What drives Market Structure? On the relation between firm demographic processes, firms' innovative behaviour and market structure.*

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Abstract

In this paper we suggest an structural model that specifies firm growth as a function of firm specific parameters and of competition for purchase power with other firms on a given market. Moreover, we explicitely model firms' innovative behaviour and distinguish between different innovation regimes. On the basis of a set of simulations of this model we derive a number of empirically testable hypotheses. A subset of these have already found support in the empirical literature. We take these as evidence in favour of the explanatory power of the model. In addition, we are able to derive further testable propositions on the interaction of firm-demographic processes, innovative behaviour and market structure that go beyond the existing literature and that we suggest for further research. We conclude that the approach chosen here provides a fruitful pathway for further research.

Keywords: Firm size distribution, innovation regime, technological regime, industrial dynamics, firm demography, carrying capacity, market concentration, rank order turbulence.
JEL-Classification: L60, O30, G30

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1 Introduction

1.1 On the Relation between Innovation and Market Structure

For a long time industrial economists have investigated whether market structure has an influence on the innovative behaviour of firms. A number of studies investigated the importance of innovation in concentrated industries or the impact of firms size on innovation intensity of industries (e.g. Mason, 1951; Scherer, 1965, 1967; Philips, 1971). However, most tests conclude that relations are non significant. Thus, Cohen and Levin[1989] conclude that the empirical results on the topic are largely unconclusive because investigators have failed to take account of more fundamental sources of variation in the innovative behavior and performance of firms and industries.

This observation is consistent with a growing body of literature on the fundamental determinants of interindustry differences in innovation and their influence on concentration, turbulence, average firm size and more generally market structure and dynamics. This literature provides evidence that the causal structure goes in the other direction, i.e. that innovation causes market structure. In this perspective, there is more and more evidence that industry specific characteristics affect the relationship between innovation and market structure and that the relative contributions of entrant and established firms to innovation may depend on these industry conditions and, in particular on the *technological regime* that dominates the industry. According to Nelson and Winter[1982] or Winter [1984], a technological regime is defined by the specific combination of technological opportunities, appropriability of innovations, cumulativeness of technical advances and the properties of the knowledge base underpinning firms innovative activities.

Following the schumpeterian tradition, Malerba and Orsenigo[1994] distinguish between two market configurations. *Schumpeter I* configuration is related to high degrees of cumulativeness and appropriability, high importance of basic sciences and relatively low importance of applied sciences as sources of innovation. Then, innovation is rather undertaken by established firms which "exploit" a specific technological trajectory by accumulation of idiosyncratic capabilities. The other configuration, which they call *Schumpeter II*, is generated by low degrees of cumulativeness and appropriability, a high importance of applied sciences and an increasing role of external sources of knowledge. Then, innovation is undertaken by new firms to the industry that "explore" new trajectories. This two technological regimes have also been labeled "routinized" and "entrepreneurial" respectively: "An entrepreneurial regime is one that is favorable to innovative entry and unfavorable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way around" (Winter, 1984, p.297).

A number of empirical studies confirm the hypothesis of the existence of these two different technological regimes (Acs and Audretsch, 1991; Audretsch, 1991; Breschi, Malerba and Orsenigo, 2000). This suggests that, from the point of view of the firm, there are two types of innovation patterns: the "exploitation" of existing trajectories or the "exploration" of new trajectories. March[1991] makes a distinction along these lines: while "explorative search" consists in experimenting with new options from which new possibilities can be learned from, "exploitative search" consists in the identification, routinization, and extension of good ideas. Almeida and Kogut[1997] and Almeida[1999] extend on this in arguing that usually small firms, are more likely to explore technologically diverse and uncrowded territories, leaving the domination of more mature technologies to larger firms. Stuart and Podolny[1996] show that large firms tend in fact to innovate along standard and well-explored fields.

These arguments are consistent with the life-cycle hypothesis according to which early in the history of an industry, when the technological trajectory is not yet fully established, uncertainty is very high while barriers to entry are very low, it is new firms that are the major innovators and the key elements in industrial evolution. Later, as the industry develops and eventually matures and technological change follows well defined trajectories, economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process. Then it is the large firms with monopolistic power that come to the forefront of the innovation process (Utterback and Abernathy, 1975; Gort and Klepper, 1982; Klepper, 1996; Geroski and Mazzucato, 2000).

Audretsch[1995], Malerba and Orsenigo[1996] and Breschi *et al.*[2000] find that industries differ in terms of concentration, innovative activities among firms, size of innovative firms, change in the hierarchy of innovative firms, importance of new innovative firms as compared to established ones, and that this is related to the technological regime that characterizes the industry. Moreover Baldwin and Johnson[1999] give evidence that stronger innovative behaviour increases firms' growth potential. In their sample of firm start-ups, they find that faster-growing entrants are more innovative than slower-growing entrants. Baldwin, Chandler, Le and Papailiads[1994] confirms this finding in showing that innovation is the key factor that discriminates between more and less successful firms. Geroski, Van Reenen and Walters[1996] find that innovators tend to be persistent, exhibiting serial correlation of growth rates.

On the theoretical side, Nelson and Winter[1982] have proposed that differential success in innovation performance conduct to variance in firm growth rates and ultimately in variations in firm size, survival, rank-order turbulence and levels of firm concentration. Hence, in their framework, innovation causes market structure. Their model implies that firm size is an endogeneous variable that is precisely affected by how firms succeed in innovation. It also implies that the industry structure depends on the variance in firms' growth that again depends on the differential successes in innovation. This implies that differential growth is related to the level of technological opportunities, whether generated by firms own R&D-activities or by external sources. Nelson and Winter predict for instance that concentration is positively affected by the level of technological opportunities.

However, their model remains unsatisfying when it comes to the consideration of firms' change in behaviour since they postulate firms with static attributes.

In a close vein, Dosi *et al.*[1995] provide a model where there are significant relations between the properties of technological regimes and concentration levels and turbulence. They find that the relation between technological opportunities and concentration depends on whether those opportunities are captured by the established firms or rather by new entrants. Moreover, their model predicts that higher opportunities for entrants imply higher market turbulence and higher interfirm asymmetries in terms of firm performance. Their model thus exhibits differential serial correlation of growth rates of entrants and incumbent firms depending on the technological regime of the industry and indicates that this affects both concentration levels and turbulence. Their model does however specify firms as either incumbents of entrants but does not investigate the nature of their innovative behaviour. In this respect, firms are modelled as a black box.

