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Abstract:
Although there are several theories of growth of the firm, the literature is limited in two interrelated respects. First, empirical evidence does not match well theoretical predictions. Second, the firm growth literature does not address the structure of knowledge both in firms and sectors as well as knowledge flows between them. Based on existing theoretical and empirical literature, the paper outlines an 'appreciative' theory of firm growth and presents new testable hypotheses to inform present and future empirical research. The paper seeks to address this gap by analysing not only levels of human capital, but also its composition both on a firm and sector level. A key departure from earlier approaches is the inclusion of the role of 'knowledge structures' played in the growth of the firm. In this context make a distinction between (a) levels of human capital available to firms, (b) the composition of various kinds of human capital ('firm- specific', 'industry-specific', and 'general knowledge') contained, and (c) the diversity of knowledge domains represented to characterise the knowledge structure of firms.

In addition, we present our first empirical results, using the knowledge structure approach. In the first part of our empirical analysis we find – while controlling for intial size and industry affiliation – that the availability of a high fraction of employees with higher education within each establishment (an aspect of 'general kowledge'), is in general conducive to establishment growth. In the second part of the empirical analysis, we find important sectoral differences with respect to the ability of the level of formal education to explain firms growth.

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1. INTRODUCTION

Firm growth is a recently much debated issue both in economics, as well as in strategy research. In this debate its has been forcefully argued that the empirical evidence does not match theoretical predictions. In the words of Paul Geroski:

> Corporate growth rates ... differ between firms in a temporary and unpredictable way, and it is hard to reconcile the inimitability and durability of organizational capabilities with [this] data. The consequence of all this is that theorizing about competencies is being driven by a correspondence with the 'facts' which is, at best, partial. (Geroski, forthcoming, 2000, our square brackets).

Given a statement of the above kind from a prominent scholar in the field of applied econometrics, one could say that it is an ambitious task to make the attempt to explain corporate growth, with the aim of making a subsequent empirical tests. However, as pointed out by Jensen and McGuckin (1997), although firm growth has not been explained in a satisfactory way, as yet, there are still unexplored sources of explanation:

> The vast majority of variation in firm performance is not associated with traditional observables such as location, industry, size, age or capital; rather it is associated with unobservable factors specific to the firm or business unit, many of which appear to be permanent attributes of the business unit. One such attribute is the *managerial capital of the firm*, another is *the skills of its workforce*. (Jensen and McGuckin, 1997, p. 44, our italics).

It is exactly aspects of the skills of the workforce (and the managerial capital of the firm) that we want to apply as explanatory variables in explaining firm growth. Generally speaking, the view of Jensen and McGuckin (1997), is supported in a recent review of findings on firms' growth by Peter Hart (1998). Hart concludes that while firm growth to a large extent is stochastic or random there are some *systematic* factors, such as capital investment and R&D. However, there is little tendency for the influence of these factors to persist over time. The interesting point is that they agree on the importance of firm-specific and idiosyncratic factors, and taking that R&D (Hart) might be correlated with the skills of workers, there is also an agreement on the type of such factors. They disagree however on the permanence of their effect.

In this context our work is inspired by the data availability on the properties of the Danish

workforce (including the managerial staff), held by Statistics Denmark, and available to us. While progress in empirical growth research has been hampered by the lack of adequate detailed firm level data, our unique data set allows us to address not only the levels and inflow of human capital in firms and sectors, but also to investigate its composition (e.g. knowledge-structure), both on a sectoral and firm level as explanatory factors of firm growth. Moreover, despite increasing interest in the growths of firms, many important issues remain beyond the scope of existing models In this paper, we pursue a 'knowledge structure approach to firm growth' to address the following questions:

1. Do levels of human capital and the composition of human resources in firms and sectors (e.g. general, firm specific) affect firm growth?
2. What is the impact of knowledge-structures on inter-sectoral differences on growth rate?
3. Do high growth firms differ systematically from low growth firms in their knowledge structure?
4. How does the inter-sectoral flow of human capital impact inter-sectoral growth rates?
5. How do tenure profiles (stability of the workforce) affect the firm's growth rates?
6. Are multi-technology characteristics (diversity) conducive to firm growth?
7. Does the diversity of the firm's knowledge-structure increase more in high-tech sectors compared to other sectors?

While these arguably diverse questions seem important for explaining firm growth (e.g. Penrose, 1959) they fall outside the purview of most empirical studies on firm growth. Despite the central role of the firm in economics, many growth studies treat the firm as little more than a black box 'production function'. Conversely we assume that firms are historical entities in time, that they can be signified by their knowledge structure, which gradually accumulates (Nelson and Winter, 1982; Dierickx and Cool, 1989). Developments in the theory of the firm (Holmström and Milgrom, 1994 ; Williamson, 1996) share our interest in the internal structure of the firm, and certainly have a bearing on explaining diseconomies of scale which may limit the firm size. However, the arguments made and insight offered focus on incentive mechanisms used inside firms to the neglect of its knowledge structure. The capability approach (Penrose, 1959; Nelson and Winter, 1982; Teece, Pisano and Shuen, 1997) highlights the importance of knowledge-assets and processes of co-ordination within firm, but to date empirical progress has been hampered by the generality of the construct capabilities. Moreover, no empirical study in this tradition has investigated the interrelation

between knowledge-structures and firm growth. One way forward is to recognise with Nelson (1991, p. 68) that 'capabilities will be defined and constrained by the skills, experience, and knowledge of personnel.' Accordingly, we submit that the knowledge structure perspective advanced in this paper with its explicit focus on the impact of idiosyncratic human capital endowments of firms, their composition and evolution sheds new light on the growth of the firm.

