages: the search stage (search for innovation or imitation) and the production stage.

The allocation of the new investment in R&D \( R_{it} \) is a random amount to be endogeneously determined during the search process. Though the R&D expenditures have a character of fixed costs, for the increase of output not consequently increases the R&D expenditures, but we assume here that firm’s R&D investment is based on a (short-term constant but) long-term evolving behavior function. That means, the ratio of R&D investment to the output is proportional. Thereby the firms have to decide

1. whether they imitate their successful competitors, i.e. they adopt a default technology which is used in the previous period,

2. or they innovate, i.e. they invest in search for a better technology.

In other words, more productive technologies can be obtained either by introducing new production processes or by mimicking the old ones. Therefore we also introduce here the according R&D ratios, \( r_{itin} \) for the innovation costs, and \( r_{itim} \) for the
imitation costs per unit of capital. The total innovation costs $R_{it}^{inno}$ and imitation costs $R_{it}^{imi}$ for firm $i$ at time $t$ is therefore:

$$R_{it}^{inno} := r_{it}^{inno} \cdot K_{it}$$
$$R_{it}^{imi} := r_{it}^{imi} \cdot K_{it}.$$  

The R&D expenditure rate per unit of sales is $r_{it}$, with $0 \leq r_{it} < 1$. A minimal investment is necessary to keep alive the R&D potential (i.e. research equipment and R&D personnel). We therefore require $r_{it} \geq r_{dmin}$. With $r_{it}$ firms invest in each period a fixed proportion of their sales in R&D (in addition to the minimal amount of R&D). Since a firm can choose to innovate or to imitate, R&D expenditures are assumed to be a function of sales and can be either innovative ($R_{it}^{inno}$) or imitative ($R_{it}^{imi}$):

$$R_{it}^{inno} = \alpha_i \cdot (r_{it} + r_{dmin}) \cdot p_t \cdot Q_{it}$$
$$R_{it}^{imi} = (1 - \alpha_i) \cdot (r_{it} + r_{dmin}) \cdot p_t \cdot Q_{it}$$

with $0 \leq \alpha_i < 1$.

The R&D expenditure of firm $i$ at one time $t$ is then:

$$R_{it} = \begin{cases} R_{it}^{inno} & \text{in case of innovation} \\ R_{it}^{imi} & \text{in case of imitation} \end{cases}$$  \hspace{1cm} (12)

Since firms can only either innovate or imitate at one time $t$, one of the values $R_{it}^{inno}$ and $R_{it}^{imi}$ is always equal to Zero. So we also can write equation (12) as follows:

$$R_{it} = R_{it}^{inno} + R_{it}^{imi}. \hspace{1cm} (13)$$

Innovation means firms search for a better technology which doesn’t exist or isn’t applied in the economy so far. Since the production techniques are embodied and there are no switching costs, the capital of the firm can be converted without any costs from one technology to another. So we only consider process innovation and no product innovation. The innovating firm does not replace its capital stock but uses is more efficiently. An innovation is therefore interpreted as a better knowledge of the production process. In other words, with innovation firms can only modify their efficiency parameters but not for instance the qualitative attributes of the output.

Imitation means firms regard the technologies applied in the economy, and if they found a better one, which grant them more productivity, and if they do not innovate, they adopt this technology in the next period.

**Innovation**

Innovation is a two-stage stochastic process. A first draw determines if the R&D investment has been successful and resulted in an innovation. The probability of such a draw is

$$Pr(d_{inno} = 1) := 1 - \exp^{-a_{inno}R_{it}^{inno}}.$$(14)
whereby $a^{inno}$ stands for the efficiency parameter for innovative R&D. This calibration parameter projects $R_{it}^{inno}$ on $[0,1]$, is constant over time and identical for all firms. $a^{inno}$ is industry-specific and an exogenous parameter of technological opportunities of innovative success. $R_{it}^{inno}$ is the innovative research level of firm $i$ at time $t$ with

$$
\hat{R}_{it}^{inno} = \psi^{inno} \cdot R_{i(t-1)}^{inno} + (1 - \psi^{inno}) \cdot (1 + r_{it}) \cdot \hat{R}_{i(t-1)}^{inno},
$$

(15)

whereby $\psi^{inno}$ can control the balance between the continuity of the research level and the research expenditure increase, $0 < \psi^{inno} < 1$.