1.2 The Aim of This Paper

We derive from these arguments that there are two types of innovation strategies: explorative and exploitative search, that they tend to be exclusive in the sense that new firms are more likely observed as doing explorative search whereas established firms are more likely observed as doing exploitative search. However, today's incumbents are former start-ups, which means that they have transited from an explorative search strategy to an exploitative search strategy. Hence firms would follow historical paths, from exploration to exploitation, with many of them failing.

The motivation of this paper is to provide a model of this process of explorative and exploitative search and of the transition between both search regimes. On this basis, we aim to analyze the implications of innovation on the demography of firms and the structure of markets. The model will therefore address all firm demographic processes such as entry, growth, selection and exit. We assume the firms to be bounded rational and to proceed in an uncertain environment.

Our approach therefore differs from existing models (Lucas, 1978; Hopenhayn, 1992; Jovanovic, 1982; Klette and Griliches, 2000; Klette and Kortum, 2000) that consider firm dynamics as movement towards a state of equilibrium. Moreover, we explicitly consider the implications of firm demographic processes on market structure. In that respect, our approach goes beyond Lucas[1978] or Jovanovic[1982] who model firm selection as neutral process with respect to market structure. In these models, the firm size distribution is a limit distribution of some underlying distribution (of managerial capabilities in the case of Lucas[1978] or cost efficiency in the case of Jovanovic[1982]). The approach to be developed here deviates from these models in that it presents a model of growth of boundedly rational firms in an uncertain environment and that the implications of the model are inductive in the sense that results are not driven by some ex ante assumed state of affairs or distribution of firm performance.

The following section presents the model. Section 3 will derive a number of stylized facts that the model reproduces. Section 4 derives a number of propositions on the relation between firm demographic processes, firms' innovation behaviours and market structure. Section 5 concludes.

2 The Model

The aim of the model is to investigate the behaviour of an economy that results from interaction of a large number of firms. These firms are heterogeneous with respect to their innovative behaviours and may shift endogeneously between those behaviours. These firms are interconnected via the potential of their products and via the *market size* of the artificial economy. This implies that the larger the potential of existing firms' products, the larger the share they occupy from the market and thus the lower the opportunities (i.e. potential and thus market share) for the new entrants or the opportunities for existing firms in increasing their potential via R&D.

Firms are classified according to whether they act within an *entrepreneurial* or a *routinized innovative regime* (see discussion above). Firms enter and try to introduce a new product (or a new technology) in the market. This product is assumed to have a certain market potential that the firms do not know a priori but will discover with the process of selling their product. Thus, firms know neither if the product they suggest is successful, nor do they know the potential of technological improvement of the product. If the product is unsuccessful, the firm engages into a (cost inducing) search for a new product. Hence the firm *explores* what could be called the "product-market space". If the product has proven to be successful and if it has shown sufficiently high market potential, the firm will start to *exploit* this technology, i.e. it will stop searching for a new one and concentrate on the production of the successful product. We refer to these states as *exploring* and *exploiting regimes*.

2.1 Specification of the Exploring Regime

Representation of Firms. Firms i are characterized by their size $s_{i,t}$ at time t and their R&D- intensity ρ_i which is independent of their size (e.g. Cohen and Klepper, 1992; Klette and Griliches, 2000). $s_{i,t}$ expresses not only *output* but can also be interpreted as *input* and as *financial endowment* of firm i at time t. That is we assume a very simple linear homogeneous production structure (where input of one factor translates directly into output). Moreover, by choice of unit we set the factor endowment of firm i at time t equal to the value of this factor and assume that this value can be monetized without loss on the market. That is we specify $s_{i,t}$ = output$_{i,t}$ = input$_{i,t}$ = financial endowment of firm i at time t.

Representation of the Firms' Products. With entry, firms are assumed to offer one *new product* on the market for consumption or intermediate goods. This can be interpreted as a single product or as a technological class of a group of products. This product/technology has a certain market potential that we denote $p_{i,t}$. The firm considers its product a viable one if it is able to realize sales which the case if $s_{i,t} \leq p_{i,t}$ In the terminology of organizational ecology (e.g. Hannan and Freeman, 1989) i.e. the product can be said to "occupy a viable niche". In that case, the firm continues to produce. However, the firm is is not aware of the precise value of $p_{i,t}$, rather it discovers (explores) it during the production and marketing process. If $s_{i,t} \geq p_{i,t}$, the niche is not viable anymore and the firm will engage into search for a new product. This search for a new product may also apply immediately after entry of a firm if it realizes that the potential of its initial product was too small, i.e. it was not accepted by the market. Then the firm will not follow the initial trajectory and engage into the search process one period after entry.

R&D process at the firm level. Firms undertake R&D to increase $p_{i,t}$. The R&D investment of firm i at time t is given according to

$$R\&D_{i,t} = \rho_i s_{i,t}, \tag{1}$$

where the outcome is specified by the following R&D production function:

$$I_{i,t} = \phi_{i,t} \left(R\&D_{i,t}\right)^{\alpha}, \tag{2}$$

$\phi_{i,t}$ being a random variable with $\mathrm{E}(\phi_{i,t}) = 1$ that accounts for idiosyncratic shocks in the transition from R&D effort to innovation I. $\alpha \in [0,1]$ denotes R&D elasticity. Successful R&D will increase the market potential of the firm's product $p_{i,t}$. At the same time, $p_{i,t}$ is subject to depreciation due to the introduction of competing products. Therefore the firm will engage into R&D activities to keep pace with new firms' products. This is specified as follows:

$$p_{i,t+1} = (1-\delta)p_{i,t} + I_{i,t}, \tag{3}$$

δ being the depreciation rate.

