DRUID Working Paper No. 10-28

Sources of Regional Resilience in the Danish ICT Sector

By

Jacob Rubæk Holm and Christian Richter Østergaard

Danish Research Unit for Industrial Dynamics

www.druid.dk

Sources of Regional Resilience in the Danish ICT Sector

Jacob Rubæk Holm
DRUID
Department of Business Studies
Aalborg University
E-mail: jrh@business.aau.dk

Christian Richter Østergaard
DRUID
Department of Business Studies
Aalborg University
E-mail: cro@business.aau.dk

Abstract:
In this paper the use of the term "resilience" is discussed and a definition for use in quantitative studies of industrial evolution is suggested. Resilience is the ability of an industry in a region to exploit the possibilities arising from external events and adapt to thrive under new selection environments. An econometric analysis is undertaken to uncover the effects of the change in selection environment that the ICT industry faced from the burst of the ICT bubble in the year 2000. It is shown that some characteristics of regional industry structure are associated with growth over the whole period while other characteristics have varying effects pre and post burst. Special attention is given to the responsiveness of growth to the evolution of sales of ICT goods and services in Denmark and it is found that the industry structures that restrain growth also are the ones, which make the regional industry better able to exploit changes in sales at the national level.

Keywords: Resilience ; Business cycle ; ICT sector; Regional growth

Jel codes: E32 ; L86 ; R11

ISBN 978- 87-7873-310-8

1. INTRODUCTION

The evolution of industries is often found to be uneven across regions. Some regions appear to provide better conditions and more stimulating environments for the growth of certain industries than other regions (Boschma and Knaap, 1999; Brenner, 2004). The regional stock of inputs, such as knowledge, skills and natural resources in combination with the initial size and composition of the industry are found to have an effect on the growth of the industry across regions (Henderson et al., 1995; Maskell et al., 1998; Feldman and Audretsch, 1999; Beardsell and Henderson, 1999, Frenken et al, 2007). However, these studies of the spatial evolution of industries often disregard the impact of changes such as the business cycle on this growth. As the business cycle unfolds the selection environment in which firms compete changes drastically. Across regions particular industries seem not to be affected much by this, while others react sharply, exhibiting highly unstable evolution. Therefore, the evolution of an industry will be influenced not only by the abilities of regions and firms to create factors that support growth, but also by the responsiveness to external events. Thus growth and resilience are two important qualities that influence the evolution of an industry in a region.

Economic systems are continuously confronted with change in the external environment. These continuously occurring changes make some firms go bankrupt while other firms thrive on the change. The consequence of these firm level dynamics can be the initiation of decline in industries and regions but it may also be the initiation of a prolonged boom for the regional industry. However, these dynamics vary across regions – an industry can appear to be unaffected in some regions and declining or booming in other regions. An industrial system in a region can remain fairly stable during a crisis or be completely transformed by the crisis and in both cases exhibit resilience. Some firms might close and workers loose their jobs but the industry and related knowledge and skills survive in the region, as long as afterwards start-ups emerge, existing companies grow or diversify into related technologies and the industry recovers. Thus being resilient does not imply being static. An industry in a region is resilient if it has a structure that allows it to exploit the possibilities arising from external events and adapt to thrive under new selection environments. Internally, the resilient regional industry could have a high churn of firms, high labour mobility and be fairly unstable under disturbances. Resilience is an important quality in the evolution of industries and might affect future growth for if there is a net decrease in activity then possibilities for future spin-offs decrease and the knowledge base erodes, as knowledgeable workers seek jobs in other industries or leave the region. Many studies have analysed which factors and industry structures that support the growth of an industry in a region, while the sources of regional resilience only have been analysed sparsely. An exception is a recent special issue of the Cambridge Journal of Regions, Economy and Society (vol. 3, no. 1, 2010) where the concept of resilience is discussed and analysed through case studies. In these studies resilience is often seen as a non-measurable and rather fuzzy quality of regions to recover from diverse types of shocks in the long-run. However, econometric evidence is still missing on why the regional resilience differs within the same industry and how the measurable factors that enhance resilience are related to factors that support regional growth.

The purpose of this paper is to analyse the sources of regional growth and resilience in the Danish ICT sector from 1992 to 2006. The ICT sector has experienced rapid growth and increasing economic importance the last couple of decades. It has also changed the working methods in almost all other sectors in the economy. The ICT sector is characterised by a rapid technological change and international competition. Thus, it exhibits a high degree of uncertainty and change, and skills become outdated quickly. The ICT sector grew faster than the rest of the economy during the 1990s, but when the Dotcom bubble burst in 2000 the business cycle turned and employment declined. But this does not mean that all ICT firms in all regions all over Denmark were affected in the same way. It is quite possible that some ICT firms thrived during the downturn as firms in other industries invested in ICT as part of a rationalization process forced by the downturn. This evolution has challenged and created opportunities for the firms as well as the ICT sector in the various regions. Consequently, the resilience in the Danish ICT sector has been revealed in this period. This paper will take its point of departure in the factors that lead to regional growth of the Danish ICT sector and then analyse which factors that supports regional resilience to the changes in the business cycles.

The empirical analysis is based on register data from Statistics Denmark that contains detailed information on all employed individuals and all Danish firms. Therefore it is possible to create precise longitudinal variables for the human capital intensity in the Danish functional urban regions and business cycle indicators based on aggregate real revenue. This paper's point of departure is a model explaining the yearly growth in ICT sector employment across regions from 1992 to 2006. These growth rates vary by region and over time. The regression models include factors such as diversity, size of the region, human capital intensity, and employment specialisation in services. It is found that diversified, blue collar regional ICT industries grew more than other regional ICT industries in the boom years of the middle and late '90s while regional ICT industries dominated by young, small service plants grew more in the years after the burst of the bubble. There is also an indication that ICT industries in urbanized regions with a high level of education performed particularly well during the boom years but particularly bad after the burst. When studying how industry structure mediates the effect of the business cycle, it is shown that after the burst not only do regions with small, young service ICT plants grow more, they do so decoupled from the business cycle. And not only do ICT industries with highly educated labour in urbanized regions have low growth after the burst, they are also highly dependent on the business cycle. This indicates that the resilience in the Danish ICT sector varies across the regions and that some of the factors that support growth are interrelated with resilience.

The paper is structured as follows: The next section presents theories of regional growth and resilience, while Section 3 describes the data and methodology for studying resilience empirically. The results of empirical analyses are presented in Section 4 followed by the conclusions in Section 5.