The effective result of the innovation is found in the second draw. There are two possibilities concerning the result of innovation:

If we consider that innovation is a **cumulative process**, firms with higher productivities have a better chance to obtain higher productivities. The productivity in this case is:

$$A_{it}^{inno-cum} \sim \Theta_{lognorm}(A_{i,(t-1)}, \sigma^2),$$

whereby $\Theta_{lognorm}$ denotes the log normal distribution, with log mean given by $A_{i,(t-1)}$ and standard deviation $\sigma$. Log mean $= A_{i,(t-1)}$ means that innovative draws are based on firms’ previous input productivity levels. Therefore we call this innovative process “cumulative”. In this case, each firm is allowed to follow its own technological trajectory according to its R&D strategy.

In the case of **science based innovations** we have an evolution of latent productivity $\lambda$ which comes from the R&D activity realized outside of the industry. The productivity in this case is:

$$A_{it}^{inno-sb} \sim \Theta_{lognorm}(\lambda_{it}, \sigma^2),$$

whereby the latent productivity $\lambda_{it}$ is given by $\lambda_{it} = \lambda_{i,t-1} \cdot (1 + g_{it})^{a_{it}^{inno}}$, and the growth rate $g_{it}$ associated with innovation.

The **rule for innovation** is described as follows:

For the case of **cumulative innovations**:  
If $\Theta_{binary}(Pr(d_{inno} = 1)) = \text{TRUE}$  
then $A_{it}^{inno} := \Theta_{lognorm}(A_{i,(t-1)}, \sigma^2)$  
else $A_{it}^{inno} := 0$

For the case of **science based innovations**:  
If $\Theta_{binary}(Pr(d_{inno} = 1)) = \text{TRUE}$  
then $A_{it}^{inno} := \Theta_{lognorm}(\lambda_{it}, \sigma^2)$  
else $A_{it}^{inno} := 0$

$\Theta_{binary}(\ldots)$ is a binary probability function and takes the value TRUE with the probability which has been putted in this function.
Imitation

Analogously we discuss the imitation process. At this we install the bounded rationality assumption: firms do not “see” all the possible existing alternatives. They only discover a subset of the total alternative set. This can be imagined as follows: only a certain number of technologies are “visible” to the firms and the others are accordingly “invisible”. Only the visible technologies can be imitated by firms. If the firm is successful in the imitation draw, the best of the “visible” practices in the industry is obtained.

The probability for a imitative draw is given by:

$$ Pr(d_{imi} = 1) := 1 - \exp^{-a_{imi}{\hat{R}}_{imi}^t}. $$

(16)

$${\hat{R}}_{imi}^t$$ is the imitative research level of firm $i$ at time $t$ with

$$ {\hat{R}}_{imi}^t = \psi_{imi} \cdot {\hat{R}}_{imi}^{t-1} + (1 - \psi_{imi}) \cdot (1 + r_{it}) \cdot {\hat{R}}_{imi}^{t-1}, $$

(17)

whereby $\psi_{imi}$ indicates the balance between continuity of the research level and the increase of the expenditure rate, $0 < \psi_{imi} < 1$.

The rule for imitation is as follows:

If $\Theta_{\text{binary}}(Pr(d_{imi} = 1)) = \text{TRUE}$
then $A_{imi}^t := \Xi(\text{visible technologies } 1_t, \ldots, \#_t)$
else $A_{imi}^t := 0$

$\Xi(\ldots)$ is a function, which selects one technology of all applied technologies in the industry which are visible to the firm. The probability of selecting one technology is proportional to the capital which has been invested in this technology.

New productivity

The new productivity of firm $i$ for the next period $t + 1$ is:

$$ A_{i,(t+1)} = \max \{ A_{it}, A_{itinno}, A_{imi}^t \}. $$

(18)

3.5 Routines

Changes of the ”routines”: Each firm adapts its routine to the economic and technological situation. In case of the Japanese economic situation we have the exceptional phase of the so-called Bubble Economy: Japan’s extraordinary speculative boom of the 1980’s and the dramatic bust of the 1990’s. In case of the German situation we have the deregulation in the 1980’s and 1990’s on the one hand, and the formation boom of companies in the 1990’s (see figure 2).

Then, for both cases, we have the four technological phases of computer platforms within the IT development, which is shown in figure 3.

Additionally, the firms can change routines, i.e. their R&D expenditure rate per unit of sales, over time, whereby each firm differs in it: We have individual strategies to
define the dimension of the R&D expenditure rate, depending firstly on a multiplier $F$ related to the actual available human capital stock (Step 1) and secondly to the innovative behavior in the period before (Step 2).