Firm Growth. Firms encounter costs C in the production process, where

$$C_{i,t} = c_i s_{i,t}, \tag{4}$$

$c_i \in [0,1]$, i.e. apart from R&D costs, they encounter only variable production costs. Firms are assumed to reinvest their profit and thus to increase their production capacity and hence their output. I.e. we have

$$s_{i,t+1} = s_{i,t} + \underbrace{(1-c_i-\rho_i)}_{g_i^{(R)}} s_{i,t}. \tag{5}$$

It thus follows that $g_i^{(R)} := (s_{i,t+1} - s_{i,t})/s_{i,t}$ is the growth rate of firm i while it is in the exploring regime, R, and selling a product. Note that $g_i^{(R)}$ is independent of the firm size by specification (compare Hall, 1987 or Evans, 1987) . If instead of selling a product the firm is searching for a new product, it only encounters search costs sc. Then

$$s_{i,t+1} = s_{i,t} - sc. \tag{6}$$

Transition to Exploiting Regime. If the potential of a firm's product $p_{i,t}$ and its size $s_{i,t}$ is above a critical level s^t, the firm's considers its product promising enough to stop exploring the technology-market space and to start to *exploit* the technology. The firm is then able to become a persistent innovator (Geroski *et al.*[1996] give support for this specification). The according behaviour will be described further in section 2.2.

Exit. Firms exit if their size falls below a critical size, $s_{i,t} < s^x$. This captures the case where firms exit since their financial endowment does not allow them to continue their activity of production or search.

2.2 Specification of the Exploiting Regime

Once a firm decides to exploit its technology it will discontinue to explore the technology-market space. In view of our model, this implies that the firm is now aware of the market potential of its product. Then we assume that the firm will exhaust this potential at its maximum, i.e. in terms of the model in the exploiting regime $s_{i,t} = p_{i,t}$ and both terms could be used interchangeably.

Once the firm has decided to engage into exploitation, the firm does not switch back into the exploring regime. In the exploiting regime, firms are subject to the same exit rule as given above, i.e. they exit if $s_{i,t} < s^x$, s^x being identical for both regimes. Moreover, we specify the R&D-process in the exploiting regime exactly like in the exploring regimes (equations 1 and 2).

Given that in the exploiting regime the size of the firm equals the potential if its product, the growth rate of a firm in the exploiting regime is now specified by a "merge" of equations (3) and (5), i.e. we obtain:

$$s_{i,t+1} = (1-\delta)s_{i,t} + (1 - c_i - \rho_i)s_{i,t} + \phi_{i,t}\,(\rho_i s_{i,t})^{\alpha} \tag{7}$$

That is the growth rate of firm i in the exploiting regime, T, is

$$g_i^{(T)} = (1 - c_i - \rho_i - \delta) + \phi_{i,t}(\rho_i)^{\alpha} s_{i,t}^{(\alpha-1)}. \tag{8}$$

For $\alpha = 1$, this equation simplifies to

$$\mathrm{E}\left(g_i^{(T)}\right) = (1 - c_i - \delta) \tag{9}$$

which is independent of the size of firm i (unlike the growth rate given in (8)). Hence, as equations (5) and (9) make evident, firms within different regimes differ in their growth rates.

3 Simulation Study

3.1 Motivation and Specification

Our aim is to study a number of processes simultaneously: The entry of firms with a certain product potential, the growth and shrinkage of firms doing R&D within different innovation regimes and finally the selection, hence exit of firms. We therefore do not aim to solve the model analytically. Rather we refer to a simulation approach.

Our economy consists of an arbitrary number of firms that enter according to a Poisson process. Firms draw their entry size from a Lognormal Distribution LN$[1, 1]$. Their R&D-intensity is drawn from a Lognormal Distribution that is specified such that 99% of the firms' R&D intensity is below 10%. $\phi_{i,t}$ is drawn from a Uniform distribution U$[0, 2]$. Variable costs are set $c_i = 0.8$ for all i. The depreciation rate is $\delta = 0.01$, R&D-elasticity is $\alpha = 1$.

We specify that firms, either when entering or when trying to increase their product potential through R&D, can only obtain a share of the *remaining* purchase power in the market. This specification has a twofold advantage: On one hand it captures a real life phenomenon, namely the fact that the market penetration of a new product depends not only on its technical specification but also on the purchase power of consumers that is dedicated to this product. On the other hand, this avoids computational overflow. Technically, this implies that early entrants will be able to introduce products with a larger potential. However, given the process described above (equation 3) this potential might reduce over time since the remaining purchase power of the market increases when firms exit since this exit of a firm leads to a deallocation of the purchase power deicated to its product. The disadvantage of this specification is that we can not investigate the interaction between innovation and purchase power dedicated to the respective market. We will leave this for further research. Following Hannan and Freeman[1989, p.100] we refer to the market size as to the *carrying capacity* of the market.

In the following sections we will present the results of a number of simulation runs of the model. We will first (section 3.2) present results that the model will generate by specification i.e. results that are common for all simulation runs even with different parameter settings. Here, we will also investigate the consequences of different realizations of parameters on the firms level. In a subsequent section (4) we investigate the impact of parameters on the market level, i.e. parameters that are identically for all firms.

3.2 Stylized Facts of The Model

The Firm Size Distribution and its Evolution. For this set of runs of the simulations, the carrying capacity of the market has been set to 20,000.[1] Figure 1 reproduces the firm

[1] Variations of this value do not modify the following findings but lead to a larger number of iteration steps until which the firms size distribution stabilizes.

size distribution of the simulation after 600 iteration steps. The resulting distribution corresponds to empirically observable patterns of size distributions, i.e. size distributions that are skewed to the right. Taking the Log of the data, the distribution can be approximated by a Normal Distribution (right hand side of Figure 1). Figure 2 shows the evolution of

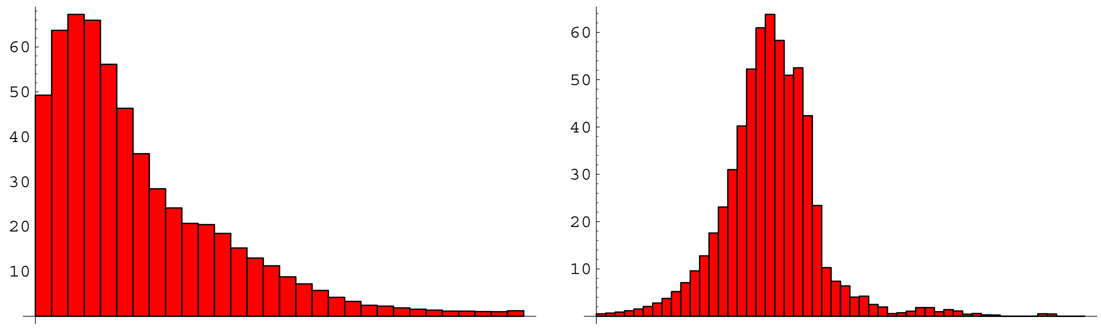

Figure 1: Histograms of firm size distribution after t=600 iteration steps. Logs are reproduced on right hand side

the number and of mean size of firms. It can be seen that the number of firms stabilizes above 500 under the given the parameter settings. The mean size converges to a value of around 40. These figures are of course dimensionless, i.e. they should be interpreted with respect to the carrying capacity (which is set to 20,000) and not be compared with realistic units of measurement. Figure 3 reproduces the evolution of the second and third