Hence, the aim of the paper is to outline a theoretical approach to firm growth, based on a knowledge perspective and on this basis to present new testable hypotheses in order to inform present and future empirical research. In addition, we also wish to present and discuss some first empirical results, based on our approach to firm growth. The remainder of the paper is organised as follows. Section 2 describes standard factors used in empirical growth studies. Section 3 describes our data set and aspects of operationalisation. Section 4 develops a framework to explicitly address the interrelation between knowledge structures on a firm and sectoral level, changes thereof, and firm growth. This facilitates the investigation of a variety of questions posed above. In Section 5 we present our initial empirical results using the knowledge structure approach. As a first step within the research programme outlined in Section 4, we limit ourselves to testing (in a regression analysis) whether the level of formal education matters for firm growth in a sample of 5788 Danish establishments, over the period from 1984 to 1996. In section 6, we summarise the conclusions of the paper, and draw some implications for future research.

2. THE STANDARD FACTORS IN EXPLAINING FIRM GROWTH

2.1. Firm size convergence?

The aim of this section is to highlight what have been the standard variables in explaining firm growth, with the purpose of informing not only present, but also future empirical work. One starting point in explaining firm growth can be the neoclassical theory of the firm, although it should be pointed out that the aim of neoclassical contributions in economics has largely been to study the principles that govern the efficient allocation of resources, when both resources and preferences are given. The neoclassical theory of the firm looks at single product firms in an industry with a U-shaped average cost curve. Firms grow until they reach the size corresponding to minimum average costs. Hence, the dispersion of firm size will be

small (due to non-optimal behaviour), and this dispersion will become smaller over time, as firms converge towards the equilibrium size. Thus the prediction from the neoclassical theory of the firm is that firm size will in the long-run converge towards some optimum size.

If the dispersion of the size of firms is decreasing, then this would be evidence of convergence. However, from an empirical point of view this prediction has not gained much support since persistent skew distributions are found. For instance, Hart and Oulton (1996) find that large companies did not regress towards the mean over the period 1990-1994. In other words, the large companies tend to grow at the same speed as do smaller companies (above a minimum efficient scale). Also, entries of new (and typically small) firms are not significantly lower in industries characterized by substantial scale economies (Audretsch, 1997).

2.2. Control variables

In our empirical analysis we wish to control for factors previously taken into account in the existing literature. Hence we want to present these factors, and in this regard discuss what the previously obtained results concerning the 'standard factors' has yielded.[1]

Several studies have included age effects in models of firm growth. There is no perfect consensus on this matter (see Jensen and McGuckin, 1997). However several studies show that the age of the firm has been found to have a negative effect on growth. In this way, e.g. Evans (1987) found that for young firms, smaller firms had faster growth, and also found a significant (and positive) coefficient of the interaction between size and age. Dunne and Hughes (1994) found –using continuous age for each firm- that age had a negative effect on company growth. Also company size –discussed in the previous section- is an effect which should be controlled for, when making an attempt to explain firm growth.

Another factor, which has been tested extensively, is persistence in growth rates. In the evolutionary literature (Nelson and Winter, 1982) firms have 'routines' embodied in persons and organisations; routines which are transferred from one period to the other. Thus successful routines which have been producing growth in the past, are likely to continue in producing growth in the future. Hence, the evolutionary approach implies that there is some serial correlation in growth. This contrasts with Gibrat's (1931) law of proportionate growth, which postulate that the proportionate growth of (surviving) firms is random, and accordingly independent of previous success.

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1 This section will not discuss industry effects, as such effects will be discussed in Section 4.3.

Empirically, authors like Paul Geroski (forthcoming, 2000) have put forward that 'firms do not display persistent differences in their growth performance.' However, it should be pointed out that some empirical studies have shown weak signs of serial correlation in firm performance (see Hart, 1998).

3. THE DATA AND ASPECTS OF OPERATIONALISATION

Although our perspective on firm growth takes its departure from the capability perspective, our model is also inspired by unique data availability. The *IDA-database* contains annual, linked data on the total population of *establishments* and workers in Denmark from 1980 onwards (to 1996 at present). It includes data at a given point in time (each November) on the characteristics of establishments and workers as well as *flow* data on establishment and worker mobility/turnover on an annual basis.

Workers are characterised by extremely detailed data on *formal* education (for example different kinds of engineers), whereas data on occupation or work function are summary.[2] For each individual worker an estimated *hourly wage* is available. Via 'historic' variables information on the year when a worker was hired (i.e. *tenure*) and for instance the year of completion of formal education is included.[3]

Characteristics of establishments are detailed industry (ISIC/NACE), location, type of ownership, and independent unit versus part of a multi-establishment firm. [Regarding those belonging to multi-establishment firms, the *largest* establishment can be identified, including its share of overall employment in the firm]. Historic variables include the year of birth of the establishment, i.e. age.

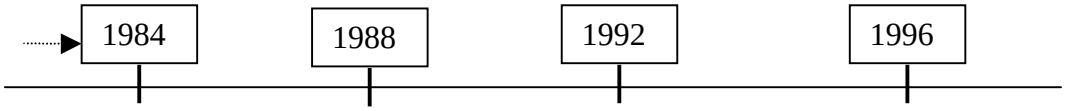
Concerning the *population*, the basic idea is to utilise a panel or *cohort* of establishments defined as the entire population of establishments existing in a specific year. Through a unique establishment identification number each establishment can be traced in subsequent years. In this way a cohort of workers per establishment can be utilised too, which is the appropriate basis for analyses of the stability of the work force and its effect on establishment

2 Only six occupational groups are defined: 1. unskilled manual workers, 2. skilled manual workers, 3-5. lover level/intermediate/upper level salaried employees, and 6. directors. In addition, a category of employees 'without further specification' occurs, which mainly consists of pupils and students employed part time.

3 The starting point at 1980 truncates these historic variables, so that we only know that the year was 'before 1980' in case of for instance being hired earlier than 1980.

growth (in contrast, the average seniority among *all* employees will be affected by growth itself). However, data on changes in the composition of the work force are available in that the entire workforce per establishment is included also in subsequent years (i.e. inclusive of newcomers). Thus, it is made possible to define the workforce in given subsequent years as cohorts.

The basic cohort is all establishments in *1984*. These establishments are traced and observed at *four year* intervals, i.e. in *1988*, *1992* and *1996*. Thus, survival and growth are registered after four, eight and twelve years respectively.