**Step 1:** R&D expenditure rate depending on Multiplier $F$

The R&D expenditure rate is depending on their actual human capital stock, i.e.:

$$r_{it} = L_{it} \cdot F.$$  \hspace{1cm} (19)

In times of an economic revival firms decide to increase their factor $F$ about a multiple of $s$, individually determined, and in times of a cyclical downturn they reduce it analogously.

**Step 2:** R&D expenditure rate depending on the previous innovative behavior

The decision in $t + 1$ concerning the modification of the R&D expenditure rate is also depending on their innovative behavior in the period $t$.

If the firm innovates in $t$, they achieve its highest productivity by performing a radical innovation, which means, they are entering a new technological paradigm. But their accumulated knowledge until $t$ is concentrated on the old technological
paradigm. Consequently, the firm cannot benefit from their full accumulated knowledge. They start at a more or less new position in the field of research, so that they have to spend more for R&D, i.e. they increase their R&D expenditure rate about the factor $\epsilon$.

On the other hand, if the firm decides to imitate at $t$, the level of their capital stock will be kept, since they can profit by their accumulated knowledge. The R&D expenditure rate will be decreased about $\epsilon$.

In the case of neither innovation nor imitation, the R&D expenditure rate will not be changed.

So we have for the change of the R&D expenditure rate:

$$r_{i,(t+1)} = \begin{cases} 
(1 + \epsilon) \cdot r_{it} & \text{if } A_{i,(t+1)} = A_{it}^{\text{inno}} \quad \text{(e.g. in case of innovation)} \\
(1 - \epsilon) \cdot r_{it} & \text{if } A_{i,(t+1)} = A_{it}^{\text{imi}} \quad \text{(e.g. in case of imitation)} \\
r_{it} & \text{if } A_{i,(t+1)} = A_{it} \quad \text{(else)} 
\end{cases}$$

**Changes of the unit production costs**

The unit production costs of the applied technology will also be changed according to the imitative and innovative steps.

A successful imitation means that the firm is able to imitate the best and visible practices in the industry. In this case, the firm chooses the technique with the lowest unit production cost:

$$c_{it}^{\text{imi}} = \min \{ \tilde{c}_{1t}, \tilde{c}_{2t}, \ldots, \tilde{c}_{nt} \}$$

where analogously to equation (2) $\tilde{c}_{it} = \frac{1}{u_{it}^{\text{max}}} \cdot \frac{m}{A_{it}}$ is the unit cost associated with the technique with the maximum efficiency within the set of visible technologies.

Finally, the firm chooses between the existing technique and the best alternative resulting from the R&D effort according to:

$$c_{i,(t+1)} = \min \{ \tilde{c}_{it}, c_{it}^{\text{inno}}, c_{it}^{\text{imi}} \} \quad (20)$$

### 3.6 Investment in physical capital

Investment in physical capital is the other source of dynamics in the model. Capital investment results directly from the arbitrage of firms between R&D investment and capital expansion.

The desired investment is depending on the price, the costs, and the market share of each firm. But such decisions must be financially feasible, i.e. the firm must be capable of paying for new capital goods either with its own and/or with borrowed resources, subject to a given precautionary demand for liquid assets. These financial variables are a constraint to the firm’s desired investment. In other words, since these decisions are depending on their actual investing capability, the firms have to compare their actual margin with the target margin reflecting its market power.
Possible investment rate

The possible investment rate is for a negative gross profit rate the sum of the de-
preciation and the return on investment (ROI). For the positive case the firm can
finance its desired investment by profit and also by borrowing from the financial
system. So we have for the possible investment rate $i^P$:

$$
i^P = \begin{cases} 
\delta + \kappa_{it} & \text{for } \kappa_{it} \leq 0 \\
\delta + (1 + b) \cdot \kappa_{it} & \text{for } \kappa_{it} > 0
\end{cases}
$$

(21)

where $b, b > 0$, is the interest rate for external financing via borrowed capital, and
$\kappa_{it} = \frac{\Pi_{it}}{K_{it}}$ the return on investment (ROI).