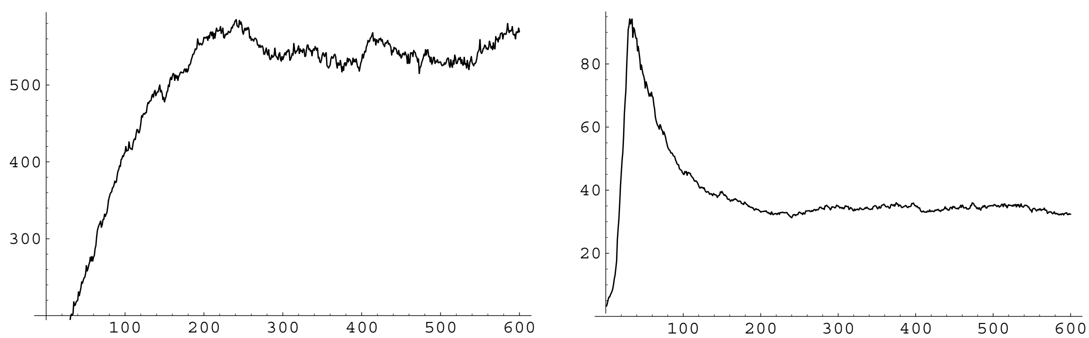

Figure 2: Evolution of number of firms in the market at time t (left) and their mean size (right)

moment of the firm size distribution. For the analysis of the standard deviation, the data have been transformed with the Log function to investigate the relation to the Lognormal Distribution. Indeed the Standard deviation fluctuates slightly above one. Also, the skewness of the distribution of the logged data fluctuates around a value slightly above 0. as the right hand side of Figure 3 points out. Thus, the size distribution generated by the model is very similar to the type empirically observed (Simon and Bonini, 1958; Ijiri and Simon, 1977; Lucas, 1978; Audretsch, 1995; Sutton, 1997; Cabral and Mata, 1996; Geroski, 1998), i.e. a firm size distribution that is skewed to the right. As will become evident later, this persistent distribution emerges although the underlying firm demographic

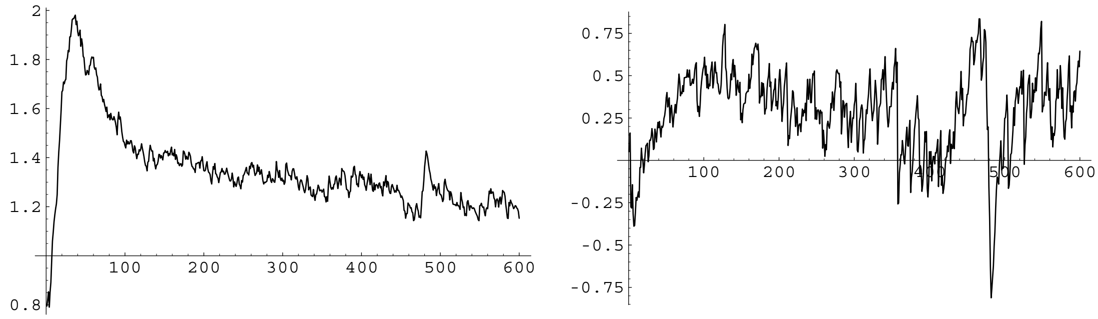

Figure 3: Evolution of standard deviation (left) and skewness (right) of the Log of the firm size distribution

processes are turbulent: firms enter at any time, they grow, others shrink in size while again others exit from the market. Hence there is a persistent change in the rank order of firms. Davies, Haltiwanger and Schuh[1996] and Dunne, Roberts and Samuelson[1989] provide evidence with respect for these phenomena. We take these findings of the model as first evidence that our model does not generate biased results.

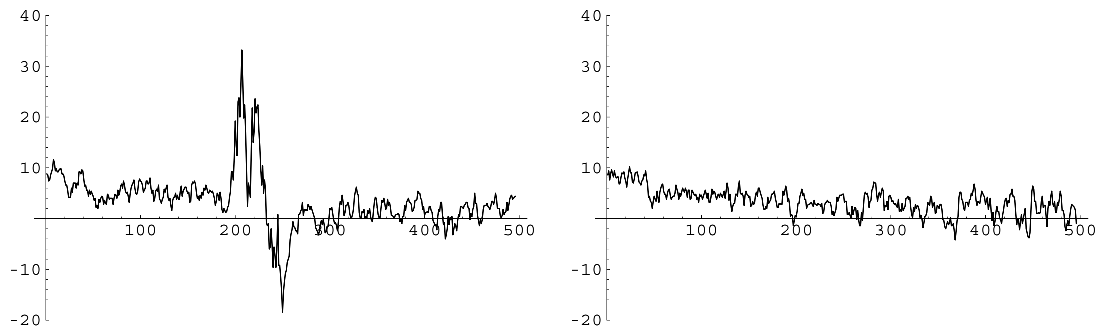

Figure 4: Net Entry (Entry -Exit). Left: implication of an entry shock (which occurs at $200 \leq t < 300$*). Right: alternative run without entry shock.*

Entry vs. Exit. A persistent result from the model is that entry and exit are strongly correlated, independent of the actual parameter settings (Dunne, Roberts and Samuelson, 1988; Cable and Schwalbach, 1991 or Caves, 1998 provide empirical evidence for this finding). Entry shocks translate into temporarily higher net entry, which is however reduced quickly and turns into a net exit once the entry shock is over (see Figure 4)[2]. This net exit reduces steadily and the number of firms falls back to the level before the shock, hence the (artificial) economy absorbes this entry shock completely.