The advantage of choosing 1984 as a starting point is that this makes available 'historic' data on establishments and workers. For establishments this concerns births since 1980 and the kind of opening for those established during the previous one-year period (1983-84). For workers it can be registered whether they have been hired since 1980 (and in which year) – i.e. the provision of initial information on tenure up to three years or above. Regarding those hired during the previous one-year period information on their former industry and occupation are available as well as information on former employment at an establishment in the same firm. In case of an opening through a spin-off in 1983-84 information on which workers that came from the mother establishment is at hand.

Based on the data presented in this section, we will in Section 5 make a first empirical analysis, applying the level of formal higher education in explaining firm (establishment) growth. In general however, inspiration drawn from our unique data set in conjunction with the capability approach provides the major impetus for the development of our knowledge structure framework to firm growth as discussed in the next section.

4. FRAMEWORK: KNOWLEDGE STRUCTURE AND FIRM GROWTH

This section develops a framework to explicitly address the interrelation between knowledge structures on a firm and sectoral level, changes thereof, and firm growth. Starting from our definition of firm growth as the process that leads to an increase of the firm's capacity to employ, educate, and reward employees, the following specifies the components of our

framework, including the relevant measure of performance (4.1); different kinds of human capital (4.2); and the combination of different types of human capital in firms and sectors (4.3). Furthermore, the framework will be used to develop pointed propositions.

4.1. The relevant measure of performance

Several measures of performance has been used in the literature, including profit rates (although it is not a measure of growth), total sales, value added and employment. Our aim is to apply *employment* as the measure of performance and growth. There are several reasons for this.

First, we disregard profits as a performance measure, simply because we are interested in wider aspects of firms in their capacity to employ, educate, and reward employees, rather than being interested in rewards to the owners of the firms solely. Capital providers remain certainly important stakeholder in the unfolding learning economy (Lundvall and Johnson, 1994). However, it is also important to recognise that authors increasingly argue that human resources are not only important, but that they are among the most strategically relevant resources (Itami and Roehl, 1987 ; Castanias and Helfat, 1991 ; Ulrich and Lake, 1991 ; Spender, 1993 ; Lei and Hitt, 1995 ; Mahoney, 1995 ; Conner and Prahalad, 1996). Once one recognises the strategic importance of human resources, profit as the residual of revenue minus costs is found limited because expenditures on human resources are treated as a cost factor rather that as an investment in the future development potential of firms.

Second, we argue that total sales of a firm is an unsatisfactory yardstick, since size measured in this way, might well be influenced by (arbitrary) decisions of firms on whether or not to vertically integrate certain production processes (or by a decision concerning increased outsourcing).

Third, value added would be a relevant candidate for measuring firm growth. However, due to data limitations this variable is not often available (and it is not available -in a compatible form with the occupational data- for the Danish data over longer time periods). Seen in this light employment measures are good and timely alternatives. The difference between size measured by value added and size measured in terms of employment is that growth due to the physical capital stock – i.e. growth in labour productivity - is not accounted for, when using the employment measure. However in as a far as we are concerned with looking at firms as the engines of creation of wealth in society, we do not find this limitation to be of crucial importance. Moreover, as Penrose (1959, p. 5) long ago argued: ‘the

experience of the firm's management will affect the productive services that all its resources are capable of rendering.' Finally, it should be noted that authors such as Hart (1998), argue that although he is using employment as the only measure of size, the limitation of having this single measure only is not crucial, since all size measures are so highly correlated across firms. As a supplementary measure we utilise changes in the product of employment and wages. We conjecture that this wage rate is a suitable growth measure; it is positively associated with value added.

4.2. The importance and effects of human capital in determining growth of firms

4.2.1. Human capital as antecedence to firm growth

The available level of human capital influences growth. In the so-called literature on New Growth Theory (see Barro and Sala-i-Martin, 1995) endogenous technological change is seen as the main engine of growth of countries. In these models variables such as technological opportunities and the efficiency of research enter the analysis. However, the most important feature is Marshallian externalities in the R&D process. For instance, in the Lucas' (1988) and in Romer's (1990) models, human capital is the fuel, feeding into the R&D process, and hence co-determines growth rate. As a result, these authors argue that differential growth rates between countries result from differential prior stocks of human capital. Subsequently, a substantial amount of empirical research has been carried out, attempting to measure the effect of human capital on the growth rates of countries (see e.g. Barro, 1991; Levine and Renelt, 1992; Barro and Lee, 1993). Although this research has been criticised for being too simplistic[4] (Verspagen, 1993), the results have in general yielded a positive impact of human capital on growth.

However, it is important to note that this research has assumed a 'representative firm' model. In this model firms in the same industry (or even within the same country in some growth models) use the same production processes, produce identical products and face identical costs. Hence –as pointed out by Jensen and McGuckin (1997, p. 26)- all firms react similarly to shocks and the industry becomes the effective unit of analysis. Using this model has meant that research in industrial organisation and in the field of economic growth has focussed on explaining differences in industry performance, not on the determinants on firm success/failure. However, more recently models have been developed featuring uncertainty

and limited information, which cause firms to solve basically the same problem in different ways, in turn leading to heterogeneity among firms, even within the same industry. This approach has found general support in the (econometric) empirical literature. In the words of Jensen and McGuckin:

> The real world appears much closer to that described by Schumpeter than to the one that exist in most economic models; the behaviour of firms within industries differs dramatically. (1997, p. 27).

Idiosyncrasies of firms (Nelson, 1991) and their performance implications have also been a concern in the recent managerial literature. For example, Cohen and Levinthal (1989)argue that prior stock of R&D knowledge (absorptive capacity) positively influence performance through an increased ability to recognise, assimilate, and apply external knowledge sources to commercial ends. Although new growth theory arguments and the absorptive capacity argument operate on different levels of analysis, they are not only similar in their underlying idea that prior knowledge influences the ease of acquiring new knowledge, thus fostering growth. Additionally, the absorptive capacity argument adds insights into knowledge present in a particular firm, and, thus moves beyond the neoclassical model of the firm employed in growth studies. In the case of a company, high stocks of R&D knowledge help absorbing ideas from others, which may not be able to commercialise or even grasp the ideas themselves. Based on the above discussion we conjecture:

P1: The level of a firm's human capital is positively associated with the growths of the firm.