2. Sources of regional growth and resilience

Many studies of growth of various sectors across regions discuss the importance of location-specific externalities related to specialization, diversity or urbanization. That is, the growth of an industry in a particular region depends mostly on the initial relative size of the industry, on the diversity in the industrial activities or on the overall size of the region. The empirical results indicate that location-specific externalities exist and influence spatial evolution of economic activities. However, often multiple types of externalities are found to be important and critics state that finding evidence of externalities is not the same as identifying their sources (Hanson, 2000) and that these externalities varies over time (Neffke, 2008). In addition, studies of location-specific externalities often focus too much on externalities and therefore overlook the differences in factors within the industry across regions that might differ greatly. Furthermore, the studies of the regional evolution of industries have largely overlooked the effect of changes in the business cycle. These shifts change firms' external environment and affect the evolution of industries especially when the business cycle suddenly turns negative. The regional industries react differently to these shocks. Resilient regions adapt to the new conditions while the industry declines in other regions

2.1 What is Resilience?

A regional ICT industry in which industry structure successfully adapts to cope with varying external conditions, e.g. to the stages of the business cycle, has a high resilience. This means that regional ICT industries which fail to evolve as required by the conditions set by the business cycle are not resilient. Resilience is thus a normative measure of direction in evolution. Good evolution is survival through adaptation. The most resilient regions evolve from a structure that is optimal for growth under current conditions to the structure that is optimal under the conditions of the following period. This use of the term contrasts with some of its other uses in fields related to economics.

In the literature on social-ecological systems the term "resilience" is used to describe the ability of a system to absorb or withstand changes inflicted onto the system form the outside (Walker et al., 2004; Gunderson and Holling, 2002; Holling, 1973). Walker et al. (2004) defines the resilience of a system as "The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004, p 5.). Thus, a system can face disruption up to a certain level and still retain the same function before it starts to collapse – resilience is the extra amount of strain that the system can take before breaking down. This form of resilience, 'ecosystem resilience', is contrasted in the literature with engineering resilience, which refers to the sensitivity of a given factor to external disturbances. Thus, engineering resilience is close to the economic concept of elasticity. The concept used in the present paper is inspired by engineering resilience in the sense that it is a concept for responsiveness of a system to external forces. But it is also related to ecosystem resilience in that it is a concept for the ability of a system to cope with changes in external environment. Farber (1995) discusses the importance of ecosystem resilience and relates it to the economic system in a quite different fashion. He argues that economic and ecological systems alike can be healthy in the sense of being resilient. In Faber's use of the term, a resilient economic system has limited poverty.

In a more policy oriented line of research the term resilience is used in relation to external change in a manner similar to ecosystem resilience: It connotes both the ability of a (regional) economy to remain in the current state and to return to the previous state (Hill et al., 2008; Rose and Liao, 2005; Rose, 2004). This form of resilience is referred to as "(regional) economic resilience" and refers to the resilience to natural disasters, terrorist attacks etc. of an economy. In this tradition an economy is said to be resilient if the relevant performance indicator either is relatively unaffected by the disturbance or returns to the pre-disturbance level relatively quickly. This concept of resilience also has similarities with elasticity and thus with engineering resilience. Another concept of resilience that is even closer to engineering resilience is used in more traditional economic research by Elmeskov et al (2007) and Wantanabe et al. (2004) independently of each other. Elmeskov et al. uses the term to describe the size and duration of business cycle fluctuations across the OECD, whereas Wantanabe et al. uses the term when describing the effect of the business cycle on the profitability of selected Japanese high-tech industries. Again, these uses of the concept come very close to elasticity. The concept that is suggested in the current paper is, as argued above, partly inspired by the concept of ecosystem resilience and therefore allows for regions to undergo large scale change in the course of evolution while still being resilient. The focus here will be on a single aspect of the external environment of the industry namely the business cycle; or more specifically: the fluctuations in sales of ICT products and services between 1992 and 2006. A more complex concept of resilience would acknowledge that there is a dimension of resilience for each identifiable factor of the external environment and that, in a continuously evolving economy, resilience to one period of fluctuations in demand need not entail resilience to future fluctuations.

The term resilience is used in a wide range of meanings and this has lead to a critique of the ambiguity of the term resulting from such ubiquitous use (Simmie and Martin, 2010). However, this paper offers an interpretation of the term for use in studies of the evolution of industries. This interpretation draws on related fields, in particular the concept of ecosystem resilience, and defines resilience in the context of evolutionary economics. Simmie and Martin (2010) suggest a similar approach for evolutionary economics, though their focus is on qualitative methods while the present paper focuses on quantitative methods.

2.2 Evolution of industries and resilience

Industries evolve differently across regions. It appears that some regions provide better conditions for the growth of a particular industry, while other regions are not able to provide the industry with the needed inputs (Boschma and Knaap, 1999). Some of these differences relate to differences in the regional stock of inputs, such as knowledge, skills, and natural resources, while others stem from the initial structure of the industry, such as size of firms and level of specialization (Henderson et al., 1995; Feldman and Audretsch, 1999; Beardsell and Henderson, 1999).

Brenner (2004) argues that three types of interactions shapes the evolution of regional industries: Within the firm population, with other firm populations in the region and with regional conditions, such as human capital, local education system, public research, local capital market, culture and historical specificities, local attitudes, and local policy. These interactions create location specific externalities. Brenner finds that when an industry in a region reaches a large size these externalities create positive feedback mechanisms that induces further growth in that particular industry, while other regions with a low level of industrial activity or insufficient positive feedback mechanisms remains lagging behind. The industry in the regions with a high level of activity is more resilient and is less likely to decline because the positive feedback mechanisms are sustaining the industry through entry of new firms. Marshall (1920) was among the first to observe that firms within the same industry often continue to colocate in some regions based on three kinds of externalities: (i) economies of specialization caused by a concentration of firms being able to attract and support specialized suppliers thereby achieving economies of scale like large companies, (ii) economies of labor pooling, where the existence of a pool of labor with particular knowledge and skills attracts firms, and (iii) technological externalities, where knowledge, ideas and information flow more easily between co-located actors than over long distances. Therefore regions with a high specialization in ICT or a large ICT sector are likely to be resilient to changes in the business cycle and also experience higher growth.