Desired investment rate

The desired investment rate is putted in that way so that the investment over-
compensates the depreciation of capital, and is depending of the ratio of production
cost to price, market share and the return on investment (ROI).
The desired investment rate is:

$$
i^D = 1 + \delta - \frac{\rho_{it}}{\mu_{it}}
$$

whereby

$$
\rho_{it} = \frac{\rho_{it}}{c_{it}/K_{i,t+1}} \quad \text{(actual mark-up factor)}
$$

$$
\mu_{it} = \frac{2\chi - MS_{it}}{2\chi - 2MS_{it}} \cdot \kappa_{it} \quad \text{(desired mark-up factor)}
$$

$\chi, \chi \geq 0$ is the lack of aggressiveness in investment strategy.

$i^D$ is increasing with the market share, its capital resp. return on investment (ROI),
and the costs, and is decreasing with the productivity of the firm.

Firms have a minimum level for the capital stock, $K_{min}$, which determines the
boundary for the desired investment rate.

If \( (1 + \delta + i^D) \cdot K_{it} < K_{min} \)

\[ \Rightarrow i^D := \frac{K_{min}}{K_{it}} - 1 + \delta. \]

To sum up the investment decision, we have:

$$
I_{it} = \left( \max \{0, \min \{i^D, i^P\} \} \right) \cdot K_{it}.
$$

(22)

For firms have different sizes measured with their capital stock and human capital,
we must not neglect their fix costs, otherwise the competition would be determined
only by their amounts of R&D investments. Therefore, the capital stock of the firm
at $t + 1$ is:

$$
K_{i,(t+1)} = (1 - \delta) \cdot K_{it} + I_{it} - R_{it} - C_{it}^{fix}.
$$

(23)
with $C_{it}^{fix}$ indicating the fix costs of firm $i$ at time $t$ given by:

$$C_{it}^{fix} = C_{it}^{Lfix} + C_{it}^{Kfix} + UK_{it}^{k-1-k}.$$  

(24)

whereby $UK_{it}^{k-1-k}$: costs for changing from technology $k - 1$ to technology $k$.

**Fix costs for human capital**

$$C_{it}^{Lfix} = p^L \cdot L_{it} \cdot e^{\beta_L + LS_{it}},$$

with $\beta^L = const$, $p^L$: price for one unit of human capital, $LS_{it} = \frac{\sum_i L_{it}}{\sum_i}$.

**Fix costs for capital stock**

$$C_{it}^{Kfix} = p^K \cdot K_{it} \cdot e^{\beta_K},$$

with $\beta^K = const$, $p^K$: price for one unit of capital.

**Market concentration**

For the development of the whole industry we take the Herfindahl-Index. Nelson and Winter (1982) use the reciprocal term of it which is interpreted as “number of firms in an industry of equal-sized firms that has the same degree of concentration as the actual industry”.\footnote{Nelson and Winter (1982) [16], p. 301}

According to Andersen (1996 [3]) it is necessary to distinguish between the Herfindahl-index of production $H_{it}^Q$ and the Herfindahl-index of capital $H_{it}^K$. Both indices display different developments.

$$H_{it}^Q = \sum_{i=1}^{n_t} (MS_{it})^2 \quad \text{and} \quad H_{it}^K = \sum_{i=1}^{n_t} \left( \frac{K_{it}}{\sum_i K_{it}} \right)^2$$

(25)

### 3.7 Market entry and exit

**Market entry**

In each period a number of firms try to enter the market. The set of routines for each entrant is generated on the base of the pool of routines of existing firms. The entering firms have an initial setting equal to $K_{init}$ and $A_{init}$. In general, any firm may enter the market. The condition for entering the market is given as follows:

**Condition for market entry:**

\[ \text{IF} \quad T_{it} \geq T_{min} \land K_{it} = 0 \forall t^* < t \]

\[ \text{THEN} \quad \text{Firm } i \text{ enters the market, i.e. } K_{i,t} \equiv K_{init} \]

By modeling the variable $T_{it}$ (the technology knowledge stock) which also contains the spillover-effects, we can state for every period the potential of a firm to innovate. $T_{it}$ grows over time, especially due to the spillover-effects. If a firm, which didn’t exist
before (condition: $K_{i,t^*} = 0 \forall t^* < t$), has enough technology knowledge (condition: $T_{i,t} \geq T_{min}$) it can enter the market.

