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Diversity of innovative strategy as a source of technological performance

by
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Abstract

This paper explores the impact of diversity of innovative strategies of firms upon the industrial dynamics through a micro-simulation model. We consider two types of firms each one being characterised by a specific innovative strategy. Basically we assume that some cumulative firms adopt an internal learning by searching strategy, while non-cumulative firms adopt an external learning strategy aiming at absorbing external sources of knowledge. The results show that the co-existence of the two types of firms leads to an oligopolistic structure characterised by asymmetries in the size of firms and high technological performances. Thus the diversity of innovative strategies generates a diversity in firms market shares and is a source of dynamic efficiency in the long run.

Keywords

Industrial dynamics, innovation, diversity, learning.

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Contents:

Introduction

Most empirical studies on industry evolution emphasise interindustry variations in terms of performances and innovative behaviour of firms (Cohen and Levin, 1989; Levin, 1995; Patel and Pavitt, 1995; Dosi, Malerba, Marsili, Orsenigo, 1997). These studies generally focus on the size of firms which is pointed out as an explanatory variable of the variations in technological performances. In the same line of inquiry, a substantial body of descriptive evidence has been accumulated on how the nature and effects of demand, opportunity and appropriability conditions differ across industry. Malerba and Orsenigo (1996, 1997) study the role of the characteristics of the technological environment upon industry evolution by using the schumpeterian concept of technological regime. The basic argument is that the nature of knowledge, the cumulativeness of innovation, as well as opportunity and appropriability conditions, lead to different patterns of innovative activities which strongly influence the evolution of technology and industrial structure. The characteristics of the technological environment, which define the technological regime, are put forward as an explanation for interindustry variations.

One neglected issue in the empirical literature is the role of *interfirm* differences in innovative strategy and technological performance. The theoretical literature provides some guidance in identifying the sources of interfirm variations in innovative activity and performance. Evolutionary theory of technological change underlines the specific and cumulative character of innovative activities of firms. The paradigmatic representation of technological change suggests that there are several local innovation processes going on at the same time in the boundaries delimited by the paradigm (Dosi, 1988). It leads to a diversity of innovation, more precisely to a diversity of technological knowledge and competencies developed by firms.

The work of Nelson and Winter (1982) puts forward that, in a world of bounded rationality and radical uncertainty, firms accumulate technological competencies and knowledge which may strongly differ according to their experience and their "innovative draws". In this framework, interfirm variations mainly result from the past history of success and failure of firms in their R&D process. Even though the model of Nelson and Winter presents some restrictions, it sheds some light on the role of heterogeneity of firms in the evolution of the structure of a single industry.

Related to this topic of diversity, Malerba (1992) proposes a conceptualisation of learning which can be summarised in two hypotheses. First, firms learn in a variety of different ways that may be linked to different sources of knowledge. Secondly these various learning processes generate a range of technological trajectories. The purpose of the model presented in this paper is to propose a framework which enables us to analyse more deeply the role of these *interfirm* technological variations in a given industry. We propose to focus on the diversity of learning and innovative strategy of firms. We investigate this issue not only by considering technological diversity as an outcome of the innovation and selection processes, but also by taking into account the diversity of firms' innovative strategy. This latter dimension corresponds to an intentional form of diversity that is linked to strategic decisions of a population of firms producing an homogeneous good. Our purpose is to explore through simulation the interplay between this diversity of

innovative strategy and the resulting technological diversity which characterises the industry in the long run.
First we present the various features of diversity and the model of industrial dynamics. In the second part, we analyse the results of the simulations in order to emphasise the impact of the diversity of innovative strategies upon the evolution of the industrial structure and the performances of the industry.

1. The role of diversity: an exploration through a micro-simulation model

The concept of diversity has different meanings depending on the theoretical background that is considered. In a first step, we propose to clarify this point of definition by proposing a taxonomy of the different types of diversity. In the second paragraph, the micro-simulation model is presented with particular emphasis on the innovative strategy of firms.

1.1. The different types of diversity

Cohendet and Llerena (1997) distinguish between four types of diversity.

- **Diversity of factor endowments**

In the neoclassical framework, the diversity of factor endowments is the main source of comparative advantages: differences in opportunity costs between economic agents, regions and countries lead to comparative advantages. This is the main reason for (and explanation of) the division of labour and trade and thus, in a way, the starting point of the whole theoretical construction of the neoclassical exchange economy.
In our model factor endowments are represented by the initial capital stock and productivity level of new firms entering the industry. These endowments do not remain constant over time since the processes of market competition and innovation induce an evolution of diversity. But our focus will not be on this type of diversity, even though it is part of the initial conditions of the simulations.

- **Diversity of products and/or processes**

The growing diversity of products and services that we use in our everyday life and in productive processes is, as Saviotti (1991) points out, one of the most important aspects of economic development. While the variety of products and services increases, some existing products and processes disappear. The balance between the emergence of new and different products and services and the disappearance of existing ones determines the net static variety of the economic system at a given point in time. Strategies of product differentiation as well as process and product innovations are laying behind these phenomena.

In our model the diversity of products is not represented since firms offer an homogeneous good on a single market. We only consider incremental process innovations that is more efficient ways of producing a given product.

- **Diversity of behaviours and strategies**

More recent developments have emphasised other sources of diversity. Many theoretical and empirical works reveal the limits of a concept of diversity only linked to the variety of products or endowments. In particular it seems important to focus more on the diversity of behaviours and strategies. This type of diversity has been at the centre of the literature in industrial organisation of the 1950s and the 1960s.
More recently, evolutionary approaches have given priority to a process of economic change driven by the diversity of economic behaviours. The competitive issue is explored through the co-existence of firms with different behaviours and the pattern of their relative growth and survival. In this framework the question is how a selection environment translates this diversity of behaviours into patterns of economic change, in particular into diversity in growth rates and market shares of firms. Focusing on the selection process, Metcalfe (1992) shows that changes take place because of the variety of behaviours coexisting in the selection environment and that the rate of change is directly related to the consequent diversity in the rate of growth of competing firms.

In our model, we also consider the innovation process and its impact upon the selection of firms. We introduce diversity of behaviours through the diversity of innovative strategies. Basically we distinguish between two types of firms: cumulative firms adopt an innovative strategy based on an internal learning by searching process, while non cumulative firms are characterised by a strategy of absorption of external sources of knowledge. Our interest is on the interplay between these two types of firms and its impact upon the industrial dynamics. This diversity of innovative strategies will determine the accumulation of knowledge of firms and the evolution of technologies and market shares.

- **Diversity of technologies: competencies and knowledge**

R&D activities and innovative strategy of firms imply specific learning processes and different technological trajectories. As a matter of fact different local innovation processes go on at the same time creating technological trajectories specific to firms. It is thus possible to describe technical change as a process of change that builds on diversity and in the meantime creates diversity: "diversity drives evolution and evolution generates diversity" (Cohendet and Llerena, 1997, p.227). More precisely we can argue that diversity is a necessary condition and a result of technological change.

The diversity of behaviours (in particular R&D and innovative strategy) can be considered as a necessary condition for the process of technological change. For instance, Silverberg, Dosi and Orsenigo (1988) show that diversity of behaviours is necessary for the adoption of a new technology characterised by uncertain returns. In the same vein, Chiaromonte and Dosi (1992) show that the diversity of behaviours and competencies has a positive effect on the rate of innovation. The results of their simulations point out that the rate of innovation and the aggregate outcome are lower when firms exhibit similar microeconomic characteristics. More recently Ballot and Taymaz (1997) consider a more complex situation including diversity of decision rules in physical investment, training and R&D. They are able to show that diversity of rules is self-sustained and that in spite of learning there is no tendency towards uniformity. Their results exhibit a fairly stable steady state of diversity and show the importance of variety for macroeconomic performances. These various contributions indicate that the diversity of firms' expectations, behaviours and learning processes tends to foster technological change and economic performance. Our paper falls within the same perspective with particular emphasis on the diversity of the processes of learning and innovation.