However, Frenken et al. (2007) argues that while specialization enhance the employment growth it also creates greater vulnerability to external shocks. Therefore regions that have a more diverse industry structure might experience a lower growth, but they are also more resilient to external shocks. If the industry is specialized it draws heavily on the same resources and it causes higher wages and other negative congestion effects. Having a more diverse regional ICT sector can avoid some of these problems and it provides a variety of employment opportunities if the employment in one part of the sector faces a shock. Diversity within the ICT sector creates a greater variety in the knowledge base and thus a greater source of cross-subsector knowledge spill-overs and opportunities for emergence of new activities (Jacobs, 1969; van Oort and Atzema, 2004). Therefore, diversity in the regional ICT sector will be a source of resilience, since diversity will mitigate the effect of crisis in one part of the ICT sector and the cross-fertilization of ideas create opportunities for new types of work.

The diversity externalities are closely related to urbanization externalities. The cities are often more diverse in their industry structure. Studies of the evolution of the ICT sector often find a positive effect of location in a large metropolitan area (Van Oort and Atzema, 2004; Eriksson, 2006). This is explained by the availability of resources for knowledge intensive services: A good infrastructure, availability of highly skilled workers, a large local market and a close distance to customers, suppliers, labor and universities. The universities and other research organizations are located in the cities, which creates and attracts highly skilled workers and creative talented people (Florida, 2002). While many new activities emerge and initially experience a high growth in the large cities, it might later on diffuse to other regions. However, the large cities have a much greater chance of attracting highly skilled workers and less chance of loosing it (Beardsell and Henderson, 1999). The urban externalities can be a source of resilience for the regional ICT sector.

The quality of the local labor market and the availability of skilled labor is key factor in the evolution of industries. This is especially important for the ICT sector that has a very skill-biased demand for labor. Despite that general computing skills are not hard to obtain, the share of employees with a masters degree is high and has been growing. Firms with higher human capital intensity are also more likely to be innovative and it can create localized knowledge spill-overs (Audretsch and Feldman, 1996; Maskell et al. 1998). Thus an increase in the human capital intensity of the firms is likely to increase the resilience in the regional ICT sector.

The size distribution of the firms in the regional ICT sector also affects its growth and resilience. Porter (1998) argues that the level of local competition will influence the regional growth. A high level of local competition will increase the overall competitiveness of the regional ICT sector and lead to higher growth rates. However, large firms often invest more in research and development and have a greater financial capital to withstand changes in the business cycle. Thus a low average firm size will increase competition and growth, while a high average firm size creates a greater resilience to the business cycle.

Entrepreneurial activity is an important source of economic change and growth (Schumpeter, 1934). It also has a geographical effect, since the entrepreneurs tend to start up their firm in the region where they live (Sorenson, 2003). The formation of new firms reproduces some of the existing industry and skill structures in the region, because entrepreneurs tend to start up in industries closely related to their previous employment experiences. These spinoffs from existing firms are an important factor in the spatial evolution of industries. However, it also adds new variety to the region, when inexperienced entrants or firms from other regions enter the regional industry (Maskell et al., 1998; Sorenson, 2003; Frenken et al., 2007; Neffke, 2008). All three types of entry will add to the growth of the regional ICT sector, but regions with a high entry rate will also be more affected by changes in the business cycle. New firms are more vulnerable when the selection environment change and the business cycle worsen. Therefore are regions with a high entry rate less resilient to changes in the business cycle.

To sum up: It is expected that a regional industry structure with small, young firms will have a high growth through the effect of competition while it may be both fragile and thus sensitive to the business cycle and adaptable and thus insensitive to the business cycle. It is expected that urban, diversified and human capital intensive regions are more resilient to the business cycle through increased adaptability. It is expected that regions with oligopolistic ICT industry structures grow slowly from weak competition but are relatively resilient to changes in the business cycle. These relationships will vary over the time period being studied.

3. DATA

The analysis is based on the IDA[1] database. IDA is maintained by Statistics Denmark and contains personal information on all workers in the Danish labour market. Focus will be on the data on workers: Their region and sector of employment, their level of education and their occupation. The remaining data comes from the complementary General Firm Statistics[2] database, from which firm level data on revenue are used to create the indicator of the business cycle. All firms with a Danish VAT number and activity over a negligibility threshold are included in this database. Although IDA data is available from 1980 onwards, a break in the sector codes in 1992 necessitate that the study will be limited to the evolution of the Danish ICT sector from 1992 to 2006; the most recent year for which data is available.

3.1. SUBSECTORS, REGIONS AND THE BUSINESS CYCLE

The primary variable of interest is the growth rate of regional ICT employment and it is thus necessary to start by delimiting both the ICT sector and the regions of Denmark. The ICT sector is defined as the aggregate of the ten subsectors presented in Table 1. Table 1 also lists the activity codes used for delimiting the subsectors. The activity code is based on the Danish DB93 (DB03 from 2003), which is identical to NACE rev 1.1 codes at the four digit level.

[1] "Integreret Database for Arbejdsmarkedsforskning".
[2] Prior to 1999: "Firmastatistik og Ressourceområdestatistik". After 1999: "Generel Firmastatistik".

NACE/DB93 Codes		
Manufacturing		
Office machinery		
	3001	Manufacture of office machinery
Computers		
	3002	Manufacture of computers and other information processing equipment
Electronic components and wires		
	3130	Manufacture of insulated wire and cable
	321010	Manufacture of printed and electronic integrated circuits
	321090	Manufacture of semi-conductor devices, condensers, resistors, etc.
Telecommunications equipment		
	322010	Manufacture of transmission apparatus for radio-telegraphy and radio-telephony
	322020	Manufacture of telephone sets, switchboards and telex apparatus
Consumer electronics		
	323010	Manufacture of radio and television receivers, etc.
	323020	Manufacture of loudspeakers, etc.
	233030	Manufacture of aerials and aerial equipment
Electro medical		
	331020	Manufacture of hearing aids and part thereof
	331030	Manufacture of electro-diagnostic apparatus
	331090	Manufacture of X-ray apparatus, dental apparatus, respiration apparatus, etc.
Instruments etc.		
	332010	Manufacture of navigation equipment
	332020	Manufacture of apparatus for measuring the flow, level, pressure, etc. of liquids or gases
	332030	Manufacture of apparatus for measuring and checking electrical quantities
	332040	Manufacture of apparatus for carrying out physical and chemical analyses
	332090	Manufacture of other measuring and checking equipment
	333000	Manufacture of industrial process control equipment
Services		
Wholesale		
	514320	Wholesale of radio and television goods
	516410	Wholesale of computers, office machinery and equipment
	516520	Wholesale of electronic components
Telecommunications		
	642000	Telecommunications
IT service and software		
	713310	Renting of office machinery and equipment, including computers
	7210	Hardware consultancy
	7220	Software consultancy and supply
	7230	Data processing
	7240	Database activities
	7250	Maintenance and repair of office, accounting and computing machinery
	7260	Other computer related services