While Cohen and Levinthal (1989) are concerned with prior R&D knowledge and 'innovative performance' of firms, we are interested in the growth of the firm rather than R&D productivity alone. As a consequence, the following sections extent the discussion to include (a) different kinds of human capital represented in a firm's knowledge structures, and (b) the diversity of this knowledge structure. Moreover, we suggest that (c) change in this knowledge structure through intra-, and extra-sectoral human capital flows influences firm growth.

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4 Typically, this strand of research has included an aggregate measure of human capital for each country.

4.2.2. The composition of the firm's knowledge structure: kinds of human capital

Not only available levels of human capital represented in a firm's structure, but also differences in its composition influences firm growth. *Human capital* has not often been applied as an explanatory variable in empirical models of firm growth. However, Leonard's (1986) finds that a higher proportion of white-collar (non-clerical) labour in firms is associated with significant higher growth rates, as well as significantly lower shrinkage rates within industry and region.

For the development of our central argument, it is useful to distinguish between general and firm-specific knowledge (e.g. Becker, 1964 ; Tsang, Rumberger and Levine, 1991). By definition, general human resources are equally useful to all companies. For example, an MBA degree represents general skills that may be equally productive across a variety of firms. General human resources can often be rented in labour markets, and because they are not firm specific, employees are less likely to suffer productivity losses when they switch to another employer. Conversely, specific human resources are less productive for other employers. For example, the skill of a company's researcher to use a firm's specialised equipment is specific to this particular firm. Specific human capital is often not available in labour market, but needs to be developed, for example, through specialised training on the job (e.g. learning-by-doing). As such, it reflects the experience of employees gained in a particular firm. Secondly, because inter-sectoral differences in knowledge structures also may have a bearing on firm growth, we additionally refine Becker's (1964) distinction by introducing 'industry-specific knowledge' as a distinct category to reflect the experience gained by employees in a particular sector. From the perspective of the individual firm such experience may be regarded as general knowledge because it is equally valuable to different firms within the same industry. However, we have reason to assume that the productivity of employees in a particular firm depends also on working experience gained in a sector in which the focal firm operates. Thus we propose:

P2: The composition of a firm's knowledge structure (e.g. the ratio between firm-specific, industry-specific and general knowledge) influences the growth of the firm.

As a measure of *general knowledge* we plan to use as a first proxy the average level of formal education within the firm. In a parallel way we will use the fraction of employees recruited from the same industry as the focal firm as a proxy of industry-specific learning-by-doing or *industry-specific knowledge*. In this way we get a measure of how the external

knowledge environment exerts its influence on growth paths of firms in terms of transfer of personally embodied knowledge from within the industry. Concerning *firm-specific* knowledge, one possibility is to apply as a proxy the average tenure among cohorts of employees within a firm (firm-specific learning-by-doing). In this context experiments on the distribution of this variable against the growth of firms shall be carried out.

4.2.3. The diversity of the firm's knowledge structure

Not only does the composition of the firm's knowledge structure as represented by different kinds of knowledge contained therein matter for firm growth. Additionally, the diversity of knowledge domains in a firm's knowledge structure might have a systematic relation to growth. For example, Hambrick *et al*. (1996) called for research into how characteristics such as educational diversity, tenure, and turnover do affect the speed and scope of reactions to competitive challenges. They recommend studying top management teams in terms of the diversity. A different, but related example which stresses the diversity of knowledge domains in knowledge structure has been discussed by Granstrand and Sjölander (1990). They point out that the product-technology relationship in firms is not of an one-to-one kind. Given the complexity of products, firms are often characterised as 'multi-technological', that is, the development, production and use of a product usually involve more than one technology and each component can be applied in more than one product. As a consequence, firms require the ability to orchestrate several technologies.

A somewhat extreme case in this context is the evidence provided by Patel and Pavitt (1994). They show that among 440 of the world's largest firms, companies situated in the industry 'motor vehicles' only take out 28.8 per cent of their patents in the technology class 'transport'. Given that one of the ingredients in gaining competitiveness in automobiles, is the application of electronics it is not surprising that 20.7 per cent of the patents taken out in the US by companies in 'motor vehicles', were situated in the patents class 'electrical equipment' (including electronics). Furthermore, Granstrand and Sjölander provide evidence of multi-technology characteristics of firms becoming increasingly important. In other words technological diversification (within the given product range) is taking place.

Additionally, based on an analysis of European patent statistics, Breschi *et al.* (1998) link technological performance and technological diversification. They measure diversification in terms of being present in more than one patent class in each of three sub-periods over the period 1982-1993, and they measure technological persistence by whether or not the firm has been taking out patents in all three sub-periods, considered in the study. The conclusion is

that the most technologically diversified firms are persistent innovators. In other words, it is a necessary condition for firms to be technologically diversified to stay innovative. However, nothing has to the mind of the present authors been said about the economic effects of multi-technology characteristics of firms. In this context a number of questions can be posed. For instance, is the level and/or growth rate of multi-technology characteristics conducive to firm growth? Do multi-technology firms grow faster in certain sectors, if they are to a higher degree multi-technological? Or more generally, how much diversity in the firm's knowledge structure is conducive for firm growth? The reasoning presented in the above discussion leads to the following proposition:

P3: The diversity of a firm's knowledge structure is positively related to firm growth

While with increasing diversity possible re-combination of human capital might fuel growth, there might be also limits to the diversity of a firm's knowledge structures. The literature on the theory of the firm (Coase, 1937; Penrose, 1959; Richardson, 1972) suggests that with increasing diversity, also dis-economies of co-ordination result. This is essentially, because boundedly rational managers increasingly face the challenge to co-ordinate dissimilar activities (Richardson, 1972). Thus we propose:

P3.1: Increasing diversity in a firm's knowledge structure affects firm growth positively, but simultaneously diseconomies of co-ordination obtain

The questions posed above may be explored using data on engineer categories contained in our data. On one argue with Jacobsson and Oskarsson (1995) – that educational categories can be used as proxies for types of technological activities within firms. Using the educational statistics in this way, a Herfindahl index can be calculated for each firm, expressing the level of dispersion or of the types of engineers, again reflecting the technological diversity of each firm.