Technological diversity is also a result of the innovation process. Indeed technological diversity emerges from the interplay between specific competencies inside and outside the firm, and from the interactions between the firm and its environment. Iwai (1984) explains the emergence and the persistence of technological diversity as the result of selection, imitation and innovation processes. In the Nelson and Winter (1982) tradition, Jonard and Yildizoglu (1998) obtain a similar result by introducing localised learning and increasing returns to adoption. In these papers, the authors study the impact of heterogeneous behaviours on the emergence of technological diversity.

In this paper, we focus on the impact of the diversity of firms' innovative strategies upon technological diversity and the whole industrial dynamics. In the perspective of Nelson (1994), the basic argument is that the two types of diversity are intertwined since rules of behaviour and innovations are likely to have reciprocal influences: "*There is a coevolution between institutions and technologies*".

1.2. The model of industrial dynamics

The influence of diversity upon industrial dynamics is studied through a micro-simulation model which depicts the evolution of firms' market share and technology.
The basic structure of the model is based on previous works of Oltra (1997a, 1997b). We consider an industry composed of n firms assumed to produce the same homogeneous good with a unique production factor which is capital. This industry faces a downward sloping demand curve with price-elasticity equal to one. Capital is numeraire so that its unit cost is supposed equal to one. In the Nelson and Winter (1982) tradition, each firm is characterised by its capital stock and its productivity level. Productivity (output per unit capital) represents the technology of each firm which can be improved through innovation. This last assumption means that technological change is not *embodied* in capital or equipment. In such a context, innovations lead to improvements in production techniques which are modelled as increases in capital productivity. In other words, innovations entail a more efficient utilisation of capital.

- The short-run system

At the beginning of period *t* the state of the industry is given by:

$$K_t = (K_{1t} ... K_{it} ... K_{nt})$$

$$A_t = (A_{1t} ... A_{it} ... A_{nt})$$

where K_{it} is the capital stock and A_{it} is the capital productivity of firm *i* at period *t*.
The output of firm *i* at period *t* (Q_{it}) is simply given by $A_{it}.K_{it}$. At the industry level, total supply Q_t corresponds to the sum of individual outputs. The price is given by the following unit-elastic demand function:

$$P_t(Q_t) = \frac{D}{Q_t^{\,1/\eta}}$$ with *D*>0 and • =1.

We assume that the variable production cost per unit capital *(c)* is constant over firms and technology so that the profit[2] of firm *i* at time *t* is given by $\Pi_{it} = (P_t.A_{it} - c).K_{it}$. For each firm, we denote π_{it} the profit rate per unit capital.

At each period firms invest in R&D and in capital in order to expand their market share. We assume that R&D is a priority for firms since their survival in the industry mainly depends on their ability to increase their productivity level. Nevertheless firms cover the physical depreciation of capital first. Thus the sequence of investment decisions is the following: first covering of the physical depreciation of capital, then investment in R&D, and finally additional capital investment in order to increase capital stock. This sequence is justified by the fact that, although R&D is a priority, firms are not willing to endure decreases in their capital stock insofar as it leads to decreases in the productive capacity.
We also assume that decision rules governing firms' investment are simple fixed rules which reflect bounded rationality. These decisions rules are differentiated among firms for R&D investment since firms exhibit distinct innovative strategy.

- Innovative strategy of firms

We differentiate between two types of firms according to their learning processes and their innovative strategies. We distinguish between cumulative firms and non-cumulative ones.

- **Innovative strategy of cumulative firms**

Cumulative firms correspond to the category of firms which invest in R&D in order to accumulate technological knowledge and to generate innovation internally. According to the taxonomy of Malerba (1992), we can say that these firms adopt a *learning by searching* process that is internal to the firm and mainly related to R&D activities aiming at developing and accumulating new technological knowledge.

- R&D investment

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[2] Π_{it} is gross profit before investment.

In this perspective we assume that these firms invest in R&D in order to maintain an efficient level of technological performances. So the level of R&D investment is determined according to a comparison between the technological performances of firms and the industry average level of performances. In our model technological performances are represented through productivity levels of firms. We assume that cumulative firms increase their R&D investment when they suffer a technological lag in comparison with the market share weighted industry average productivity.

The desired investment rate in R&D per sales unit of firm *i* at time *t* (r_{it}^{des}) is determined according to the following rule :

$$If\ A_{it} < \overline{A}_t,\quad r_{it}^{des} = r_{i,t-1}^{des} + \lambda.(\overline{A}_t - A_{it})$$

$$If\ A_{it} \geq \overline{A}_t,\quad r_{it}^{des} = r_{i,t-1}^{des}$$

with $\overline{A}_t$ the market share weighted industry average productivity given by $\sum_{i=1}^{n} \mu_{it}.A_{it}$, μ_{it} being the market share of firm *i* at time *t*. λ is an adaptation parameter of R&D investment such as $0 < \lambda < 1$.
According to this rule cumulative firms increase their R&D investment proportionally to their technological lag.

Effective R&D expenditure are bounded above by the funding constraint i.e. profit minus capital depreciation. Thus total R&D expenditure of firm *i* at time *t* are given by :

$$R_{it} = Min(r_{it}^{des}.P_t.Q_{it}\,;\Pi_{it} - \delta K_{it})$$

with δ the depreciation rate of capital.

Firms' R&D expenditure determine their research level $(\overline{R}_{it})$ which is a weighted average of past research level and the current R&D expenditure. This research level index describes the evolution of firms' R&D expenditure:

$\overline{R}_{it} = \alpha_R.\overline{R}_{i,t-1} + (1-\alpha_R).R_{it}$ with α_R a parameter weighting past research level $(0 < \alpha_R < 1)$

R&D activities of firms enable them to develop and to accumulate new technological knowledge. In other words, firms build their knowledge base through their research activities. Then this knowledge base determines the firms' ability to innovate. In order to represent this process of learning and knowledge accumulation, we introduce a function of knowledge accumulation depending on R&D activities of firms.

- Knowledge accumulation and innovation

We model the learning by searching process of cumulative firms through a knowledge accumulation function depending on R&D investment. We assume that at time *t* the stock of accumulated knowledge of firm *i* is given by the following equation:

$$z_{it} = (1-\alpha_z).z_{i,t-1} + \overline{R}_{it}$$

with α_z the depreciation rate of knowledge and $\overline{R}_{it}$ the research level of the firm.

Then we assume that the stock of exploitable technological knowledge of the firm $(\overline{z}_{it})$ is given by a logarithmic function of accumulated knowledge, which implies decreasing returns on R&D:

$$\overline{z}_{it} = \ln(1 + z_{it})$$

This stock of exploitable knowledge determines the probability to innovate which is a logistic probability function:

$$P_{it}^{Inn} = \frac{P_1}{P_2 + P_3.\exp(-a_n.\overline{z}_{it})}$$

with P_{it}^{Inn} the probability of firm *i* to innovate at time *t*, P_1, P_2, P_3 the parameters bounding the logistic function and a_n the speed at which the maximum probability to innovate is approached. This logistic function implies increasing and then decreasing returns in the process of knowledge accumulation and innovation.