**Market exit**

There are several reasons for a firm to decide to exit a market. These selection of the firms depends on the firm’s performance. Therefore, we introduce a performance indicator $Z_{it}$ and $Z_{i,t}^*$ which depend on firm’s outputs like patents and publications and their development over time. The performance indicators of firm $i$ at $t$ are given by

$$Z_{i,t} = PD_{it} + SCID_{it} \quad \text{and} \quad Z_{i,t}^* = \frac{PD_{it} + PS_{it}}{2},$$

with

$$SCID_{it} = \frac{SCI_{it} - SCI_{i,t(t-1)}}{SCI_{it}} \quad (SCI: \text{Publication Development})$$

$$PD_{it} = \frac{Pat_{it} - Pat_{i,t(t-1)}}{Pat_{it}} \quad (PD: \text{Patent Development})$$

$$PS_{it} = \frac{Pat_{it}}{\sum_i Pat_{it}} \quad (PS: \text{Patent Share}).$$

$Z_{i,t}$ denotes the growths both of the patents ($Pat_{it}$) and the publication output ($SCI_{it}$), whereby the negative growth of one indicator can be compensated by the positive growth of the other one. $Z_{i,t}^*$ respects the development of the patents over time ($PD_{it}$) and the Patent Share $PS_{it}$. The specific conditions for market exit depend on the calibration. Therefore we introduce these conditions in section 4.1.

**4 Simulation**

**4.1 Empirical data and scenarios**

The analysis of the outcomes of competitive dynamics is computed with a simulation model developed with Vensim, a system dynamic based simulation tool for constructing models of business, scientific, environmental, and social systems.

System dynamics is a continuous simulation methodology that uses concepts from engineering feedback control theory to model and analyze dynamic socioeconomic systems. The mathematical description is realized with the help of ordinary differential equations. One important advantage of system dynamics is the possibility to deduce the occurrence of a specific behavior mode because the structure that leads to systems behavior is made transparent.

The simulation run is matched to the empirical data base: it contains for the Japanese case data from 1978 to 2002, and for the German case from 1961 to 2002. The data are taken from the Japanese companies NTT, NEC, Toshiba, Hitachi and Fujitsu, and from the German companies Siemens, IBM Germany, SAP, Nixdorf, Step Ahead and Vobis.\(^{10}\)

\(^{10}\)for empirical data see also appendix A.2
Country scenario A and B: Scenario A is the calibration with the Japanese data, scenario B the calibration with the German data. As mentioned in section 3.7 the market entry conditions are fixed and given, but we have separate conditions for market exit for each country scenario:

**Condition for market exit for scenario A:**

If \( K_{i,t} \leq K_{\text{min}} \)

or \( \Pi_{i,t} \leq 0 \) for \( t^* \) periods

or \( Z_{i,t} \leq 0 \) and \( MS_{it} < MS_{i,(t-1)} \)

or \( Z_{i,t} \leq 0 \) for \( t^* \) periods

then Firm \( i \) exits the market, i.e. \( K_{i,t'} := 0 \) for all \( t' > t \)

**Condition for market exit for scenario B:**

If \( K_{i,t} \leq K_{\text{min}} \) and \( MS_{it} < MS_{i,(t-1)} \) and \( Z_{it}^* < 0 \)

or \( PD_{it} \leq 0 \) and \( Z_{it}^* < 0 \) for \( t^* \) periods

or \( \Pi_{it} \leq 0 \) for \( t^{**} \) periods

then Firm \( i \) exits the market, i.e. \( K_{i,t'} := 0 \) for all \( t' > t \)

**Market scenario 1, 2, and 3:** Furthermore, there are three scenarios for A and B. Scenario 1 is the so-called base-scenario for which the values for the efficiency is set with \( a_{\text{inno}} = 0.25 \) and \( a_{\text{imi}} = 0.55 \).

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_{\text{inno}} )</td>
<td>0.25</td>
<td>0.025</td>
<td>0.55</td>
</tr>
<tr>
<td>( a_{\text{imi}} )</td>
<td>0.55</td>
<td>0.55</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Given \( a_{\text{inno}} = 0.025 \) the probability to innovate is 0.5% for each firm and period, i.e. there are an average of 0.05 innovations in the industry per period. Analogously, \( a_{\text{inno}} = 0.25 \) delivers a probability of 5% resp. 0.5 innovations.

The scenario 1 is composed to show a market development where innovations are possible and profitable, but imitations are more easily to realize. The second scenario represents a market with a lower efficiency for innovation (here innovation is less worthwhile compared to scenario 1), and in scenario 3 innovation is more profitable compared to scenario 1.