Source: Based on Pedersen (2005)

Table 1 – Subsectors of the ICT sector

Delimiting a sector of an economy needs more careful deliberation than settling on the number of digits of the official industry classifications. It is important to see a sector as a set of firms, whose actions are interdependent. Table 1 shows the definition of the ICT sector with ten subsectors based on Pedersen (2005). The data contains information on firm level revenue for firms in all but one of the ten subsectors: Telecommunication services. The growth rate of real aggregate revenue for the remaining nine subsectors will be used as an indicator of fluctuations in sales for the whole ICT sector. The evolution of the growth rate of real sales (revenue deflated by the price index of the domestic supply of goods) in the ICT sector is illustrated in Figure 1 where is it also contrasted with the evolution of the growth rate of ICT employment at the national level.

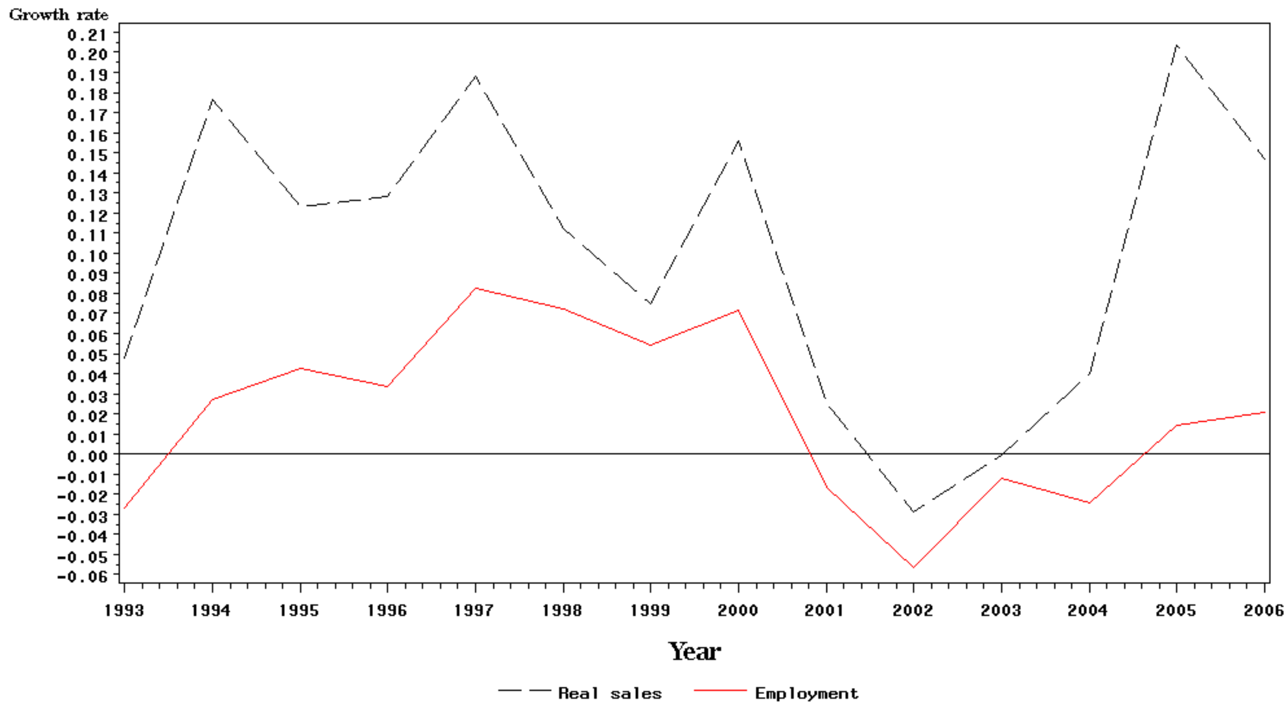


Figure 1 – The business cycle: sales and employment growth

The growth rates in Figure 1 are relative to the previous year. The spike of sales in 2000 that seems to spill over slightly into employment may at least partially be explained by the panic about the Y2K bug. But this will not be explored further here. The ICT bubble itself does not show up as clearly in these indicators as it does in, for example, stock market data such as that presented in Figure A.1 in the appendix. Figure 1 illustrates a stylized fact:

The ICT sector grew almost explosively during the late 1990s and it shows negative growth rates in 2000-3 following the burst of the dotcom bubble in 2000. By 2005 the sector seems to have recovered.

The responsiveness of employment to changes in sales seems to vary over time when observing the growth rates plotted in Figure 1. The negative ICT sales growth in 2002 corresponds to the year with the largest drop in ICT employment, but the large growth in ICT sales in 2005 is barely identifiable on the employment side. The sales variable in Figure 1 is used as a business cycle indicator. As already mentioned this variable does not include firms in the subsector "Telecommunication services". Another limitation is that it is based on firm level data whereas the sector of employment in the worker level data refers to the plant level and the plants of a given firm may very well have different sector codes. Nevertheless this variable is employed as an indicator of growth in sales in the ICT sector. Using sales as an explanatory variable for employment growth entails assuming that changes in sales precede changes in employment but it is not difficult to think of scenarios where changes in employment precede changes in sales. Thus the growth rate of sales will be lagged one period.

Functional urban regions are used as proxies for regional industrial systems and for identifying such regions the approach of Andersen (2000) is used. Andersen (2000) uses an algorithm based on commuting patterns to segregate Denmark into a number of functional urban regions. The algorithm works by first determining a subset of municipalities to be centres of regions and assigning the remaining municipalities to these centres. The least isolated region is then split up, the centre is removed and the municipalities are re-assigned. This continues until a threshold of isolation/closedness is reached. The algorithm takes two inputs: K_1: The share of people living in a municipality who must also work there for the municipality to be a potential centre of a region. K_2: The factor by which the people living and working within a region must outnumber the gross sum of people commuting in and out of the region for the region to be closed to stop the algorithm.[3] Andersen's approach is implemented in the IDA database and the final results are much more dependent on K_2 than on K_1 and the number of regions for a given parameterization decreases as the algorithm is applied to later years. The algorithm is not capable on its own of dividing Denmark up into a number of meaningful industrial regions. As K_2 is increased the number of regions decreases but this does not mean that the regions have centres at the industrial centres of the country. Rather, perfectly meaningful functional urban regions are broken up and the most peripheral municipalities are left as

[3] Example: Assuming net commuting is zero and 80 pct of workers live and work within the region K_2 would equal 2 (80/(20+20)).

regions on their own.[4] The regions used in the present paper are constructed by running the algorithm for 2005 with K_1 equal to 0.5 and the minimum requirement for K_2 equal to 1.33. This yields 38 regions which are discretely grouped into 21 regions. The 38 regions are shown in Figure A.2.a in the appendix while the 21 regions are shown in Figure A.2.b and the final regions are listed in Table A.1, also in the appendix.