This result seems to be highly relevant within the context of the increasing political effort of promoting the new finding of firms. If these efforts aim to decrease the unemployment rate, they would be useless if on the other hand they force other firms to exit[3]. An

[2]For the generation of this realization we assumed demand in the market to be growing. Otherwise an entry shock translates into an immediate exit shock such that net entry fluctuates still around 0.

[3]Here, we do not consider structural changes (such as e.g. an increase in the overall R&D-intensity) that

explanation can be that successful entering firms will decrease the chance for incumbent firms to find a new successful product given constant carrying capacity of the market. This phenomenon should be investigated in more detail. We leave this for further research.

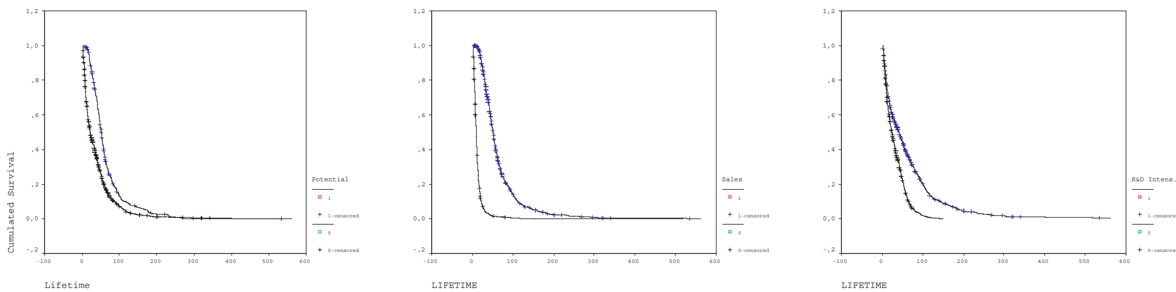

Figure 5: Survival functions for firms whose initial potential (left), initial size (middle) or R&D intensity (right) is above or below average

Survival of firms. Firms are characterized by three parameters when they enter the market: their start-up size, the potential of their product and their R&D intensity. We computed a Kaplan-Meier test on the influence of these parameters on survival. Figure 5 gives a graphical interpretation of these tests.

Here, it is made evident that all of the parameters have a significant influence on the survival of the firms. The case of R&D intensity is especially interesting to observe: Apparently, the contribution of R&D intensity to the chance of survival is manifest only after a certain time interval. However, after that time interval firms whose R&D-intensity is below average exit significantly earlier and their maximum age never attains the full duration of the simulation.

	$\hat{\beta}$	$\hat{\sigma}$	*p-value*	Exp$\{\hat{\beta}\}$
Potential	-0.128	0.004	0.000	0.880
Start-Up size	-0.065	0.008	0.000	0.937
R&D-Intensity	-33.308	1.272	0.000	0.000
$\chi^2(3)$	1016.3			

Table 1: Results of a Cox-Regression of firms' lifetime against their potential, start-up size and R&D-intensity.

From a Cox regression using all three variables simultaneously, we see (Table 1) that all three variables are significant at $\alpha = 0.01$ in the expected direction, i.e. large values of each of the three parameters decrease the hazard rate. We derive from these findings a first proposition from the model:

Proposition 1 *The larger a firm at entry, the higher its chances to survive. Also, the larger the potential of the product the higher the firm's chances to survive. The effect of current R&D only*

are driven by these activities.

sets in after a certain time lag. Hence current R&D can not compensate for a product wth low potential.

The first part of the proposition is in accordance with Agarwal and Gort [1996] who found that initial wealth (which is expressed by size in our model) contributes positively to the probability of survival. The results of Audretsch and Mahmood [1994], Agarwal and Audrestsch[2001, Table III] and Dunne *et al.*[1989]point in the same direction. The latter identify entrants by type (new or diversifying firms) and find that the probability of survival is positively correlated with the size at entry. The part of the proposition that is concerned with R&D is left for futher research. Further analysis shows that these shake-

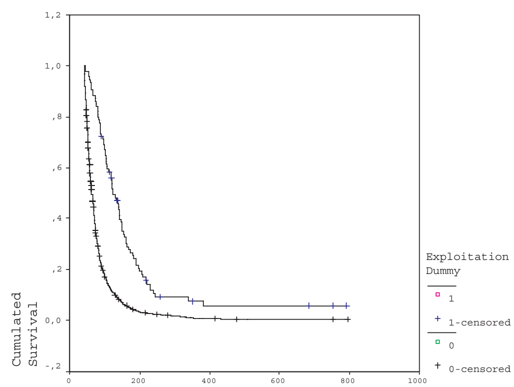

Figure 6: Survival functions of firms with a viable product (top) and without (bottom).

	$\hat{\beta}$	*p-value*	$\bar{v}_i$
Potential	0.000173	0.000	10.2291
Start-Up Size	0.000349	0.000	2.5512
R&D-Intensity	0.200748	0.000	0.0223
Pseudo R^2	0.5761		

Note: Results report marginal effects dP/dv_i

Table 2: Results of a Stata-`dprobit` *regression of variables against the probability to find a viable product.*

out dynamics can be explained by whether the firm has found a viable product or not. As Figure 6 shows, firms with a viable product have a significant larger chance to survive. Correspondingly, Table 2 shows the results of a maximum likelihood estimation, reporting changes in the probability for an infinitesimal change in each independent variable. All variables have positive and significant impact on the probability of finding a viable product, hence implicitely on the survival rates, with R&D-intensity having the largest marginal effect. Results correspond therefore to those in Table 1

	MarkSize	GRMarket	StartUpS	Potentl	RDShare	Delta	SearCost
Average Age	0.683	0.990	0.975	0.965	0.935	-0.980	-0.798
(*p-values*)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average Firm Size	0.973	-0.848	0.892	-0.753	-0.879	0.845	0.956
(*p-values*)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
StdDev. of Firm Size	0.689	-0.891	-0.482	-0.859	-0.837	0.867	0.896
(*p-values*)	(0.000)	(0.027)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average Number of Firms	0.819	0.997	-0.853	0.972	0.924	-0.967	-0.863
(*p-values*)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Entropy Index	-0.816	-0.993	0.721	-0.971	-0.941	0.975	0.799
(*p-values*)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Turbulence	-0.720	-0.614	-0.093	-0.722	-0.308	0.978	0.824
(*p-values*)	(0.000)	(0.001)	(0.690)	(0.000)	(0.097)	(0.000)	(0.000)
Share of Explt.	0.891	-0.673	-0.112	-0.786	-0.772	0.900	0.618
(*p-values*)	(0.000)	(0.000)	(0.630)	(0.000)	(0.000)	(0.000)	(0.000)
Market Share of Explt.	0.728	-0.889	-0.255	-0.979	-0.903	0.702	0.121
(*p-values*)	(0.000)	(0.000)	(0.265)	(0.000)	(0.000)	(0.000)	(0.396)
Av. Age to Explt.	-0.763	-0.610	-0.568	-0.926	0.526	-0.801	0.924
(*p-values*)	(0.000)	(0.002)	(0.007)	(0.000)	(0.003)	(0.000)	(0.000)

Note: p-values indicate probabilities of correlations to be insignificant, derived from a two-sided t-test.