### 4.2 Results from simulation

In this section the most interesting and important results are presented.

After building up the simulation model and setting the initial values according to the real data set, we first have to ask if the simulation can trace the real development. This can be done by adjusting the according parameters in the model: The simulation model is able to trace the decision of the firms concerning their R&D investment and their innovation strategies.

**Result 1:** The base-scenario can trace the historical development, both for scenario A and for scenario B (so the first target is achieved, as to see in figure 4 and 5).
Figure 4: Development of the variables "R&D ratio to net sales" and "capital" in Scenario A (Base-scenario). The graphics show the real development (above) compared to the simulated development (beneath).

Figure 5: Development of the variable "labour" in Scenario B (Base-scenario), left: real development, right: simulated development.

**Result 2:** Learning and relevance of history and accumulated knowledge
But the more interesting question is, what do we learn from developing such a simulation model. By changing the "learning speed", the simulation can describe variants of the historical reality. Firms learn and adapt their routines, and adaptive learning can result in incremental improvements or change in existing competencies. In varying the learning speed, firms can change both their adoption and their innovation rate which has again an influence on their R&D status for the following periods. The dynamics underlying evolutionary theory is further supported by the finding that decisions in general and in particular to stay in the market or to exit the market are depending not only on their actual status but on their past development. So history matters (North 1990 [17]), i.e. their accumulated knowledge is a base for their actual decisions and economic performance.

**Result 3:** Incremental innovation and keiretsu in scenario A (the Japanese case)
For the Japanese case (scenario A) we conclude from the simulation that for none of the firms dramatic transformations of their routines could be obtained, consistent
with the cultural and institutional characteristics of the organizations and environment in Japan. The persistence of the firms, i.e. the economic survival of the firms in spite of their negative performance in the past shows the typical situation in Japan, that firms with long company tradition are not automatically forced to exit the market through the selection process. So a slackness of the market reaction could be demonstrated by the simulation model. Furthermore, Japanese firms operate in groups (keiretsu). They profit from the team-spirit and bond of the members of the group, exchange both (technological) knowledge and human capital. Therefore, spillover-effects are only gained within the own group-network, independent from the industry knowledge.

**Result 4:** persistence of the structure in scenario A (the Japanese case)
Another interesting result is, that in none of the scenario cases in scenario A market entrants could be observed. Regardless whether the market is open for innovations or not (i.e. independent from the specification of the efficiency parameters), firms cannot enter the market as long as they are not a member of a keiretsu group. There, oligopoly relationships (keiretsu) dominate the technological search stages for innovation.

**Result 5:** spillover and industry knowledge in scenario B (the German case)
A contrary observation is obtained in scenario B, the case with the German data. There, market entrance is possible, and there is a high relevance of technological knowledge of the industry for the German companies, in contrast to the Japanese case: the German firms do profit from the technology knowledge of the whole industry. Differently weighted, but the spillover-effects from other firms do influence the own knowledge and performance.

**Result 6:** the case of the company Nixdorf
Another interesting result for the German case is the development of the computer manufacturer Nixdorf: In the simulation model this firm is named “firm 3”, and this firm always has to exit the market, independent from the specification of the efficiency parameter. The question is why: Why must firm 3 always exit the market, why can firm 3 not survive? A look at the parameter ”learning” shows the answer: the parameter ”learning” demonstrates how this firm concentrates his focus on the technology phases (figure 6).

![Figure 6: Development of the variables "learning" in Scenario B.](image-url)
It is obvious that firm 3 persists in his viewpoint to concentrate on technology phase 1 and 2, although new technologies are already available. Firm 3 doesn’t want to invest time and money in new technologies, it wishes to stay at the technologies of phase 1 and 2. So, the fact that firm 3 adheres stubbornly to this own position is the true reason for the negative performance in the end and its unavoidable market exit. Since firm 3 never survives because of this "wrong” (not adequate regarding the technological development) behaviour.

Result 7: a counterfactual scenario for scenario B
The last step is now: One has to ask, what if firm 3 had behaved differently. This question results in the last experiment, i.e. scenario, where firm 3 has the same initial setting as before, but the learning parameters are now set similarly to the behavioural parameters of firm 1. This "what-if"-scenario shows a new development for firm 3: The result is that the computer manufacturer Nixdorf not necessarily had to exit the market in the year 1992, if it had followed another strategy (in the simulation done by assuming for Nixdorf to adopt routines of IBM Germany).