With 21 regions and 14 observations of growth rates per region the total panel dataset contains 294 observations. 21 are lost as a lag of the growth in regional ICT employment is used in the regressions. Thus there are 273 observations for statistical analysis.

3.2. DEPENDENT AND EXPLANATORY VARIABLES

The key variable of interest in this paper is $grICT_{it}$; the growth rate of ICT employment in region *i* at time *t*. The data in IDA is compiled in November of each year and thus growth rates of employment will refer to the growth rate from November to November. As the aim is to explain this growth rate by industry structure in the base year growth for a given year will be relative to the following year.

It is necessary to control for factors expected to cause diverging growth rates before additional variation is explained as differences in resilience. For this purpose the following eight variables are introduced. The variation by year and region will be controlled for by fixed effects where appropriate.

The first variable is diversity (*Diver*) which is calculated as the Shannon index of diversity[5] of the regional distribution of employment among the ten subsectors of the ICT sector. The second is human capital intensity (*HCint*) which is the share of regional ICT employment with at least a master's degree. The third variable is urbanization (*Urban*) which is the natural logarithm of total regional employment.[6] The fourth variable is specialisation in services (*Service*) which is the share of regional ICT employment working within the three bottom subsectors of Table 1. The fifth variable is the average size of ICT plants in the region (*AvSize*, measured by the average number of employees), while the sixth variable is the share of workers employed in plants, which have been set up during the current or the previous year (*New*). Variable number seven is the share of workers in blue collar occupations (*Blue*) and the final variable (*ICTspec*) is the regional specialisation in ICT (defined as the share of

[4] These peripheral municipalities are places with low population and barely any commuting in and out; often they are islands. It is therefore necessary to stop the algorithm at a relatively early stage and then either ignore the peripheral regions or join them to the nearest other region. The later solution is applied here.

[5] Also known as entropy or the Teachman index (Harrison and Sin, 2006).

[6] Using the logarithmic transformation entails assuming decreasing returns to urbanization; i.e. the difference between 1,000 and 1,100 workers matters more than the difference between 10,000 and 10,100 workers.

regional employment working in the ICT sector). These variables for industry structure are suspected to have exhibited a trend in development during 1992-2006 and therefore a linear time trend at the national level has been estimated and subtracted from the observations. The slope coefficients of these eight regressions are given in the bottom row of Table 2 below.[7] Seven of the slopes are statistically significant. There has been a trend towards less diversity, higher education, more urbanization, a movement from manufacturing towards services, smaller plants and less blue collar workers and lastly a trend towards increased weight in the national economy of the ICT sector. There is no trend in the share of new plants. These trends are closely intertwined. The shift of the ICT sector from manufacturing to services will typically entail a decrease in diversity as there are 7 manufacturing subsectors and only 3 service subsectors specified in the data. Service plants are also generally smaller and have more educated workers and fewer blue collar workers. They are often also younger though this has not resulted in a trend in *New*.

Variable	*grICT*	*Sales*	*Diver*	*HCint*	*Urban*	*Service*	*AvSize*	*New*	*Blue*	*ICTspec*
Sales	0.232***	1								
Diver	0.035	-0.069	1							
HCint	0.119*	0.100*	0.106*	1						
Urban	0.065	0.016	0.342***	0.772***	1					
Service	-0.007	0.005	-0.152**	0.225***	0.202***	1				
AvSize	0.023	0.046	-0.177***	0.246***	0.135**	-0.689***	1			
New	-0.052	-0.156	0.028	0.109*	0.121**	0.217***	-0.219***	1		
Blue	-0.035	0.041	-0.036	-0.647***	-0.561***	-0.558***	0.092	-0.121**	1	
ICTspec	0.089	0.055	0.112*	0.735***	0.571***	-0.333***	0.699***	-0.073	-0.336***	1
Mean	0.0094	0.0959	1.5294	0.0427	11.135	0.6419	18.795	0.0965	0.5660	0.0241
Std Dev	0.0841	0.0724	0.2220	0.0385	0.8214	0.2278	13.118	0.0750	0.1240	0.0176
Time slope	-	-	-0.017***	0.006***	0.015***	0.010***	-0.517***	0.001	-0.009**	0.001***

Diver, HCint, Urban, Service, AvSize, New, Blue and ICTspec were de-trended before correlations were computed. Asterisks denote significance: *: 10%, **: 5%, ***: 1%. n=273. Time slope is the slope coefficient from an OLS regression at the national level of the variable in question on year. n=14 for the regressions. Source: Own calculations based on IDA.

Table 2 – Descriptive statistics

[7] There is a break in the data underlying *Blue* between 1995 and 1996. From 1996 onwards the IDA database does not distinguish between white and blue collar wage earners so blue collar is defined as the lowest level of wages earners. This results in a shift upwards in the level of *Blue* from 1996 which is accounted for by including dummy for the years 1992-5 in the estimation of the time trend.

Table 2 shows the mean, standard deviation and matrix of correlation for *grICT*, the eight variables introduced above and the sales variable, (*Sales*), the growth rate of real revenue for the ICT industry at the national level lagged one period.

Table 2 shows that the mean regional growth rate of ICT employment is 0.94 pct. per year and that it is positively correlated with the growth rate of sales (*Sales*). Only one of the variables for industry structure is correlated with employment growth: Human capital intensity, *HCint*, and this is also the only variable for industry structure that are correlated with the growth rate of sales. There is a general correlation among the variables for industry structure. This is not surprising. The larger regions (*Urban*) will generally also have greater the scope for diversity (*Diver*) and be centred on the larger cities and relatively educated workers and relatively few blue collar workers (*HCint* and *Blue*). The correlation between service specialization and urbanization, new plants and size of plants corresponds to service plants being smaller, having a higher churn and more often being located in larger cities than manufacturing plants. This corresponds to results also found in other studies (see Eriksson, 2006; van Oort and Atzema, 2004).