To recapitulate the argument: First we have distinguished (a) levels of human capital available to firms, (b) the composition of various kinds of human capital (firm-specific, industry-specific, and general knowledge) contained, and (c) the diversity of knowledge domains represented to characterise the knowledge structure of firms. Based on this analysis we have argued that all three components of a firm's knowledge structure are systematically related to firm growth. In the next section we extent the argument by asserting that change in

firm's knowledge structures constitutes an additional explanatory factor in the growth of firms.

4.2.4. Changes in the firm's knowledge structure: inflow of human capital

Edith Penrose (1959) suggested that rapid expansion is particularly difficult to manage as previous growth binds human resources until routines have been transferred from the incumbent employees (in particular management) to the new employees. This phenomena has been termed to 'Penrose-effect'. Given that the skills required to co-ordinate the many activities in a firm in a coherent manner are likely to be tacit, such transfer of routines can only be learned directly from incumbent managers, or through a troublesome process of trial-and-error. Hence, the resources of incumbent managers have to be released from current operations – through routinisation - before training of new staff is possible. This points to stepwise growth across time.[5]

To see how changes of knowledge structures influence firm growth, the Penrose effect can be considered. While the firm's current resources and capabilities in conjunction with subjective images of the environment held by its management team determine its productive opportunities, the exploitation of these opportunities (e.g. productive possibilities), and, thus, growth rates preliminarily depend on free managerial capacity. In Penrose's (1959) theory of firm growth the learning of human resources about non human resources figures pre-dominantly. In particular, Penrose (1959, p. 45) suggests that the '…capacities of the existing managerial personnel of the firm necessarily set a limit to the expansion of that firm in any given period of time.' During expansion managerial capacity is partially used to educate new personal, which limits the pace of further expansion. However, once new managerial capacity is created from such training, and operations of prior expansion become routinised, managerial capacity is released, thus, providing possibilities for new growth. The above discussion suggests:

P4: Firm growth is systematically related to the inflow of human capital

5 In fact, Geroski (forthcoming, 2000) argues that since firms which are close to the capacity constraint – due to the Penrose-effect- face higher costs of growth when compared to other firms, firms are likely to smooth our their current growth opportunities, sacrificing current profits but saving some of the costs of growth which they may otherwise incur to gain those profits.

In conjunction the discussion in (4.1)-(4.3) we can specify this proposition as follows:

P4.1: Ceteris paribus, the more human capital inflow consists of industry-specific human resources the higher will growth rates be.

P4:2: The more human capital inflow increases the diversity of the firm's knowledge structure the lower will growth rates be, ceteris paribus.

One possible measure of the Penrose effect, using our database, would be to trace across time the fraction of managers with a tenure of less than a certain period (say a year) to the total number of managers within the firm. Additionally our data allow us to control for intra- and inter-sectoral human capital flows.

4.3. External knowledge structures: sectoral regimes

So far we have discussed the firm's knowledge structure and changes thereof. However, firms are not isolated entities; they are embedded in exchange and production relations (Granovetter, 1985). As a consequence, the knowledge structure of the firm is embedded in the knowledge structure of the sectors in which it is active.

In their seminal book on evolutionary economics, Nelson and Winter (1982, pp. 258-259) introduced the notion of 'technological regimes' as determinants of patterns of innovative activities across industries. The idea has later on been further developed by Malerba and Orsenigo (1990), such that a technological regime is viewed as a particular combination of some fundamental properties of technologies. These properties are, opportunity and appropriability conditions; degrees of cumulativeness of technological knowledge[6]; and finally characteristics of the relevant knowledge-structures – both in firms and sectors.

The *characteristics of external knowledge structures* refer to various types and sources of knowledge firms can draw upon. In this context, Smith (1995) distinguishes between three

6 Opportunity conditions reflect the easiness of innovating, given an amount invested in technological search, while appropriability conditions echo the possibilities of protecting innovations from imitation and of reaping profits from innovative activities. Cumulativeness represents the probability of innovating in t+1, given an innovation at time t (or in earlier periods). More generally, cumulativeness denotes an economic environment, characterised by relevant continuities in technological activities performed on different knowledge bases (Richardson, 1972). At the technological level cumulativeness refers to specific features of technologies and to the mode of learning.

different areas of production of relevant knowledge related to different levels of specificity. The *first* level is the *general scientific knowledge structure*, which consists of very differentiated fields of knowledge with a widely varying relevance for industrial production. The fields with the closest connections with major industrial sectors are to be found within areas such as molecular biology, physics, genetics and inorganic chemistry. The *second* level is the knowledge structure at the level of the *industry or product- field*. At this level industries' often share particular scientific and technological parameters, and with industries intellectual understandings concerning technical functions, performance characteristics, the use of materials etc. are shared. The *third* level concerns the knowledge structure of *particular firms*. At this level we are dealing with only one or a few technologies, which are well integrated into the firms and form the basis of their competitive position. Due to the high level of specificity of technology at this level, there are clear limits of the firms' competencies. Thus, the firms must be able to access and use knowledge from outside the core area of the firm.

Our analysis will not aim at estimating the elements of technological regimes[7] *per se*, since we have no data on innovation output. Nevertheless, such regimes will enter the analysis in two different ways. First, the characteristics of the knowledge-base will – as discussed above- enter in a rather direct ways, as we will look at the inflow of knowledge embodied in people from other parts of the economy, as well as on the composition of the formal competencies of the workforce. Second, we consider abandoning the assumption of sectoral invariance, found in most of the empirical analyses of firm growth we are aware of. In other words we want to estimate models with sector-specific slopes, across firms (and time), and want to make subsequent econometric tests to see whether such a procedure is appropriate.