Table 3: Correlation of market level parameters and firm-demographic variables

4 Implications of Variations of Market Level Parameters

In this section we will present results, that come out of the variation of parameters that affect all firms in the sample simultaneously, i.e. parameters on the *market level*. The parameters to be investigated are related to market size and to the difficulty of finding or keeping a viable innovation (i.e. a viable niche). We also consider the effect of varying the firm level parameters that have been investigated in section 3.2 for all firms simultaneously. We analyse the impact of these parameters on nine firm-demographic variables: average age, average firm size, standard deviation of firm size, average number of firms, entropy index, rank-order turbulence, share of firms in exploiting regime, their aggregate market share, and the average age of firms that move to the exploiting regime.

It is in this possibility of varying parameters of interest that cannot be easily varied in real life economies and investigate the implications of this variation that simulation approaches can fully show their advantages. Figure 7 and Table 3 show the impact of the variation of these parameters on firm demographic variables. Each dot in Figure 7 represents the result of one simulation run, where the parameter under consideration has been varied while the other paramters – such as distribution of R&D-intensity, parameters of entry process etc. – have been kept constant. Let us now discuss these results.

4.1 Market Size, Carring Capacity

To analyze the effect of market dynamics on the firm-demographic variables mentioned above, we chose two approaches. *First*, we kept the level of the market size constant during each respective simulation run, however letting it vary from from 5,000 to 50,000 by steps

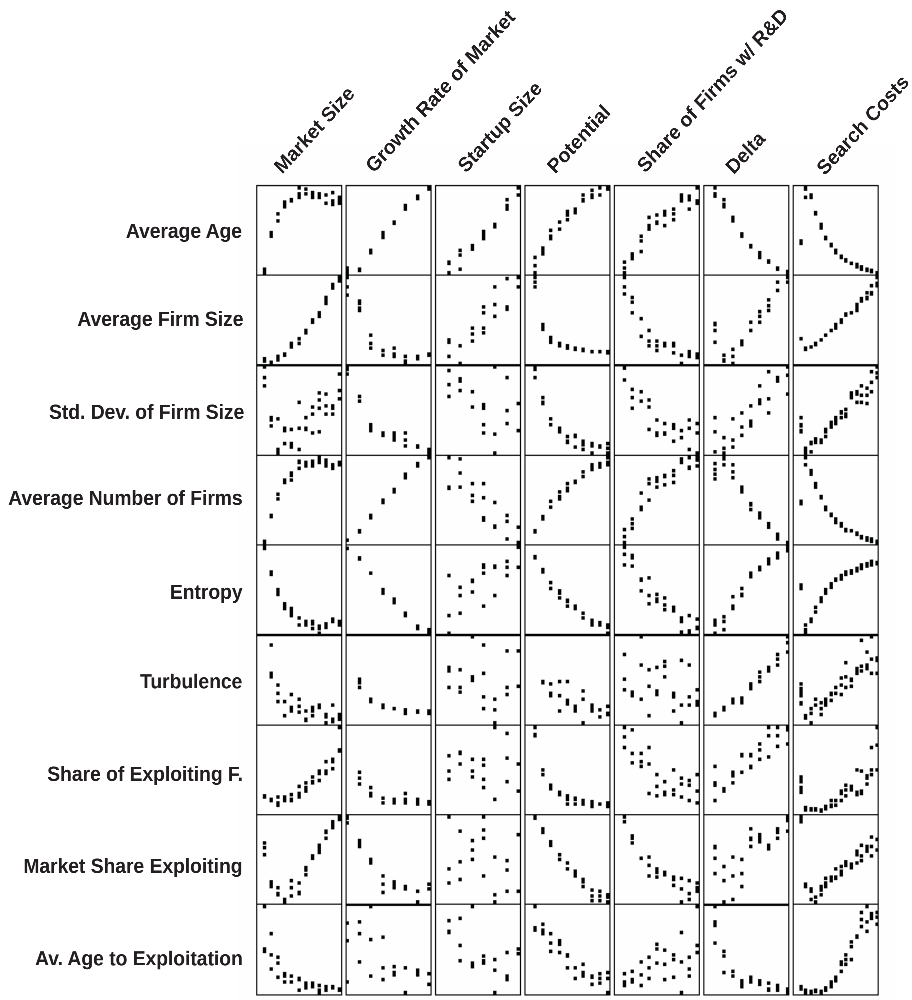

Figure 7: Effect of different market level parameters on firm-demographic variables

of 5,000, running three simulations for each value. This approach is rather "comparative static"[4] since the market size does not increase nor decrease within a simulation run. Think of *market size* as sales in an industry or even as GDP in an economy. Hence it expresses also demand and firms compete for this demand with their products. From this background, this notion of sales is closely related to the notion of *carrying capacity* (Hannan and Freeman, 1989).

Second, we chose a small initial market size and let the market grow linearly by rates varying from 0.5% to 3.5% *with each iteration step*. This illuminates the effects when markets grow. It is fruitful to think of the first case as of mature markets with settled demand sructure and of the second case as of young markets with increasing demand.

[4]In this context this notion might of course be misleading since we do not refer to the textbook notion of static models.

While varying these market size parameters, other parameters – such as distribution of R&D-intensity, parameters of entry process etc. – have been kept constant. Each simulation has been run over 600 iteration steps which is a value that allows the variables to stabilize. The first two columns of Table 3 and Figure 7 represent the outcome of these simulation runs. A few interesting observations emerge from this first set of simulations.