The technological trajectory of the industry is given by the *technology space* which is a set of productivity levels (see appendix). This technology space, which represents the potentialities of the prevailing technology, is not known by firms. Through their innovative activities firms try to progress in their exploitation of the technology potentialities. In this perspective, we assume that the innovation process consists in a draw of a productivity level in a normal distribution centered around the current productivity level of the innovative firm (with standard deviation σ). Then the productivity level of the new technology (A_{it}^{Inn}) is the productivity level of the technology space that is closest to the innovative draw.

The new technology is adopted by the firm only if it provides a higher productivity level than the prevailing technology. Thus the productivity level of firm *i* for the next period is given by:

$$A_{i,t+1} = Max(A_{it}; A_{it}^{Inn})$$

The assumption according to which innovative draws are centered around the current productivity level of firms reflects the *cumulativeness* of innovation. It implies that the result of innovation is determined by past technological performances of innovative firms. It means that each firm is able to follow its own technological trajectory according to its research activities and knowledge accumulation. In that sense, the innovation process is cumulative at the firm level.

- Innovative strategy of non-cumulative firms

This second category of firms is involved in an innovation process depending on external sources of knowledge. We assume that non-cumulative firms learn from public research and intra-industry spillovers. Cohen and Levinthal (1989, 1990) emphasise this dimension of R&D activities by arguing that while R&D generates innovations, it also develops the ability of firms to exploit knowledge coming from the environment. This ability is what the authors call *the absorptive capacity* of firms: this capacity to absorb externally generated knowledge depends on R&D activities and on the characteristics of the knowledge to be absorbed. In Cohen and Levinthal (1989), these characteristics are represented by a parameter (β) that reflects the degree of complexity and specificity of knowledge. (β) is increasing with the complexity of knowledge and decreasing with the degree to which it is targeted to industrial applied developments and to the needs of firms: the higher (β), the more difficult the absorption of knowledge.

Following Cohen and Levinthal, we assume that non-cumulative firms build up their absorptive capacity progressively on the basis of their R&D activities. We consider the absorptive capacity of non-cumulative firms (γ_{it}) to be a function of their research level[3]:

$$\gamma_{it} = 1 - \frac{2\beta}{\sqrt{\overline{\mathrm{R}}_{it}}} \quad \text{with } 0 < \beta < 1$$

The research strategy of non-cumulative firms consists in investing in R&D in order to improve their absorptive capacity and to exploit technological knowledge coming from public research and intra-industry spillovers.

- R&D investment

The motivation of non-cumulative firms to invest in R&D is linked to their absorptive capacity. We assume that their purpose is to reach the maximum absorptive capacity in order to be able to exploit the maximum of the technological knowledge externally generated. This upper limit of the absorptive capacity function is noted $(\overline{\gamma})$. The desired investment rate in R&D per sales unit is given by:

$$\text{If } \gamma_{it} < \overline{\gamma}, \quad r_{it}^{des} = r_{i,t-1}^{des} + \lambda.(\overline{\gamma} - \gamma_{it})$$
$$\text{If } \gamma_{it} \geq \overline{\gamma}, \quad r_{it}^{des} = r_{i,t-1}^{des}$$

This rule reflects the fact that non-cumulative firms increase their desired investment rate in R&D proportionally to their lack of absorptive capacity. But effective R&D expenditure are bounded above by the residual profit after the covering of the physical depreciation of capital. Total R&D expenditure of firm *i* at time *t* are given by:

$$\mathrm{R}_{it} = Min(r_{it}^{des}.P_t.Q_{it}\,;\Pi_{it} - \delta K_{it})$$

This R&D investment determines the research level of non-cumulative firms $(\overline{\mathrm{R}}_{it})$ according to the same equation as the one used for cumulative firms.

- Knowledge accumulation and innovation

[3]As in Cohen and Levinthal (1989), the absorptive capacity function is increasing at a decreasing rate with firms' R&D investment, decreasing with β and so that the marginal impact of own R&D on absorptive capacity is increasing with β.

Non-cumulative firms accumulate technological knowledge by absorbing knowledge resulting from intra-industry spillovers and public research. We assume that the level of spillovers depends on the market share weighted average research level $(\overline{R}_t)$ which is given by:

$$\overline{R}_t = \sum_{i=1}^{n} \mu_{it} . \overline{R}_{it} \quad \text{with } \mu_{it} = \frac{Q_{it}}{\sum_{i=1}^{n} Q_{it}}$$

μ_{it} is the market share of firm *i* at time *t*.

We assume that the largest firms (in terms of market share) generate more spillovers than the smallest ones. That is the reason why we assume that the level of spillovers is given by the rate of spillovers (θ_s) multiplied by the market share weighted average research level $(\overline{R}_t)$.

Thus the stock of exploitable technological knowledge of firm *i* at time *t* is given by:

$$\overline{z}_{it} = (1-\alpha_z).\overline{z}_{i,t-1} + \gamma_{it}.\left[\theta_s.\overline{R}_t + R_p\right]$$

with α_z the depreciation rate of knowledge and (R_p) the level of public research exploitable by firms. According to this equation, the stock of exploitable technological knowledge of non-cumulative firms is composed of the knowledge previously accumulated and the absorbed external knowledge. This external knowledge is given by the level of intra-industry spillovers and the public research which is relevant for firms within the considered industry.

The stock of exploitable knowledge determines the probability to innovate according to the same logistic probability function as the one of cumulative firms. The innovation process also consists in a draw of a productivity level in a normal distribution. The distinctive feature of the innovation process of non-cumulative firms is that innovative draws are centered around the market share weighted industry average productivity $(\overline{A}_t)$. This feature implies that non-cumulative firms do not follow their own technological trajectory but the one of the industry. We call these firms non-cumulative since they do not accumulate knowledge generated internally, but exploit external sources of knowledge and try to absorb technological advances of the industry. The purpose of non-cumulative firms is mainly to follow the technological trend of the industry. In that sense, the innovation process is not cumulative at the level of firms but at the level of the whole industry. The innovative strategy of these firms is closer to a specific type of technology imitation than to a purely innovative strategy. To summarise we can say that the innovative strategy of non-cumulative firms is based on external learning and on the absorption of technological knowledge coming from their environment.

- Capital investment

After having invested in R&D, firms determine whether they increase their capital stock or not. We assume that they use a simple satisficing rule to fix this additional investment in capital.. The return on investment per capital unit is given by the profit rate π_{it}. Let ρ denote the minimum expected rate of return on capital. If the rate of return π_{it} is smaller than this minimum rate, firms do not make any additional investment, that is they do not invest more than the physical depreciation of their capital stock. In the opposite case, firms invest part of their profits to increase their capital stock. In that case, the desired rate of capital growth (τ) is constant and equal for each firm. Let ΔK_{it} denote the additional capital investment of firm *i* at time *t* in capital units (the unit price of capital being equal to 1). Given that there is no external financing, additional capital investment is bounded above by residual profits after the covering of physical depreciation and R&D investment. Thus the decision rule governing additional capital investment is given by:

$$If\ \pi_{it} < \rho \quad \Delta K_{it} = 0$$

$$If\ \pi_{it} \geq \rho \quad \Delta K_{it} = Min[\tau.K_{it}; (\Pi_{it} - \delta K_{it} - R_{it})]$$

with δ the depreciation rate of capital.