In continuation hereof, we wish to make an attempt to classify patterns of determinants of firm growth. For instance, it might well be that the effect of human capital is only found to be important for particular types of firms, within specific sectors, or that diversity of the workforce has an impact only for some other type of firms. In particular we expect that the relative importance of the sources of knowledge (firm-specific vis-a-vis industry-specific knowledge) for firm growth, will differ according to the sectoral affiliation of the firms. On a general level, we thus propose that:

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7 Breschi and Malerba (1997) discuss how particular combinations of the elements of technological regimes can be said to make up 'sectoral innovation systems'.

P5: Firm growth is related to the sectoral regimes of firms.

4.4. The knowledge structure 'model' of firm growth

So far, we have discussed possible relationships between aspects of external knowledge structure on the one hand side and firm growth on the other (Section 4). Additionally, we have discussed how the data available to us can be used to address these aspects. On the basis of the above discussion we integrate our main propositions into the knowledge structure 'appreciative model' (c.f. Nelson and Winter, 1982) of firm-growth (see Figure 1, below).

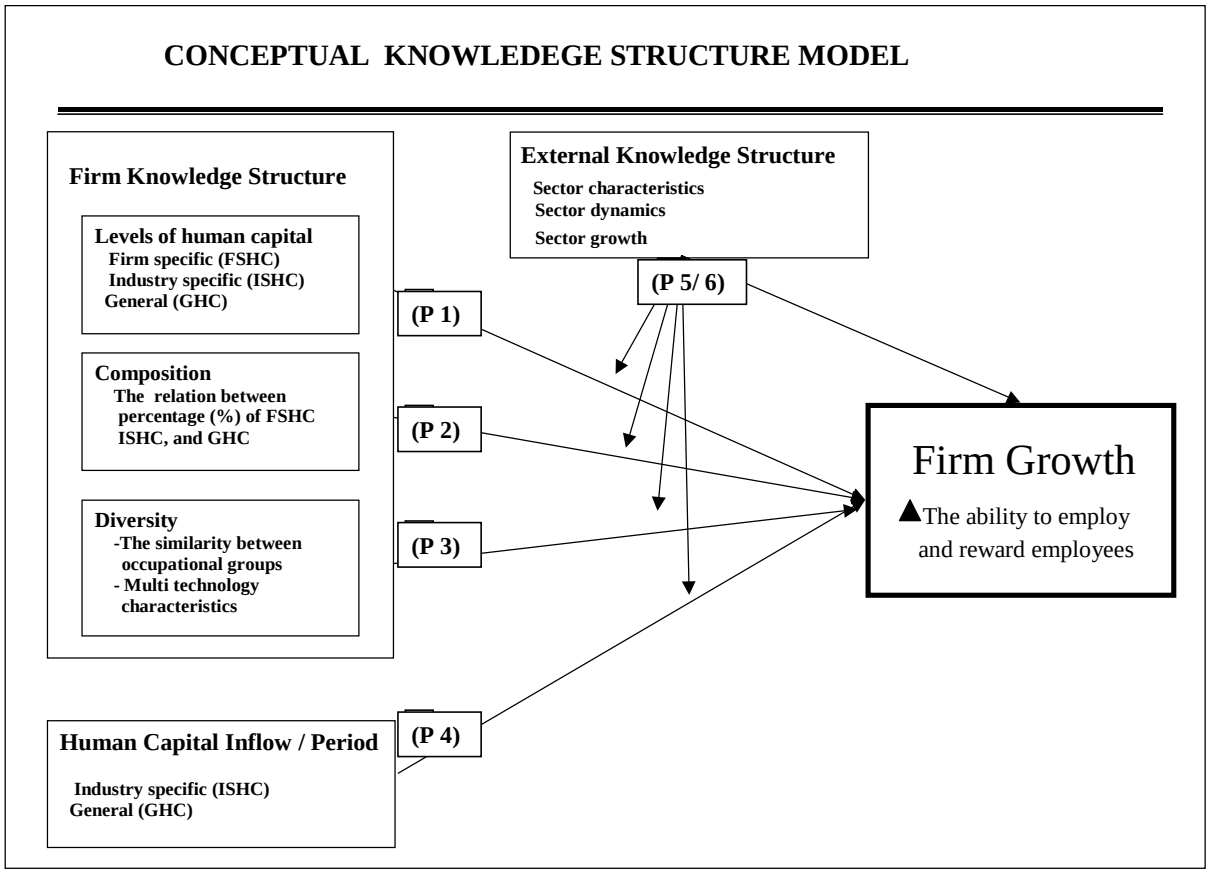

Figure 1: The proposed effects of knowledge structure on firm growth

5. FIRST RESULTS

In the previous part of the paper we have discussed a quite elaborate 'model' of firm growth. However, in this section we wish – as an initial empirical step – to present some first results in attempting to explain firm growth by means of the knowledge structure approach. Our purpose is to look at the impact of what has been termed 'general knowledge' previously in the paper. Basically, we will in this section of the paper operationalise general knowledge to being the *formal* qualifications of the workforce only. That is, we will look at whether it matters for firm growth that firms have a higher fraction of people with higher education (longer, medium and shorter higher education) employed in the initial year. In doing so, we will *first* attempt to replicate one of the few studies we are aware of, looking at the impact of aspects of knowledge on firm growth, namely Leonard (1986). The reason for doing that is that we wish to benchmark our data against previous findings, in order to validate the potential generality, which can be obtained from our data (the *IDA* database, discussed in Section 3). *Second*, we will extend the model of Leonard, by explicitly looking at sectoral (industry) differences in the ability of 'general knowledge' to explain firm growth.