Market Size. With constant but increasing market size, the number of firms increases up to a maximum level. At the same time, their average size as well as the variance in firm size (expressed by the standard deviation) increases. At the same time the age of firms increases. Larger markets lead to a decrease in the age in which firms move to the exploiting regime. At the same time, the share of firms with a viable product and their market share increases.

Growth Rate of Market. The results for dynamic markets are very similar with two interesting exeptions: higher growth rate of markets lead to lower firm size in average but also with lower variance. The share of firms in exploiting regime as well as their market size decreases. From these findings , we derive the following propositions:

Proposition 2 *Larger markets can accommodate a larger number of firms. On larger markets the* number *of small firms will increase more than proportionally. At the same time the* size *of the largest firms will increase more than proportionally.*

These findings follow from the correlation of *market size* and *growth rate* with *average firm size*, *standard deviation of firm size* and with *average number of firms*. Both parts of this proposition have been analyszed in the literature. Lucas[1978, Table 1] finds that larger markets (expressed as GNP, using US data form 1900 to 1970) indeed will have a positive impact on the average firm size. He estimates the elasticity to be slightly belo unity, hence a 1% increase in GDP implies a 1% increase in average firm size, thus giving support for proposition 2. These findings seem highly relevant in the context of the European integration: Larger markets leading to larger firms would implies that integration increases the tendency to engage for mergers.

Proposition 3 *The larger a market, the more favourable it is for survival of firms.*

This proposition is derived from the simple correlation of *market size* and *growth rate* with the *average age* of firms. Using a sample of 11,000 young US manufacturing firms, Audretsch and Mahmood[1994] find that the likelihood of survival of these firms is positively influenced by market growth, thus giving support for this hypothesis.

Proposition 4 *The larger a market, the easier it will be for firms to find a viable product.*

This propositon is derived from the finding that the average age of moving to exploitation decreases while the share of firms in the exploiting regime and their market share increases with market size. We are not aware of any empirical study that investigates this relationship between market size and the type of product. This is certainly due to the fact that the notion of "viability" is not easy to capture empirically. We suggest this for further research.

Proposition 5 *The stronger the growth rate of the market, the easier it will be for firms to find a viable product but also the larger the number of firms in search of a viable product (firms in exploring regime).*

This proposition is derived from the negative correlation of (market)share of firms in exploiting and the average age of firms when they move to the exploiting regime. However, the problem with respect to empirical research, discussed with proposition 4 remains.

The findings of this section and of section 3.2 can be summarized such that the success of young firms is the larger, the larger the market or the growth rate of this market, hence the larger the growth and innovation opportunities are. Thus the success of these firms is *demand driven*. From this point of view, a mere increase in firm foundations cannot be considered as a success unless it is accompanied by an increase in the demand. Policies to increase firm foundations should rather target market size than accounting firm foundations as such as a success.

4.2 Effect of the variation of Average Startup Size, Average Products' Potential and Average R&D-Intensity

In section 3.2, we investigated the impact of firms' startup size, the potential of their product and their R&D-intensity on their probability of survival. Here, we consider the implications of these parameters varying in the expected value for all firms. Columns 3 to 5 of Figure 7 or of Table 3 show the implications of the variations of these parameters.

Let us simply state that the simulation results on the aggregate level of the economy confirm proposition 1, given that average lifetime is positively correlated with startup size, products' potential and R&D-intensity (expressed by the share of firms engaging into R&D).

4.3 Effects of Pace of Innovation and "Ease of Innovation": Depreciation Rate of Innovation and Costs of Search for new Product

The "easiness of innovation" is a concept that is difficult to capture empirically, it can however be hypothesized to have a large impact on the demography of innovating firms: In a market where it is difficult to find a new product or (on the other hand) it is difficult to keep the rent of a new product due to high innovation pressure of other firms, we expect more turbulence in market shares and firms to exit more quickly. Let us consider two parameters that express these dynamics ("Delta" and "Search Costs"), the final two columns of Figure 7 and Table 3 reflect the impact of these parameters. We discuss them in turn.

Delta, δ. This parameter specifies *depreciation* of the products' potential or of firms' market share (as specified in equations 3 and 7). Technically spoken, this parameter reduces the potential of a product of a firm in the exploring regime (from equation 3) or the size (i.e. sales) of a firm in the exploiting regime (from 7). With this parameter we aim to describe the *pace of innovation* and thus the competition that emerges from other innovators: the stronger this competition, the larger the depreciation rate δ since consumers switch their demand more quickly to other products, i.e. to other firms.

The impact of this parameter can be described as follows. With increasing δ (i.e. with increasing competition), average age of firms and their average number decreases. The average firm size and its standard deviation increase with δ. The time needed to find a viable product decreases as well as the share of firms with such a product and their market share. The variation in the rank of market shares (turbulence) increases. We derive the following propositions from these findings:

Proposition 6 *Higher pace of innovation will decrease average lifetime of firms.*

Given the findings of section 3.2 (especially proposition 1) we conclude that increasing competition will primarily affect firms with lower potential and lower startup size. Hence, firms with larger potential can expand their potential even more quickly, since demand is stronger concentrated on these firms. In our model this will imply that firms will enter the exploiting regime more quickly, i.e. that incumbent firms will find a viable product more easily. This leads us to the following proposition.

Proposition 7 *Higher pace of innovation will increase average firm size*

The intuition behind this proposition is that competition will induce weak firms to exit more quickly and will allow the demand for their products to deallocate. Then, remaining firms will find a viable product more easily and have larger opportunities to expand. In turn, the market becomes more quickly one that can be characterized by a small number of firms with established products. Hence

Proposition 8 *Higher pace of innovation will increase selection pressure and dominance of established technologies.*

Nelson and Winter [1982, chapters 12 & 13] find a similar outcome in their model. However, we do not know any empirical evidence for these propositions. We suggest the investigation of propositions 6 to 8 for further research.