- Entry and exit of firms

Each firm is characterised by a performance index (X_{it}^{P}) which depends on its profit rate:

$X_{it}^{P} = \alpha_{P}.X_{i,t-1}^{P} + (1-\alpha_{P}).\pi_{it} \quad with\ \alpha_{P} \in \left]0,1\right[$ a parameter weighting past performance

A firm may exit the industry for either of two reasons. The first reason is the decrease of the capital stock below a minimum capital stock level K_{Min}. The second condition for exit is that the performance level of the firm is below a critical negative level X_{Min}.

As to entry of firms, we differentiate between two types of entrants, that is between cumulative and non-cumulative firms. For each type of entrants, the entry process is a Poisson process with means N^{C} and N^{NC} corresponding respectively to the average number of potential cumulative and non-cumulative entrants.

We assume that cumulative firms enter the industry endowed with a technology resulting from innovation. More precisely they draw a productivity level in a normal distribution centred around the market share weighted industry average productivity[4]. Then they adopt the technology (A^{C}) which corresponds to the productivity level of the technology space that is the closest to this innovative draw. Concerning non-cumulative firms, we assume that they enter the industry by imitating the best technology prevailing in the industry. By this hypothesis, we assume that non-cumulative entrants correspond to the most efficient imitative firms trying to enter the industry. Let (A^{NC}) denote the productivity level of non-cumulative potential entrants.

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[4] We can not assume a draw centred around the current productivity level of firms since, before entry, cumulative firms are not endowed with any technology.

Whether a potential entrant becomes an actual entrant depends on the evaluation of the profit opportunities generated by the technology of entry. This evaluation consists in multiplying the productivity level of entrants $(A^{NC}\ or\ A^{C})$ by the current price of output (P_t) and subtracting from the result the cost of production per capital unit (c). This calculation determines the net rate of excess return per period which must be superior to the entry barrier rate (r_e) for the potential entrant to become an actual entrant.

2. The impact of diversity upon industrial dynamics: results of the simulations

In order to study the role of the diversity of innovative strategies, we compare three configurations:

- the first one corresponds to the non-cumulative case in which every firm adopts the non-cumulative innovative strategy;
- the second configuration corresponds to the pure cumulative case - i.e. only cumulative firms enter the industry -;
- in the third configuration, which corresponds to the diversity case, the mean of the Poisson entry process for cumulative and non-cumulative firms is calibrated so that the number of effective entrants of each type is approximately the same.

By comparing these configurations, we explore the impact of the co-existence of the two types of firms upon the industrial dynamics.

Given that the industrial dynamics is mainly driven by stochastic innovative draws, we run 100 simulations for each configuration. The purpose is to generate enough *histories* to be able to tackle the emergent properties of the industrial dynamics and in particular to infer properties relatively independent of the sequences of random numbers. The values of the parameters used in the simulations are presented in appendix. In a first step we present the average results of these 100 simulation runs by specifying the standard deviation. Then for the most relevant variables, such as productivities and market shares, we use the whole distribution generated by the simulations.

2.1 Average results of the simulations

The following table presents the average final period results of 100 simulation runs for each configuration. The numbers in parentheses correspond to the standard deviations of the 100-run samples. To characterise the evolution of the industrial structure, we use the Herfindahl numbers equivalent index ($1/H_t$) :

$$\frac{1}{H_t} = \frac{1}{\sum_{i=1}^{n_t} \mu_{it}^2}$$

where n_t is the number of firms in the industry at period *t* and μ_{it} is the market share of firm *i* at time *t*.

In table 1, C-firms denotes cumulative firms and NC-firms non-cumulative ones. For each type, we distinguish the number of entrants from the number of firms surviving in the industry in the long run.

	Non-Cumulative Case	Cumulative Case	Diversity Case
Herfindahl numbers equivalent	10.3 (2.4)	1.9 (0.7)	5.5 (2.5)
Capital stock per firm	225.5 (55.1)	1086 (296)	332 (117)
R&D expenditure per firm	3.4 (1)	11.3 (6.8)	4.3 (1.96)
Nb. of C-entrants	-	15.8 (3)	8.9 (1.9)
Nb. of NC- entrants	12.2 (3.1)	-	7.4 (2.6)
Nb. of surviving C-firms	-	2.5 (1)	1.3 (0.6)
Nb. of surviving NC-firms	12 (3)	-	7.2 (2.4)
Average productivity level	1.95 (0.3)	2.1 (0.34)	2.2 (0.3)
Maximum productivity level	1.98 (0.3)	2.28 (0.36)	2.27 (0.3)

Table 1: Average final period results of each configuration

- Market structure

We notice a significant difference in concentration between the three configurations. On average the cumulative case is concentrated as if it was composed of two firms of equal size. We have observed that in 63% of the cases the industrial structure ends up in a duopoly. We also observe that the number of cumulative entrants surviving in the long run is very low: on average almost 16 cumulative firms enter the industry but only 2.5 survive. This feature characterises the trend towards concentration of the cumulative configuration. This trend is also illustrated by the distribution of the final period market share of firms (figure 1 in appendix)[5]. The median of this distribution is equal to 0.3 which means that 50% of the firms reach a market share superior to 30%. This distribution also exhibits a wide dispersion which is due to cumulativeness. The high market shares of firms explain the intensity in capital and in R&D of the cumulative configuration. Indeed we observe that the average capital stock and R&D expenditure per firm are markedly higher than in both other configurations. This result is linked to a self-enforcing effect between concentration and intensity in capital and in R&D, which is one of the characteristics of cumulative technological regimes (Oltra, 1997a).

As to the non-cumulative case, it exhibits the opposite properties that is a low degree of concentration, a high rate of survival of NC-entrants (almost equal to 1) and a low intensity in capital and in R&D. The distribution of the final period market share of firms (figure 2 in appendix) points out that the market is equitably shared among firms which

[5] More precisely, figure 1 represents the distribution of the final period market share attained by firms in each simulation run (over the 100-runs samples).

have a final period market share contained between 5% and 15% (with a mode equal to 10%).
The diversity case exhibits an intermediate value of the Herfindahl numbers equivalent which is equal to 5.5 (on average). We can say that, in terms of concentration, the diversity case corresponds to an intermediate configuration in comparison with both other cases. We can notice that almost all the NC-entrants survive in the long run, while the rate of survival of C-firms is only equal to 15%. Thus the diversity case ends up in an oligopolistic structure composed of a few cumulative firms and of almost all the non-cumulative entrants.

These results can be summarised by the following proposition:

Proposition 1: *The evolution of the industrial structure is conditioned by the innovative strategy of firms. The purely cumulative case leads to a highly concentrated market structure very intensive in capital and in R&D, while the non-cumulative case generates an industrial structure much less concentrated. The co-existence of both types of firms (diversity case) leads to an oligopolistic structure characterised by a few C-firms and a high rate of survival of NC-entrants.*

In order to characterise more precisely the industrial structure of the diversity case, we have to distinguish between C-firms and NC-firms. Figures 3 and 4 in appendix present the distribution of the final period market shares and capital stocks of C-firms and NC-firms in the diversity case. We observe strong similarities between these distributions. Indeed the form of the distribution of final period market shares is very similar to the one of the distribution of capital stocks for each type of firms. It appears that the diversity case is characterised in the long run by a few cumulative firms which dominate the industry with high market shares and large capital stocks. As to non-cumulative firms, they survive with low market shares and small capital stocks. We also notice that NC-firms exhibit quite homogeneous market shares, while the distribution of the market shares of C-firms presents a wide dispersion. This feature is linked to cumulativeness which entails strong path-dependencies and irreversibilities. We observe a strong linear correlation between capital stocks and market shares (see figure 5 in appendix) which characterises this self-enforcing effect between the intensity in capital and the market shares of C-firms.
These differences between C-firms and NC-firms are summarised by the following proposition:

Proposition 2: *Diversity of innovative strategies creates diversity of firms' capital stocks and market shares.*

This proposition illustrates the argument according to which diversity drives evolution and evolution generates diversity (Cohendet and Llerena, 1997). In our framework, the diversity of innovative strategies influences the industrial dynamics by creating asymmetries in the productive capacities and the market shares of firms.