Our dependent variable is the (logarithmic) growth rate of the number of employees, weighted by the initial size of the firm:

$$GR_j = (\ln(SIZE_{t1}) - \ln(SIZE_{t0})) * \ln(SIZE_{t0}), \tag{1}$$

where *j* denotes firm and *t0* and *t1* denote initial and end year, respectively. The reason for following this procedure is that we think that a firm which grows from 10 to 20 employees should count less in the regression than a firm growing, say from 1000 to 2000 employees. We took data for two years from the *IDA* database, the initial year being 1984, and the end year being 1996. From this sample we selected all Danish firms in manufacturing and in business services with more than 10 employees both in the initial as well as in the final year. Another criteria was that the firms selected, needed to be present in the sample in both years.

In a first step we attempt to 'replicate' the findings of Leonard (1986). Leonard looks at a sample of 68,690 US establishments in private business enterprise (primary products, manufacturing and private service), using 1974 as the start year, while 1980 is the end year. Leonard's dependent variable is the (unweighted) logarithmic growth rate over the period. The right hand side variables includes initial (1974, logarithmic) size and the proportion of

non-clerical white collar workers as a proportion of each firm's workforce (a measure of human capital), as well as 28 industry and 4 geographical dummies. He finds that initial size is negatively correlated with firm growth. However, Leonard is keen to point out that in a stochastic model of firm growth as presented in his paper, a negative coefficient of initial size is not a sufficient condition for concluding that growth is concentrated in small establishments. With regression to the mean (for a good presentation and discussion of this concept, see Hart and Prais, 1956) a negative coefficient on lagged size is likely even if the direct effect of growth is positive. In this model strong evidence of size hindering growth would be that the parameter for initial size would be smaller than –1. Since the coefficient is found to be significantly larger than -1, the hypothesis of size being a hindrance to growth is found to be unacceptable to Leonard. However, more importantly in relation to our paper, Leonard finds that the measure of human capital has a positive and significant impact on firm growth.

Our first analysis basically corresponds to the set-up of Leonard (leaving out the regional dummies):

$$GR_j = \alpha\ D_i + \beta_1 SIZE_j + \beta_2 GENKNOW_j + \varepsilon_j, \qquad (2)$$

where D_i is a dummy for the sectoral (industrial) affiliation of the establishment, while $SIZE_j$ is the initial size (1984), measured in the (logarithmic) number of employees in establishment j. $GENKNOW_j$ is the level of general knowledge in the establishments, measured as the fraction of employees with higher education within each establishment in the initial year. ε_j is an error term.

The results of the estimation based on Equation (2) are reported in Table 1. It can be seen from Table 1 that initial size has a negative parameter. Nevertheless, as pointed out by Leonard, we need to be cautious about the interpretation of this parameter. If we have a model, where (unweighted) logarithmic growth is to be explained by initial logarithmic size then the necessary condition is that the parameter of size is significantly smaller than –1. If we alter our set-up in such a way; that is by using unweighted logarithmic growth, rather than the weighted growth measure (indeed, if our prime motive was to examine the issue of size effects on growth, the unweighted measure would have been more appropriate), we obtain a

Table 1: Regression results for explaining firm (establishment) growth 1984-1996, in a model with (industry) fixed effects (n = 5788)

	R^2= 0.109 (adj. 0.107)	
Variable	Estimate	*p*-value
SIZE84	-0.74	0.0001
GENKNOW84	1.18	0.0001
S1	0.40	0.0001
S2	-0.77	0.0001
S3	0.50	0.0001
S4	0.25	0.0288
S5	0.44	0.0008
S6	1.36	0.0056
S7	0.64	0.0001
S8	0.58	0.0001
S9	-0.39	0.4945
S10	0.40	0.2100
S11	0.08	0.7334
S12	1.02	0.0010
S13	-0.05	0.8372
S14	0.13	0.3616
S15	2.44	0.0001

Note: For a description of the sectors *S1-S15*, see Table 2. *SIZE84* expressed in logarithms

negative estimate for this variable (β = -0.19, *p*-value = 0.0001).[8] Nevertheless, the size of the parameter is significantly larger than –1. Hence, it is premature to conclude that size is detrimental to establishment growth, based on our estimations. Concerning the industry-specific effects, nine industries (food, drink and tobacco [S1]; wood, cork and furniture [S3]; paper and printing [S4]; chemical products, incl. refined oil [S5]; pharmaceuticals [S6]; metals and fabricated metals [S7]; machinery [S8]; motor vehicles [S12];and business services [S15]) have been the most consistent growth sectors, while textiles, footwear and leather [S2] has been the most consistent shrinkage sector.

However, the single most important result in the context of this paper is that general knowledge intensities appear to matter to firm growth, even in this relatively rough empirical set-up, since the parameter for the variable measuring the initial intensity of employees with higher education is strongly significant.

Since we found important sectoral differences in the first part of the analysis, our second

8 The complete set of estimations, based on the unweighted growth measure is available from the authors on request.

Table 2: Regression results for explaining firm (establishment) growth 1984-1996, in a model allowing for variable slopes (n = 5788)

R^2= 0.137 (adj. 0.130)			
Variable	Sector	Estimate	*p*-value
SIZE84	Food, drink and tobacco	-0.74	0.0001
	Textiles, footwear and leather	-1.30	0.0001
	Wood, cork and furniture	-0.34	0.0310
	Paper and printing	-1.02	0.0001
	Chemical products, incl. Refined oil	-0.51	0.0001
	Pharmaceuticals	-0.47	0.2651
	Metals and fabricated metals	-0.63	0.0001
	Machinery	-0.72	0.0001
	Office machines and computers	-3.43	0.0001
	Communic. eq. and semiconductors	-1.94	0.0001
	Other transport	-0.32	0.1301
	Motor vehicles	0.41	0.1833
	Instruments	-2.06	0.0001
	Other manufacturing	-1.11	0.0001
	Business services	-0.61	0.0001
GENKNOW84	Food, drink and tobacco	-3.09	0.0171
	Textiles, footwear and leather	10.28	0.0130
	Wood, cork and furniture	-2.22	0.4222
	Paper and printing	1.04	0.3583
	Chemical products, incl. Refined oil	-1.66	0.4263
	Pharmaceuticals	4.09	0.4609
	Metals and fabricated metals	4.38	0.0572
	Machinery	1.51	0.1342
	Office machines and computers	12.18	0.0030
	Communic. eq. and semiconductors	4.40	0.2413
	Other transport	4.78	0.3317
	Motor vehicles	1.33	0.8152
	Instruments	-10.69	0.0001
	Other manufacturing	2.61	0.2251
	Business services	1.43	0.0001