Search Costs, sc**.** As expressed in equation (6), firms encounter search costs when they explore the product market space for a new technology. The larger these search costs, i.e. more expensive the search process, the faster the financial means of the firms will be exhausted which increases the probability for exit. Hence, search costs can be considered as a proxy for the ease of finding a new viable product and thus for *innovation opportunities.*

The last columns of Figure 7 and Table 3 show the effect of variations in these search costs. The following results are of interest: with increasing search costs, the number and age of firms declines while average firm size and standard deviation increases. The average age of moving to the exploitation will increase with search costs. This applies also for the share of exploiting firms and their market share. This leads us to the following propositions:

Proposition 9 *Higher search costs, hence a lower level of innovation opportunities, lead to a stronger shakeout of firms and imply longer time to find a viable product.*

This first part is true by definition of search costs. The intuition behind the second part is that firms will have more difficulties to find viable products when search costs are high. If we interprete proposition 9 in the opposite direction, we obtain

Proposition 10 *If innovation opportunities are high, the industry will be characterized by a large number of small firms.*

This proposition seems intuitive, however we are not aware of any empirical analysis in that direction. This proposition is therefore left for further research.

4.4 Findings on Market Concentration and Demographic Turbulence

Starting from a more general perspective, we now derive a set of propositions concerning the implications of Market Level Parameters on market concentration and on variations in the rank order of firms (i.e. on turbulence). Here, we will discuss the joint implications of several parameters simultaneously.

It is noticeable (from Table 3 and Figure 7) that concentration (measured by an Entropy index) is significantly correlated with all of the market level parameters. The same applies to a measure of turbulence[5], with the exception of Startup-size, that does not seem to influence turbulence. It is also noticeable that the sign of the correlation of market level parameters with concentration on one hand as well as with turbulene on the other hand are similar. Hence, by reverse conclusion, concentration and turbulence are positively correlated. Davies and Geroski[1997] provide empirical evidence that supports his finding.

We see from Table 3 and Figure 7 that bigger market size and higher growth rates of market size lead to decreasing levels of concentration. Hence

[5]Turbulence is measured as the variance of the rate of change of market shares.

Proposition 11 *Larger market will accomodate a larger number of firms, hence display lower levels of concentration.*

This proposition is especially interesting in connection with proposition 2. Thus, larger but static markets (MarkSize) accomodate a larger number of firms that are also larger in average. Given that the standard deviation of firm size increases with market size as well, we conclude that the concentration level decreases due to the fact that even in mature markets with a static market size the number of small firms increases more than propotionally (see the discussion of proposition 2.) This effect is even stronger in young markets, i.e. when the market grows over time (GRMarket). Here, with increasing growth rate, the market is more and more dominated by an increasing number of small firms, hence concentration decreases.

Implications are slightly different for innovation-oriented parameters. A higher pace of innovation (Delta) increases concentration. In connection with propositions 7 and 8 we hypothesize that concentration increases since the higher pace of innovation leads to stronger shakeout. For search costs, based on propositions 9 and 10 the effects are similar.

Interpreting increasing market size as decreasing selection pressure and increasing pace and cost of innovation as increasing selection pressure, we derive

Proposition 12 *Increasing selection pressure leads to an increase in market concentration and to an increase in market turbulence.*

Although this proposition is rather intuitive, we are not aware of any empirical study that points in that direction. The second part of this hypothesis follows from the fact that in the simulations, concentration and turbulence vary in the same direction (Davies and Geroski, 1997).

Interpreting the findings of the model in the opposite direction we suggest to use high levels of rank order turbulence and or concentration as proxies for markets with high selection pressure in empirical research.

5 Summary and Conclusion

The aim of this paper has been to develop a model that explicitely considers the interaction of firm demographic processes, innovation regimes and market structure. For this purpose, we specify a structural model of firm growth, where growth is driven by reinvestment of profits which in turn depends on firms' R&D-intensity and on costs of search for a new product. Firms can be in different innovation regimes, i.e. they can explore the technology space in search for a new technology or they exploit existing technological trajectories. While we associate with the first regime the search for a "viable product", the latter state is associated with the firm offering such a product. Firms can pass from the exploring to the exploiting regime.

Firms are characterized by their size and a set of variables that are related to innovation. The growth of firms does however not only depend on these parameters but on the interaction with other firms which in the model is mainly driven by competition for a limited purchase power. In the model, firms are boundedly rational, the number of firms is potentially illimited and we do not refer to limit states such as an optimizing equlibrium or a priori given limit distributions. In that sense, the model is microfounded and represents an inductive approach.

We use a simulation based approach to derive a number of empirically testable hypotheses on the basis of this model. On the one hand, we are able to derive a set of propositions that have found empirical support in the literature. We take these propositions as evidence in favor of the explanatory power of the model. Moreover, the model shows implicitly that the aggregate regularities of market structures are consistent with a dynamic coexistence of firms engaging in exploration and exploitation of economic opportunities. On the other hand, we go beyond these literature, suggesting a set of propostions on the relation between firm dempgraphic processes, firms' inovative behaviour and market structure that have not yet been investigated and that we suggest for further empirical research.

The approach has shown that firm innovative strategies affect market structures. The model suggests that the reason why firm size distribution is skewed, meaning that there is a persistent asymmetry of firms sizes and a predominance of small firms, is that firms shall explore the space of economic opportunities before they are able to exploit some profitable avenue. This necessity of initial exploration can be interpreted as the necessity for firms to test their ideas and learn how to proceed as well as the necessity for customers to accomodate new goods and reallocate their resources. Then small entrants have to grow in order to survive. Thus, among the small firms in the tail of the distribution, a few will grow enough to become exploiters and many will fail. The skewed firm size distribution thus reflects this dynamics of exploration and exploitation.

The model provides evidence that market concentration is positively correlated with turbulence in firms' rank order. The correlation is in fact generated by the relation of both variables with the intensity of competition. The more intense the competition, the more turbulence and concentration. Indeed, more intense competition implies that competitive advantages vanish more quickly, but as explorers might have the supplementary burden to investigate for a new product while exploiters follow a specific trajectory, more competition implies on average more selective pressure on the explorers than on the exploiters. Hence the share of exploiters increases with the intensity of competition. This in turn is an outcome that contradicts standard results according to which concentration is due to a lack of competition. Hence the model suggests that a rise in the concentration level does not conflict with harder competition between large firms.

To our knowledge, the approach chosen in this paper: 1) specification of a structural model 2) simulation and 3) deduction of propositions, has not been used previously. The propositions suggested here represent only a subset of their possible number, i.e. the richness of results has not been tapped completely. In our view, this approach represents a fruitful avenue for further research.

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