- Technological performances

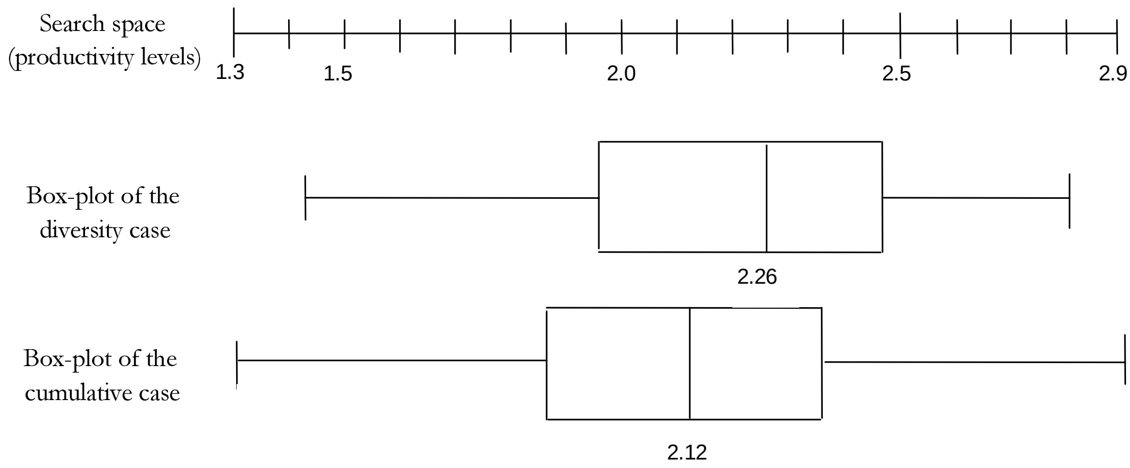
In our model, technological performances correspond to the ability of firms to exploit the potentialities of the prevailing technology (given by the technology space). Thus we can evaluate these performances by the productivity level of firms. The average results presented in table 1 enable us to compare the industry average and maximum productivity levels that are reached in the long run in each configuration. We observe that the NC-case exhibits lower average and maximum productivity levels than both other configurations. We deduce from these results that, in the NC-configuration, firms exploit the technology space less efficiently.
In order to compare the cumulative case with the diversity one, we need to consider the whole distribution of the final period productivity level of firms since the difference is not significant on average. More precisely, for each configuration we consider the distribution of the final period productivity levels reached by firms in all the 100 simulation runs. In this way we avoid using average results over the simulation runs. Both distributions are represented by figure 6 in appendix. Table 2 presents the main statistics of the distribution of each configuration.

	Diversity case	Cumulative case
Mean	2.2	2.1
Standard deviation	0.34	0.33
Variance	0.11	0.11
First quartile	**1.975**	**1.865**
Median	**2.26**	**2.12**
Third quartile	**2.47**	**2.35**
Mode	**2.44**	**1.825**
Minimum value	1.425	1.3
Maximum value	2.8	2.9

Table 2: Statistics of the distribution of the final productivities of firms (100 simulation runs)

Each distribution can be summarised by a box-plot[6] representation :

[6] The box-plot summarises the central value and the dispersion of the distribution. The limits of the box correspond to the first and the third quartiles of the distribution, while the vertical line in the box indicates the median.



These results show that the distribution of the final period productivity levels of firms tends to be concentrated on higher productivity values in the diversity case than in the cumulative one. We notice that the median and the mode are significantly higher in the diversity case than in the cumulative one. We conclude that firms better exploit the technology space in the diversity case than in the purely cumulative one. This argument is strengthened by the average R&D expenditure per firm which are lower in the diversity case (cf. table 1). This feature underscores that R&D activities are more efficient when both types of firms co-exist: in the diversity case, firms reach higher productivity levels with lower R&D expenditure.

These results suggest our third proposition.

Proposition 3: *The diversity of innovative strategies of firms tends to further the technological evolution of the industry. In that sense, diversity of innovative strategies appears as a source of technological performances.*

In order to describe the diversity case more precisely, we have to consider separately the productivity levels of C-firms and NC-firms. Table 3 gives us the main statistics of the distribution of the final period productivity of C-firms and NC-firms in the diversity case.

	Cumulative firms	Non-cumulative firms
Mean	2.22	2.20
Standard deviation	0.32	0.34
First quartile	2.02	1.97
Median	2.28	2.24
Third quartile	2.47	2.47
Mode	2.53	2.44

Table 3: Statistics of the distribution of the final period productivity levels of firms (diversity case)

We notice that C-firms and NC-firms exhibit close productivity levels. This feature is due to technological interdependencies between firms. Indeed the innovative activities of NC-firms depend on the technological performances of C-firms, since their innovative draws are centred around the market share weighted industry average productivity. Insofar as the surviving C-firms have high market share, their productivity levels strongly influence innovative draws of NC-firms. Thus in the long run, a few C-firms tend to dominate the industry (in terms of market share) and their innovative activities generate technological spillovers which are exploited by NC-firms. The exploitation of these technological interdependencies leads to higher technological performances.

Finally to characterise the global efficiency of the industrial dynamics, we can distinguish between static and dynamic efficiency. Static efficiency is mainly linked to social surplus in the short run, while dynamic efficiency concerns technological performances in the long run. Given that the diversity case is much less concentrated than the cumulative one, we conclude that static efficiency is superior in the diversity case. As to dynamic efficiency, the analysis of technological performances of firms clearly shows that it is higher in the diversity case than in the cumulative one. This leads us to conclude that the diversity of innovative strategies tends to foster the efficiency of the industrial dynamics.

Conclusion

This paper explores the impact of the diversity of innovative strategies upon the industrial dynamics through a micro-simulation model. We consider two types of firms each one being characterised by a specific innovative strategy. Basically we assume that C-firms adopt an internal learning by searching strategy, while NC-firms adopt an external learning strategy aiming at absorbing external sources of knowledge.
The results show that the co-existence of the two types of firms leads to an oligopolistic structure characterised by asymmetries in the size of firms and high technological performances. Thus diversity appears to be both a result of the industrial dynamics, in particular in terms of capital stocks and market shares, and a condition for the innovation process since the diversity of innovative strategies tends to increase the technological performances of the whole industry. In that sense, the simulations illustrate the argument according to which diversity is a necessary condition and a result of technological change. Finally these results suggest that an increase in the diversity of innovative strategies of firms may lead to an increase in the efficiency of the industrial dynamics. In this context there is room for policy tools appropriated for enhancing diversity.

References

BALLOT G. and TAYMAZ E., 1997, "Technological change, rule generation by firms and macroeconomic coordination: an evolutionary model", *Journal of Artificial Societies and Social Simulation*, Vol. 2, Issue 2, march 1999.

CHIAROMONTE F. and DOSI G., 1992, "The micro-foundations of competitiveness and their macroeconomic applications", in FREEMAN C. and FORAY D. (eds.), *Technology and the wealth of nations*, Pinter: London, pp. 107-134.

COHEN W.M., 1995, "Empirical studies of innovative activity", in STONEMAN P. (ed.), *Handbook of the economics of innovation and technological change*, Blackwell, pp. 182-265.