Variable	Factor 1	Factor 2	Factor 3
Diver	-0.041	-0.030	0.804
HCint	0.324	0.006	-0.040
Urban	0.264	-0.032	0.235
Service	0.125	-0.393	-0.220
AvSize	0.091	0.400	-0.166
New	0.025	-0.169	0.204
Blue	-0.289	0.180	0.173
ICTspec	0.248	0.255	-0.009
Label	Metro	Districts	Hetero

Principal component analysis. Three factors with eigenvalue > 1 explaining 80.1 pct. of the variation in the data. The table present the correlation between factors and original variables after varimax rotation.

Table 3 – Factor analysis

The high correlation among the eight variables for industry structure means that using them in a single regression model would result in multicollinearity and low significance of estimates from the inflated standard errors.

Therefore the variables are submitted to a principal component analysis in order to reduce the number of variables used in the regressions. Table 3 shows the result of the principal component analysis after varimax rotation.

Table 3 shows the three factors with eigenvalue greater then one resulting from a principal component analysis on the eight variables for industry structure after applying varimax rotation. The first factor especially loads positively on the variables for urbanization and human capital intensity and negatively on the variable for share of blue collar workers. This factor is labeled *Metro* as regions scoring particularly high in this factor are the metropolitan regions of Denmark with high quality workers in high level occupations. The second factor 2 is labeled *Districts*. It captures the traditional Marshallian industry districts of the ICT sector: regions scoring high on this factor have relatively large ICT sectors (*ICTspec*), large plants (*AvSize*) and a bias towards manufacturing (*Service*). The last factor is strongly correlated with *Diver* but is also the factor correlated the strongest with *New*. It is labeled *Hetero* as it captures regional ICT industries with a lively heterogeneity of young firms. For all three factors the mean is zero, the standard deviation is one and their correlation with each other is zero. *Sales* is also standardized to mean zero and standard deviation one before being used in the regressions.

3.3. MODELS

All of the regression models in the following section are estimated with OLS. They are fixed effects models with fixed effects for regions and for years when the *Sales* variable is not included. There is some evidence that switching the year fixed effects with *Sales* introduces heteroskedasticity in the models. Robust standard errors are therefore reported throughout the analyses. In the case of the two-way fixed effects models, the models are estimated by subtracting from the observation the mean for the year in question and the mean for the region in question and then adding the overall mean. For the one-way fixed effects models the regional mean is simply subtracted from the observation. This is alternative to actually adding dummies for years and regions but the results will be identical.

Three growth models are estimated in Section 4.1: One for the whole period 1993-2005, one for the period leading up to the burst of the bubble (1993-9) and one for the post bubble period (2000-5). In Section 4.2 these models will be expanded by interacting *Sales* with the three factors for industry structure in order to study how structure mediates the effect of changes in sales.

4. RESULTS

The period being studied in this paper includes a very turbulent period for firms in the ICT sector. From 1992 the sector grew rapidly, but in 2001 the growth rate turned negative and only became positive again in 2004. However, the various regional ICT industries in Denmark evolved very differently from the aggregate and the aim of this paper is to expose the regional differences in industry structure that can explain this.

Figure 2 plots the 21 regions in a 'pre-burst growth' by 'post-burst growth' space. The horizontal axis is the cumulative growth from 1992 to 2000 while the vertical axis is the cumulative growth from 2000 to 2006. A regression line is also shown in the figure. The line has a slope of 0.015 and an R-square of 0.0005 indicating that pre-burst growth is not at all an indicator of post-burst growth. Interestingly two regional ICT sectors actually shrank during the boom years: Region 4 (Lolland-Falster) and 20 (Vendsyssel). Region 20 is the only regional ICT sector to decline during the boom years and then grow after the burst.

The largest regions (1: Copenhagen, 6: Odense, 18: Århus and 21: Aalborg, cf. appendix Table A.1) tend to show a decreasing relationship between pre- and post-burst growth. Of the four, Aalborg grew the most during the boom but receded slightly after the burst while Odense hardly grew during the boom but performed better than most after the burst. This indicates that neither of the two regions managed to fit its ICT industry structure to the requirements of the period and thus neither regions is particularly resilience. The best performing regions, growing strongly in both periods, include some of the smallest regions (7: Svendborg and 19: Viborg) but also the medium sized Vejle region (12)

Figure 2 – Regional ICT Employment Change, percentages performs well.