Result 8: relevance of the firm size not confirmed
What do we learn through simulation about the meaning of the firm size: For both cases (both scenario A and B) we could find that the size of a firm and the age of a firm are not an essential necessity for a positive performance. Both small-sized firms and traditional, large firms can survive and even grow. The assumed dependence or correlation between firm size and positive performance is unconfirmed by the simulation results, an interesting point.

5 Final Remarks

System Dynamics is an approach for the modeling and simulation of nonlinear dynamic systems that aims at the understanding of a system’s structure and the deduction of the behavior from it. This focus on understanding is a great advantage of the system dynamics methodology as it is a requirement for the development of policies that lead to the improvement of the system’s performance. On the other hand in a system dynamics model the structure has to be determined before starting the simulation and can not be changed during the course of a simulation experiment. The analysis of certain questions however, require the structure to be flexible. A innovation chain with technological phases is an excellent example of a dynamic system with a flexible structure. A firm can select the technology they use for production, decide whether they innovate, imitate or remain, switch from one technology to another, and firms can enter or exit the market.

The empirical findings reported in this paper are very interesting and new, but are limited by nature of the data set available. The time series cover merely a interval from 1961 to 2000 with only five firms for each country. We do not have complete information on the size and sector of the firms. Empirical studies of innovating firms show different patterns by size and sector (Pavitt 1984 [18], Malerba and Orsenigo 1996 [14]).

A deeper investigation, especially a more matched mechanism for the firms’ organizational routines and additional studies could help to advance knowledge of internal
firm dynamics and of the structure and processes of the routines, according to these the firms are acting. So the next step would be to represent the whole industry adequately, for it becomes necessary to extend the time series and to combine this micro-level with macro-level data to get the dynamic impact concerning the economic outcome at the industry level.

A Appendix

A.1 Some specifications of the parameters

At the beginning of the simulation, at time \( t = 0 \), each firm \( i \) is characterized by the productivity of its technology \( A_{i,t=0} \), its labour employed in production \( L_{i,t=0} \) and its capital stock \( K_{i,t=0} \), which are taken from the empirical data base. The characteristics of the five firms at \( t = 0 \) are \( A_{i,t=0} = 0.16 \ \forall \ i \), and:

<table>
<thead>
<tr>
<th></th>
<th>for scenario A</th>
<th>for scenario B</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_{1,t=0} )</td>
<td>45.000</td>
<td>23.000</td>
</tr>
<tr>
<td>( K_{2,t=0} )</td>
<td>70.000</td>
<td>18.000</td>
</tr>
<tr>
<td>( K_{3,t=0} )</td>
<td>106.000</td>
<td>0</td>
</tr>
<tr>
<td>( K_{4,t=0} )</td>
<td>200.000</td>
<td>0</td>
</tr>
<tr>
<td>( K_{5,t=0} )</td>
<td>1.500.000</td>
<td>0</td>
</tr>
</tbody>
</table>

for market entry observation: at least one \( i \) with \( K_{i,t=0} = 0 \)

Firms are acting in a market where they can operate as an individual competitor or in cooperation with another firm. If they cooperate we call it "family" or "keiretsu". The variable "keiretsu" determines where a firm searches for a new technology, influences the learning way and learning speed of a firm, has an affect on the spillover-effects (and therefore the technology knowledge), and last but not least controls the pool of human capital where a firm scoop for new employees. This relation modeled in Vensim is shown in figure 7.

![Figure 7: The variable keiretsu](image)

The technology knowledge stock \( T_{i,t} \) contains among others also the variables \( \rho_T \) and \( \Lambda \), which are exogenously given to the simulation model in respect to the specific sector (here: IT sector).

\( \rho_T \) indicates the rate of obsolescence of technology \( T \) and is equal to the reciprocal value of the life-span of a technology. In the case of the IT sector we have 4.9 years.