COHEN W.M. and LEVINTHAL D., 1989, "Innovation and learning: the two faces of R&D", *The Economic Journal,* Vol.99, pp. 569-596.

COHEN W.M. and LEVINTHAL D., 1990, "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly,* Vol. 35, pp. 128-152.

COHEN W.M. and LEVIN R.C., 1989, "Empirical studies of innovation and market structure", in SCHMALENSEE R. and WILLIG R.D. (eds.), *Handbook of industrial organization*, Vol.2, Amsterdam: Elsevier, pp. 1059-1107.

COHENDET P. and LLERENA P., 1997, "Learning, technical change and public policy: how to create and exploit diversity", in EDQUIST C. (ed.), *Systems of innovation: technologies, institutions and organisations,* Cassel Pinter, Chap.10, pp.223-241.

DOSI G., 1988, "Sources, procedures and microeconomic effects of innovation", *Journal of Economic Litterature*, Vol. XXVI, pp. 1120-1171.

DOSI G., MALERBA F., MARSILI O. and ORSENIGO L., 1997, "Industry structures and dynamics: evidence, interpretations and puzzles", *Industrial and Corporate Change*, Vol. 6, pp. 1-24.

IWAI K., 1984, "Schumpeterian dynamics I and II", *Journal of Economic Behaviour and Organization*, Vol.5, pp. 159-190, 321-351.

JONARD N. and YILDIZOGLU M., 1998, *Sources of technological diversity,* Strasbourg: mimeo BETA.

LLERENA P. and OLTRA V., 1998, "The role of diversity in industrial dynamics", Paper presented at the International J.A. Schumpeter Society, Vienna, Austria, 13-16 June 1998.

MALERBA F., 1992, "Learning by firms and incremental technical change", *The Economic Journal*, Vol. 102, pp. 845-859.

MALERBA F. and ORSENIGO L., 1996, "Schumpeterian patterns of innovation are technology specific", *Research Policy*, Vol. 25, pp. 451-478.

MALERBA F. and ORSENIGO L., 1997, "Technological regimes and sectoral patterns of innovation activities", *Industrial and Corporate Change*, Vol. 6, pp. 83-117.

METCALFE S., 1992, "Variety, structure and change: an evolutionary perspective on the competitive process", *Revue d'Economie Industrielle*, Special Issue, *Technological diversity and coherence in Europe*, Vol.59, pp. 46-61.

NELSON R.R. and WINTER S.G., 1982, *An evolutionary theory of economic change*, Boston, Mass., The Belknap Press of Harvard University Press.

NELSON R.R., 1994, "The co-evolution of technology, industrial structure and supporting institutions", *Industrial and Corporate Change*, Vol. 3, pp. 47-63.

OLTRA (1997a), *Industrial Dynamics and diversity in schumpeterian technological regimes*, Strasbourg: Mimeo BETA n° 9715.

OLTRA (1997b), *Politiques technologiques et dynamique industrielle*, Thèse de Doctorat de l'Université Louis Pasteur, Strasbourg.

PATEL P. and PAVITT K., 1995, "Patterns of technological activity: their measurement and interpretation", in STONEMAN P. (ed.), *Handbook of the economics of innovation and technological change*, Blackwell, pp. 14-52.

SAVIOTTI P.P., 1991, "The role of variety in economics and technological development", in SAVIOTTI P.P. and METCALFE S. (eds.), *Evolutionary theories of economic and technical change: present status and future prospects*, Chur (GBR): Harwood Academic Publishers, pp. 172-208.

SILVERBERG G., DOSI G. and ORSENIGO L., 1988, "Innovation, diversity and diffusion: a self-organization model", *The Economic Journal*, Vol.98, pp. 1032-1054.

Appendix

- Parameter settings

Parameter in the demand function: D = 500
Production cost per unit capital: c = 0.16
Depreciation rate of capital: δ = 0.02
Expected return rate of capital: $\rho = 0.05$
Increase rate of capital: $\tau = 0.05$
Parameters weighting past performances: $\alpha_R = \alpha_P = 0.5$
Adaptation coefficient in R&D investment rate: $\lambda = 0.1$
Degree of complexity of knowledge: $\beta = 0.3$
Depreciation rate of knowledge: $\alpha_z = 0.3$
Spillovers rate: $\theta_s = 0.03$
Public research level: R_P= 0.3
Upper limit of the absorptive capacity: $\bar{\gamma} = 0.8$
Parameters in the logistic function of probability to innovate:
$P_1 = 0.035, P_2 = 0.05, P_3 = 0.65, a_n = 4.5$
Standard deviation of innovative draws: $\sigma = 0.025$
Means of the entry Poisson process:
- cumulative case $N^C = 0.35$
- non-cumulative case $N^{NC} = 0.25$
- diversity case $N^C = 0.2$ and $N^{NC} = 0.05$
Entry barrier rate: $r_e = 0.05$
Minimum performance level: $X^P_{Min} = -0.05$
Minimum capital stock level: $K_{Min} = 20$
Initial R&D desired investment rate: $r^{des} = 0.05$

- Technology space (productivity levels):

{0.4, 0.41, 0.42, 0.43, 0.435, 0.44, 0.45, 0.46, 0.48, 0.5, 0.506, 0.51, 0.515, 0.52, 0.53, 0.54, 0.55, 0.56, 0.58, 0.60, 0.64, 0.67, 0.7, 0.705, 0.71, 0.715, 0.72, 0.726, 0.730, 0.74, 0.745, 0.75, 0.76, 0.77, 0.80, 0.81, 0.815, 0.82, 0.83, 0.838, 0.842, 0.85, 0.86, 0.87, 0.875, 0.88, 0.888, 0.9, 0.92, 0.95, 0.97, 1.01, 1.05, 1.08, 1.10, 1.105, 1.110, 1.115, 1.120, 1.130, 1.14, 1.15, 1.158, 1.166, 1.176, 1.186, 1.201, 1.211, 1.22, 1.23, 1.245, 1.263, 1.283, 1.303, 1.33, 1.36, 1.39, 1.425, 1.475, 1.5, 1.51, 1.515, 1.52, 1.53, 1.538, 1.545, 1.55, 1.576, 1.604, 1.614, 1.619, 1.629, 1.644, 1.659, 1.677, 1.69, 1.705, 1.723, 1.74, 1.755, 1.775, 1.795, 1.825, 1.865, 1.895, 1.925, 1.95, 1.975, 2.0, 2.01, 2.02, 2.03, 2.035, 2.04, 2.05, 2.072, 2.087, 2.105, 2.12, 2.14, 2.16, 2.185, 2.20, 2.22, 2.23, 2.24, 2.255, 2.26, 2.27, 2.275, 2.28, 2.29, 2.298, 2.313, 2.33, 2.347, 2.36, 2.378, 2.396, 2.416, 2.44, 2.47, 2.5, 2.53, 2.56, 2.58, 2.6, 2.63, 2.65, 2.67, 2.69, 2.7, 2.73, 2.75, 2.77, 2.80, 2.82, 2.84, 2.87, 2.9, 2.95, 3.0}

Results of the simulations

Figure 1: Distribution of the final period market share of firms in the cumulative case