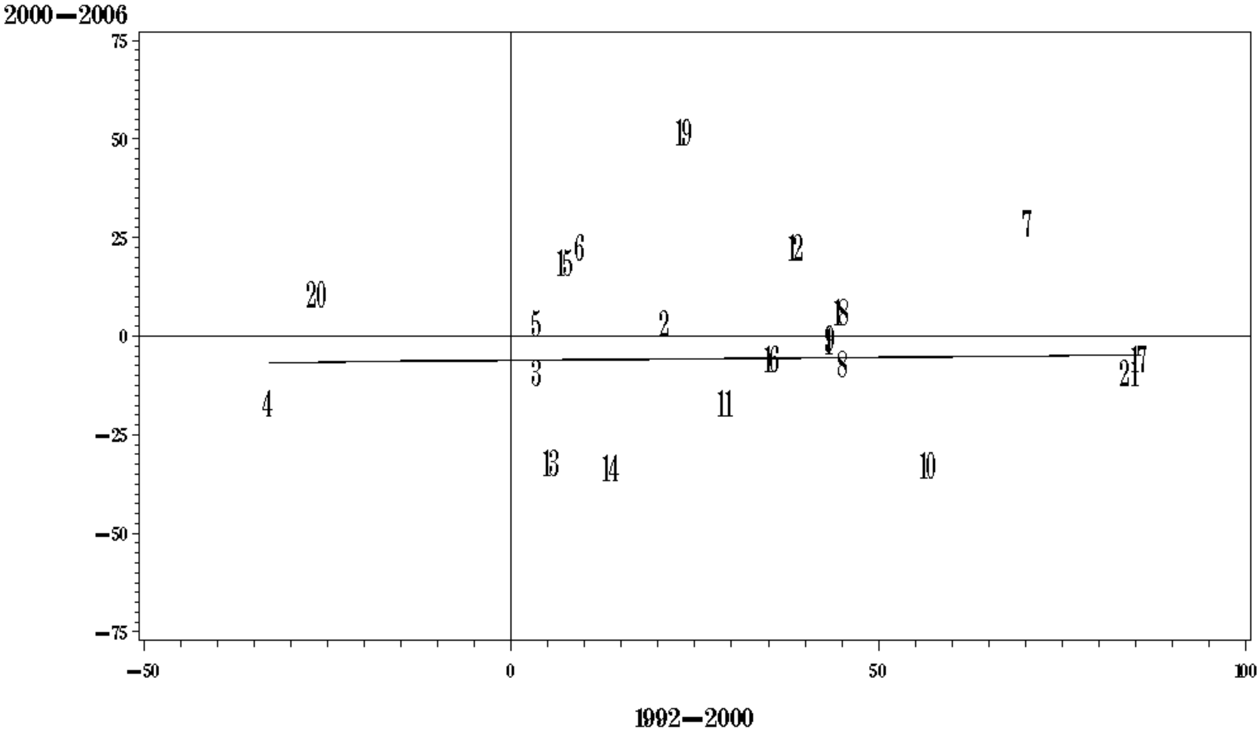


Figure notes: The regions corresponding to each number can be found in appendix Table A.1. Regions 1 and 9 are located on top of each other at roughly 45 pct pre burst growth and 0 post burst growth. The slope of the regression line is 0.01546 with a p-value of 0.9221.

The evolution of the ten subsectors of the ICT sector during 1992-2006 follow highly disparate patterns. Only two subsectors have a larger number of employees in 2006 than in 1992. The levels of employment and the distribution of employment in 1992 and 2006 are shown in Table 4 along with summaries of the change over the period.

Table 4 shows how employment in the ICT sector and its ten subsectors evolved during the period of 1992-2006. While the ICT sector as a whole had grown by 30.7 pct. by 2006, six of the ten subsectors declined and almost all of the growth stems from the subsector "IT Service and Software" and to some degree "Telecommunication services". These subsectors along with the third service subsector "Wholesale" are of particular focus in the following analyses and regional specialisation in services is part of the second factor, which was labelled *Mark I* as it seems that the Mark I industry structure is especially prevalent in services. Except for the subsector "Instruments etc." the manufacturing subsectors in particular have declined during the period. "Manufacturing of Office Machinery" has almost disappeared from the Danish ICT sector in 2006 (92.78 pct. decrease) and "Manufacturing of Telecommunications Equipment" has been more than halved (61.15 pct. decrease). Another perspective on this evolution can be seen by looking at the number of plants in each subsector. In 2006, 3780 of the 6357 plants in the sector were in the ICT Services and Software subsector while there were only 6 plants left in the Manufacturing of Office Machinery subsector.

	Office	Computers	Components	Telecom equipment	Consumer electronics	Medical equipment	Instruments etc.	Wholesale	Telecom services	IT service and software	ICT sector total
ICT subsectors in 1992											
#Empl.	637	1.671	4.467	3.333	4.821	5.293	5.799	19.845	16.024	16.429	78.319
Share	0,81%	2,13%	5,70%	4,26%	6,16%	6,76%	7,40%	25,34%	20,46%	20,98%	100,00%
#Plants	13	67	104	52	73	309	184	1.164	307	1.269	3.542
#empl./plant	49,0	24,9	43,0	64,1	66,0	17,1	31,5	17,0	52,2	12,9	22,1
ICT subsectors in 2006											
#Empl.	46	1.222	2.681	1.295	3.871	5.631	6.721	19.446	17.869	43.605	102.387
Share	0,04%	1,19%	2,62%	1,26%	3,78%	5,50%	6,56%	18,99%	17,45%	42,59%	100,00%
#Plants	6	51	82	35	65	277	203	1.351	507	3.780	6.357
#empl./plant	7,7	24,0	32,7	37,0	59,6	20,3	33,1	14,4	35,2	11,5	16,1
Change in ICT subsectors 1992-2006											
Empl. Growth	-92,78%	-26,87%	-39,98%	-61,15%	-19,71%	6,39%	15,90%	-2,01%	11,51%	165,41%	30,73%
p.a.	-17,12%	-2,21%	-3,58%	-6,53%	-1,56%	0,44%	1,06%	-0,14%	0,78%	7,22%	1,93%
Empl. in 2006 in old plants	60,87%	69,07%	64,45%	82,55%	82,61%	78,94%	64,48%	51,14%	19,19%	35,74%	43,57%

"Old plants" are plants established in 1992 or earlier. p.a. employment growth is the geometric mean by sector and thus not equal to the average of grICT in table 2, which is the un-weighted arithmetic mean by region and year. Source: Own calculations based on IDA.

Table 4 – The evolution of the Danish ICT sector, 1992-2006

The table also shows the average number of employees at the plants of the subsectors. While this number has generally dropped or increased slightly over the period the subsectors are very heterogeneous. Firms in the two service subsectors "Wholesale" and "IT service and software" are generally quite small – which translates into 'near mean', as these two subsectors sums to more than three fourths of the total. The manufacturing sectors on the other hand range from almost 60 workers per plant in Consumer Electronics to 20 in Medical equipment and 8 in Office Machinery. Table 4 also reports the entry dynamics. It shows the percentage of workers employed in 2006 at plants set up in 1992 or earlier (that is, the share of 'old' plants weighted by employment). In the fastest growing subsector, IT Service and Software, old plants only account for roughly one third of employment, and it is even lower in the "Telecommunication services" subsector at about one fifth. However, the two other growing subsectors, "Medical Equipment" and "Instruments etc", still have most employment in old firms, again indicating that the oligopolistic Mark II structure is typical of manufacturing while Mark I is typical of services.

4.1. Growth models

The question of the resilience of the ICT sector to the business cycle is approached in a stepwise manner. First, a growth model explaining regional ICT employment growth (*grICT*) as a function of the three factors for industry structure and with fixed effects for years and regions is estimated. The model also includes the lag of *grICT* in order to account for potential trend effects in employment growth. Then the model is augmented with the *Sales* variable to take into account the effect of changes in national ICT sales growth on regional ICT employment. Thus in Model 2 there will be no fixed effects for years. Lastly, it will be studied how industry structure mediates the effect of variation in sales by including interaction of *Sales* and the factors for industry structure in Model 3.