Note: Sector fixed effects not reported for reasons of space. *SIZE84* expressed in logarithms.

step is to estimate a model, allowing for the slopes to differ according to the sectoral affiliation of the establishment in question:

$$GR_{ij} = \alpha_i D_i + \beta_{1i} D_i SIZE_{ij} + \beta_{2i} D_i GENKNOW_{ij} + \varepsilon_{ij}, \quad (3)$$

where the notation is the same as in Equation (2). The results of the estimation based on Equation (3) are reported in Table 2. It can be seen from Table 2 that initial size turns out to

have negative and significant parameters in 12 out of 15 cases. Nevertheless, by using the unweighted growth measure all industry size coefficients are significantly larger than –1.

For what concerns the variable measuring general knowledge, it is found to be positive and significant in 4 out of 15 cases. The positive parameter in the case of textiles, footwear and leather is probably due to the fact that this sector has experienced a marked decline (as documented in Table 2) in Denmark, due to the movement of production facilities out of Denmark and into low wage areas. However, the establishments which have performed relatively well have been the high knowledge intensive establishments (e.g. design & marketing intensive establishments). For what concerns the significant and positive parameter for metals and metal products, the high skilled labour in question appear to consist of engineers. For machinery the same story goes, but the parameter escapes the 10 per cent level of significance. In addition, traditionally high knowledge intensive establishments situated in office machines and computers and within business services, appear to be dependent on having relatively high proportions of employees with a higher education, in achieving high levels of establishment growth. In the case of office machines and computers it can be noted that the parameter is particularly high (12.18).

6. CONCLUSION

Inspired from the capability approach and from our unique data set, we have argued in this paper, that one way to advance empirical research on firm growth is to conceptualise firm growth as being determined by the knowledge structure and its evolution. As a consequence, we suggest to explicitly account for dynamics and change in knowledge structures both on a firm and sector-level of analysis. To be concrete, we focus on human capital flows both within and between sectors. Additionally, we try to add flesh to the capability approach through the construct of knowledge structure. This potentially facilitates to investigate how human capital combines idiosyncratically in firms to fuel or impede growth in terms of the capacity to employ, educate, and reward employees.

The paper began by stressing the fact (in Section 1) that previous empirical research on firm growth has faired rather poorly. Furthermore, a set of new research questions were posed, addressing the relationship between firm growth on the one hand and various variables related to knowledge on the other hand. Section 2 dealt with the issue of standard explanations of firm growth, as well as with the standard control variables previously applied

in analyses of firm growth. Section 3 contained a description of the data set available, as well as a subsequent discussion of how the available data set can be managed. In this regard, it was contemplated that a cohort of establishments and a cohort of workforce characteristics would be an advantageous means of organising the large data set.

Section 4 started out by discussing relevant performance measures of firms. It was argued that the growth in terms of employees will serve as a good measure, when compared to other possible yardsticks. Further the Section established that a number of theoretical contributions -at various levels of analysis- have seen human capital as key to the understanding of growth processes. In the context of the importance of human capital for growth, we distinguished between (a) levels of human capital available to firms, (b) the composition of various kinds of human capital ('firm- specific', 'industry-specific', and 'general knowledge') contained, and (c) the diversity of knowledge domains represented to characterise the knowledge structure of firms. Based on this categorisation we argued that all three components of a firm's knowledge structure are likely to influence firm growth. In addition, we contemplate that important sectoral variation exists, in relation to the explanatory power of the various independent variables already discussed. For instance, we can speculate that types of formal education will be more important in high-tech sectors, while learning-by-doing types of variables ('sector-specific knowledge' and 'firm specific knowledge') will be relatively more important in more mature sectors. Finally, Section 4 ended up by attempting to condense the possible correlations and causations into a conceptual or 'appreciative' model of firm growth.

In Section 5 we presented our first empirical results, using the knowledge structure approach. In the first part of our empirical analysis we found – while controlling for intial size and industry affiliation – that the availability of a high fraction of employees with higher education within each establishment, was in general conducive to establishment growth. In the second part of the empirical analysis, we found important sectoral differences with respect to the ability of the level of (higher) formal education to explain firm growth. Admittedly this is only one aspect of knowledge structures; something which is also clear from our theoretical discussion in Section 4. Future research should include variables reflecting not only *different* catagories of formal education, but also variables reflecting the learning-by-doing types of knowledge structures.

So far we have tried to identify possible antecedence to firm growth, which upon empirical testing may be modified, dropped, or extended. As a consequence, making more precise theoretical predictions about growth patterns would be overly pre-mature. Both the relevance of the suggested antecedence to firm growth as well as predictions about growth

patterns will emerge as the development of the knowledge structure ‘model’ to firm growth proceeds. For the moment being, we believe it is far more important to go a step back and investigate further antecedence to firm growth as well as their interrelations empirically.

As Kant long ago argued, perception without conception is blind and conception without perception is empty. In other words, available data and empirical research to stimulate new conceptual models while new conceptual models are needed to make new sense out of available data. This paper, thus, advocated an empirical knowledge structure approach to firm growth to make sense out of available data. In this way our first empirical results were in accordance with the knowledge structure approach. As demonstrated in the theoretical part of this paper much still awaits to be done in further research. Nevertheless, although this paper sets the agenda for future research, the initial analysis of the empirical evidence is promising.

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Danish **R**esearch **U**nit for **I**ndustrial **D**ynamics

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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.

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