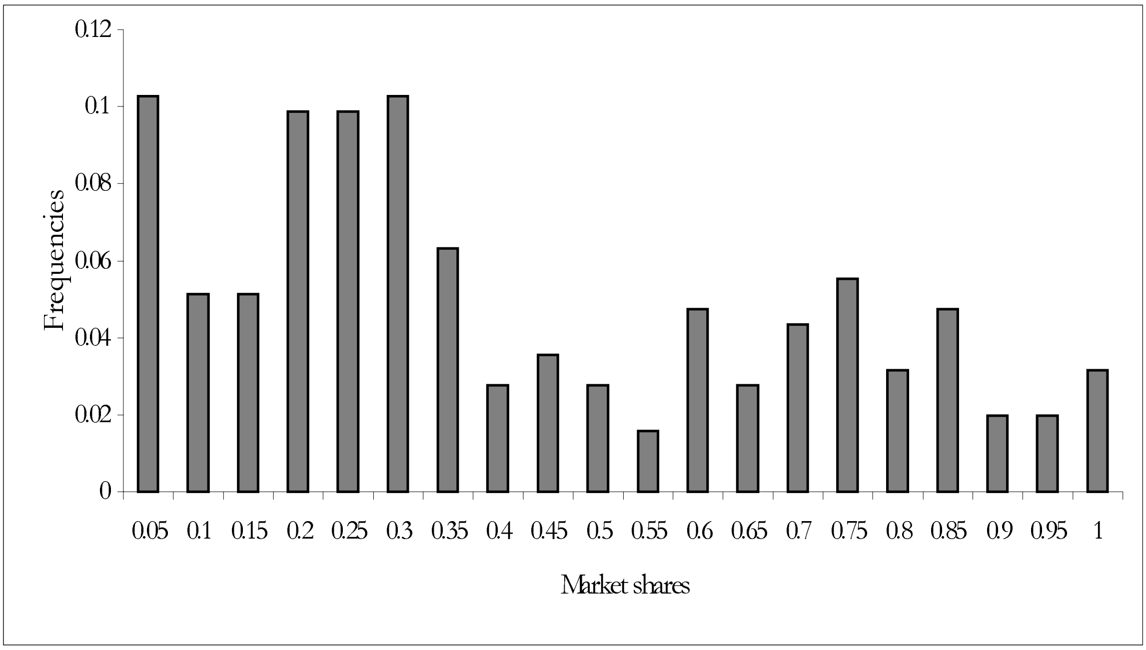


Figure 2: Distribution of the final period market share of firms in the non-cumulative case

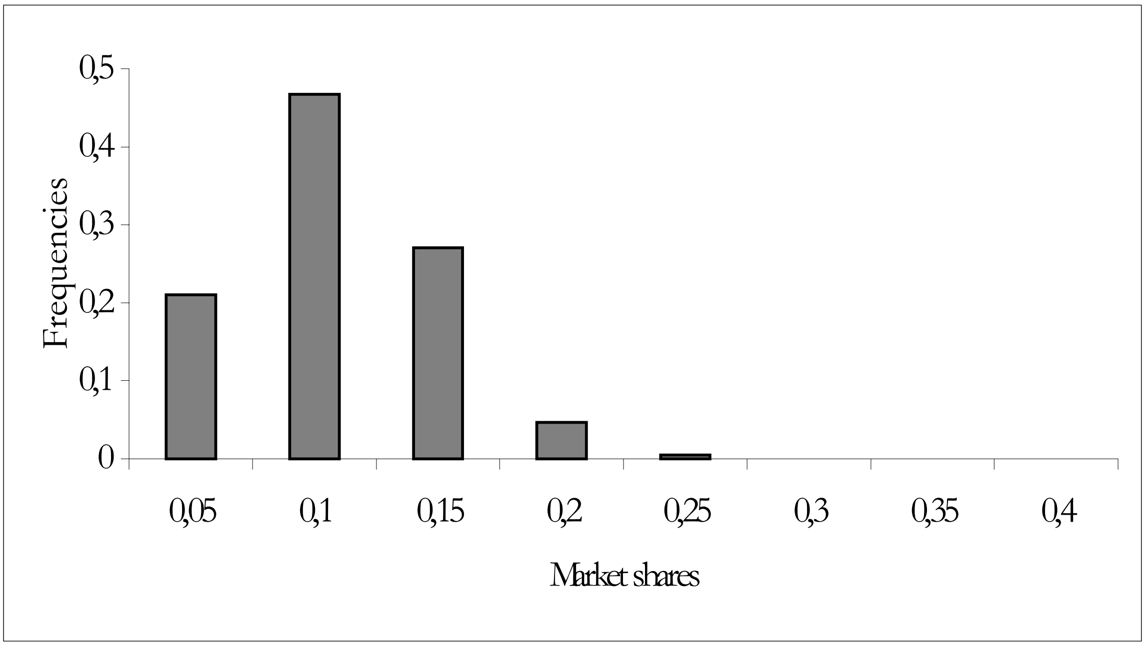


Figure 3: Distribution of the final period market share of firms in the diversity case

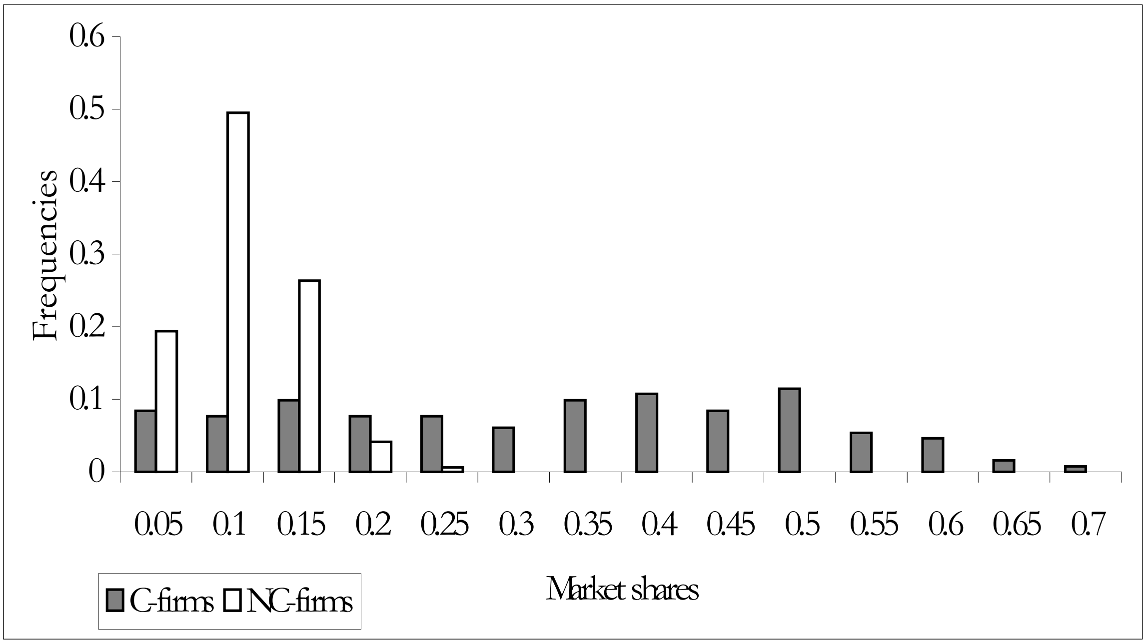


Figure 4: Capital stocks and market shares of C-firms in the diversity case (linear regression)