\[
\frac{1}{4.9 \text{ years}} = 0.2041 = 20.4\% \text{ per year} \quad \Rightarrow \rho_T = 0.2041
\]
Λ is the so-called lead time of a technology, i.e. the time lag between R&D and commercialization. In the case of the IT sector we have 2.8 years ($\Rightarrow \Lambda = 3$). Therewith, for the calculation of $T_{it}$ we regard R&D investment rates of the last three years but with different weights, i.e.:

$$\sum_{j=1}^{\Lambda} \frac{1}{\Lambda!} \cdot (\Lambda - j + 1) \cdot R_{i,t-j} = 3 \sum_{j=1}^{3} \frac{1}{3!} \cdot (3 - j + 1) \cdot R_{i,t-j}$$

$$= \frac{1}{6} \cdot 3 \cdot R_{i,t-1} + \frac{1}{6} \cdot 2 \cdot R_{i,t-2} + \frac{1}{6} \cdot 1 \cdot R_{i,t-3}$$

$$= 0.5 \cdot R_{i,t-1} + 0.333 \cdot R_{i,t-2} + 0.167 \cdot R_{i,t-3}$$

### A.2 Empirical data base

The empirical data are based on interviews with following firms (in alphabetic order, not connected with the order of labelling the firms in the simulation model) and on research at institutions listed as follows:

**For the Japanese case:**

- **Fujitsu Limited**
  6-1, Marunouchi 1-chome, Chiyoda-ku, Tokyo 100-8211, Japan.

- **Hitachi, Ltd.**
  6, Kanda-Surugadai 4-chome, Chiyoda-ku, Tokyo 101, Japan.

- **NEC Corporation**
  7-1, Shiba 5-chome, Minato-ku, Tokyo 108-8001, Japan.

- **Nippon Telegraph and Telephone Corporation (NTT)**
  3-1, Otemachi 2-chome, Chiyoda-ku, Tokyo 100-8116, Japan.

- **Toshiba Corporation**
  1-1, Shibaura 1-chome, Minato-ku, Tokyo 105-8001, Japan.

- **Outline of the Telecommunications Business in Japan: Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT)**
  2-1-2, Kasumigaseki, Chiyodaku, Tokyo 100-8926, Japan.

URL: http://www.soumu.go.jp/

- **The patent information** are obtained by the Japan Patent Office (JPO), based on JAPIO (Japan Patent Information Organization database)
  3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100, Japan.

- **The number of publications** of the firms are researched at the National Institute of Science and Technology Policy (NISTEP): 1-3-2 Kasumigaseki, Chiyoda-ku, Tokyo, 100-0013, Japan.

- **Teikoku Data base, Ltd.**
  2-5-20 Minami Aoyama, Minato-ku, Tokyo,107-8680, Japan.

URL: http://www.tdb.co.jp/

11) especially for Corporate Credit Research; Database Service; Market Research; Electronic Commerce Support; Publishing.
For the German case:

- **Ahead (Step Ahead AG)**
  Burgweg 6, 82110 Germering, Internet: http://www.stepahead.de

- **IBM Deutschland GmbH**
  "Haus zur Geschichte der IBM Datenverarbeitung" in Sindelfingen, Bahnhofstrasse 43, 71063 Sindelfingen, Tel.: +49-7031-415108

- **MAXDATA Computer GmbH & Co.**
  Elbestraße 12-16, 45768 Marl, Tel: +49-2365-952-2000,
  Internet: http://www.maxdata.de/

- **Nixdorf Computer AG**
  The Heinz Nixdorf Forum in Paderborn:
  Heinz Nixdorf MuseumsForum, Fürstenallee 7, 33102 Paderborn,
  Telefon +49-5251-3066-00, Telefax +49-5251-3066-09,
  URL: http://www.hnf.de/

- **SAP Deutschland AG & Co. KG**
  Neurottstrasse 15a, 69190 Walldorf,
  Tel: +49-6227-747474, Fax: +49-6227-757575, E-Mail: info.germany@sap.com,
  Internet: http://www50.sap.com/germany/

- **Siemens AG**
  Corporate Technology (Zentrale): Otto-Hahn-Ring 6, 81739 München,
  Tel.: +49-89-636-00, URL: http://www.siemens.de/

- **VOBIS AG**
  Berliner Straße 140, 14467 Potsdam,
  Tel: +49-331-201363-00, Fax: +49-331-201363-10,
  Internet: http://www1.vobis.de/

- for the patent information: Data base of: DEPATIS-Systems (Deutsches Patent- und Markenamtes (DPMA)) (URL: http://depatisnet.dpma.de/)
  Data base of: european patent office (Europäisches Patentamt (EPA)) (URL: www.epoline.org)

- Firm data base "Hoppenstedt" (for development of number of start-up firms)

- Stifterverband Wissenschaftsstatistik (Classification of Economic Activities according to NACE)

- Federal Statistical Office Germany, BMBF

References