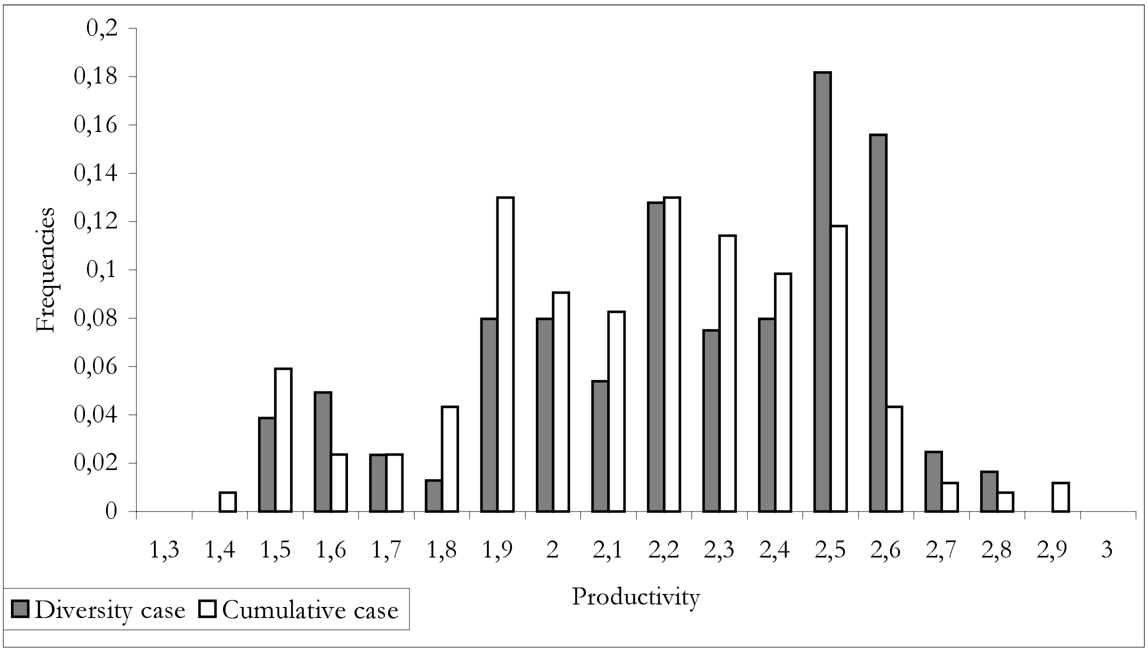


Figure 5: Capital stocks and market shares of C-firms in the diversity case (linear regression)

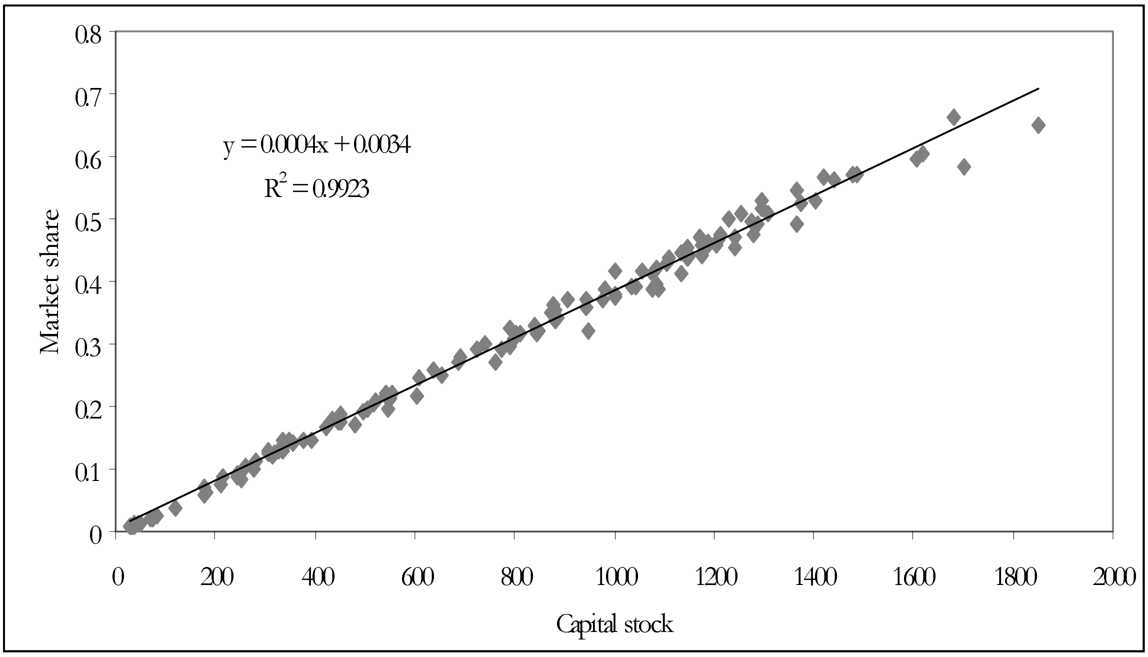
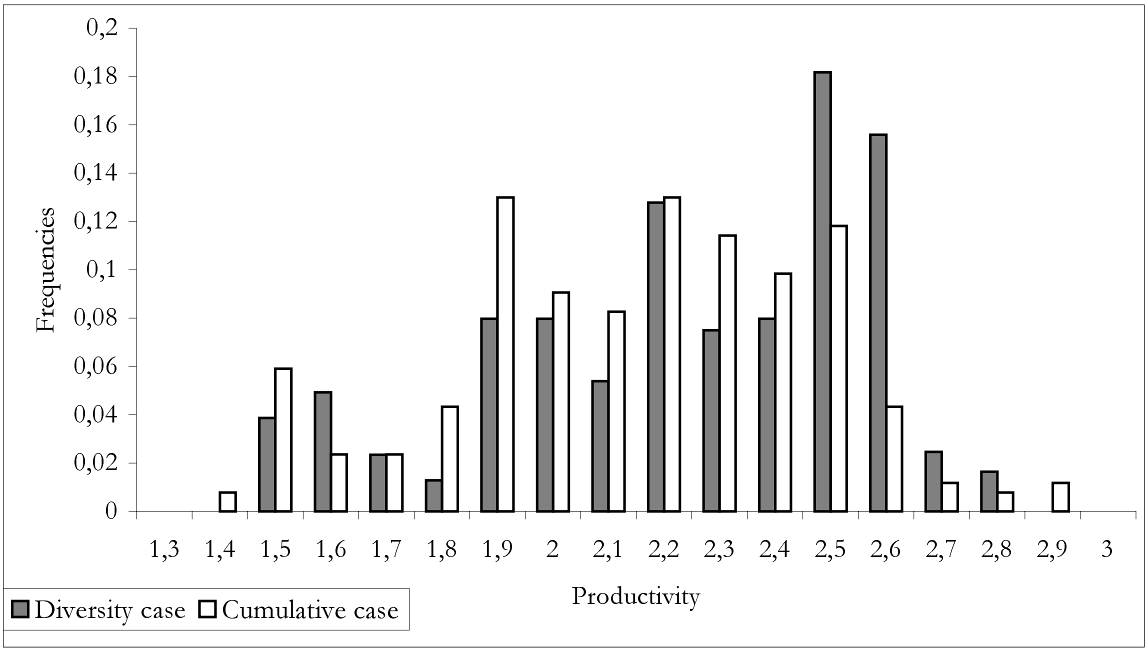


Figure 6: Distribution of the final period productivity of firms



Danish Research Unit for Industrial Dynamics

The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the resource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human resources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

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There are at present more than 10 Ph.D.-students working in close connection to the DRUID research programme. DRUID organises regularly specific Ph.D-activities such as workshops, seminars and courses, often in a co-operation with other Danish or international institutes. Also important is the role of DRUID as an environment which stimulates the Ph.D.-students to become creative and effective. This involves several elements:

- access to the international network in the form of visiting fellows and visits at the sister institutions
- participation in research projects
- access to supervision of theses
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