The following model relates regional ICT employment growth to regional characteristics that are expected to affect it, cf. the earlier discussion of the literature:

Model 1:

$$grICT_{it} = \beta_{0,1} + \beta_{1,1} grICT_{it-1} + \beta_{2,1} Metro_{it} + \beta_{3,1} Districts_{it} + \beta_{4,1} Hetero_{it} + fixed\ effects\ for\ regions\ and\ years + u_{it,1}$$

Model 2 is an extension of Model 1 taking into account also the effect of adaptation to variations in sales.

Model 2:

$$grICT_{it} = \beta_{0,2} + \beta_{1,2} grICT_{it-1} + \beta_{2,2} Metro_{it} + \beta_{3,2} Districts_{it} + \beta_{4,2} Hetero_{it} + \beta_{5,2} Sales_{t-1} + fixed\ effects\ for\ regions + u_{it,2}$$

$u_{it,1}$ (and all subsequent *u*s) is a classical error term. The second subscript of the slope coefficients and the error refers to the model number. Fixed effects are used to account for regional and yearly peculiarities. Models that include *Sales* as an explanatory variable do not include fixed effects for years since these would introduce perfect multicollinearity.

The results from fitting Models 1 and 2 with OLS using the full panel of 21 regions and 13 years are reported in Table A.2 in the appendix as models 1a and 2a. The table shows that the slope coefficient for *Metro* is the only statistically significant slope in Model 1a and that the slope for *Sales* is the only significant slope in Model 2a. The estimate for *Metro* is negative indicating that ICT sectors with low human capital intensity and relatively many blue collar workers in rural areas grow the most, but once the fixed effects for years are replaced by the *Sales* variable the result disappears and it seems that all that matters for regional ICT employment growth is the evolution of sales at the national level. However, the relationship between industry structure and employment growth should depend on the conditions for industrial evolution and these must differ markedly before and after the burst of the ICT bubble. To test for the presence of a structural break at the burst of the ICT bubble a dummy is defined to be 1 in the early period (until and including 1999) and 0 in the late period. By adding interactions of the dummy and the respective explanatory variables to the model it is possible to tell whether the slopes are significantly different from 2000 onwards. The bottom row of Table A.2 presents the p-value for a joint test of all variables at once. The test evaluates whether the values of the beta parameters of models 1 and 2 would be equal if the model was fitted independently for 1993-9 and 2000-5. For both models the test allows us to reject the hypothesis. Thus models 1 and 2 are refitted for 1993-9 and 2000-5 yielding models 1b, 2b, 1c and 2c respectively. The results from these estimations are also presented in Table A.2.

Regardless of whether Model 1 or 2 is employed the results show that *Metro* is statistically significant for regional ICT employment growth in both periods while *Districts* is statistically significant for growth in 2000-5. This means that the ICT industry structure that characterized growing regions over the whole periods is rural and has low human capital intensity and blue collar bias. The negative slope coefficient for *Districts* after 2000 means that growing regional ICT industries in the new millennium were characterised by a bias towards small service plants and centred in regions where ICT employment made up a relatively low share of total employment. The results also show a weak indication that *Hetero* was positive for growth in the '90s but negative after the burst. I.e. that ndustries with a diversity of young plants grew strongly pre burst but weakly post burst. It is also worth noticing that *Sales* is only significant in the late years indicating that sales at the national level meant little for growth in the boom years but mattered much more after the burst. In order to study the varying effect of the variation in sales over the business cycle in more detail interactions of *Sales* and the three factors for industry structure are added to Model 2 one at a time yielding Model 3.

Model 3_*j*:

$$grICT_{it} = \beta_{0,3\_j} + \beta_{1,3,j}grICT_{it-1} + \beta_{2,3\_j}Metro_{it} + \beta_{3,3\_j}Districts_{it} + \beta_{4,3\_j}Hetero_{it} + \beta_{5,3\_j}Sales_{t-1} + \beta_{6,3\_j}Interaction_{jit} + fixed\ effects\ for\ regions + u_{it,3\_j}$$

with *j* in (1,2,3) indicating interactions of *Sales* and *Metro*, *Districts* and *Hetero* respectively. The models will be estimated for the early and late years separately. In the following section Model 3 will be used to study the mediating effect of regional characteristics on the effect of changes in sales growth on changes in regional ICT employment.

4.2. Models of resilience

The growth models developed above is used to study the resilience of regional ICT employment to sales changes by adding a number of interaction terms. The variable that is hypothesised to have a varying effect on the dependent variable is the growth rate of real national ICT revenue, *Sales*. This variable will be referred to as the focal variable. It has been hypothesised that the effects of the focal variable varies according to industry structure and therefore the three indicators of industry structure, *Metro*, *District* and *Hetero*, are referred to as moderator variables. The three moderator variables and the focal variable result in a total of three interaction terms, which are included in Model 3 one at a time. The resulting models will be estimated for the periods 1993-9 and 2000-5 independently. The results are presented in Table A.3 in the appendix and again, a *b* following the model name indicates that it is estimated for the early years while a *c* indicates the late years. For each model the joint significance of the interaction term and the focal variable is tested using the LaGrange multiplier test. The result of this test is also presented in Table A.3.

The results presented in Table A.3 confirm the result from the previous models that scoring low on the *Metro* factor was associated with high growth over the whole period and that scoring low on *District* was associated with high growth after the burst of the bubble. That is, over the whole period ICT employment grew the most in relatively rural regions in which the ICT industries were low in human capital intensity and had a blue collar bias. But after the burst of the bubble there was also a tendency for regional ICT industries with a large share of small service plants to grow more than other regional ICT industries.

The results in Table A.3 also strengthen the finding that regions scoring highly on *Hetero*; having a highly diverse ICT industry with relatively young firms, grew relatively much during the '90s but weakly in the first half of the '00s. Growth in sales is a significant indicator of employment growth in none of the models pertaining to the early years but it is significant in all of the models for the late years. That is, only after the burst of the bubble did growing sales translate into future employment growth. The fact that the lag of employment growth is mostly significant in the early years and has a negative estimate shows that regions growing strongly in one year often grow relatively weakly in the subsequent year indicating that underneath the national ICT employment boom in the '90s were some highly irregular local developments.

The results for the last three models presented in Table A.3 pertain to the period 2000-5 and are very different from the results for the earlier period. The differences in the effects of industry structure on growth were described above but there are also significant interactions of *Sales* and industry structure in model 3_1 and 3_2, i.e. the two interaction terms, *Sales*Metro* and *Sales*District*, indicate that *Metro* and *District* mediates the effect of *Sales* on regional ICT employment growth. In both cases the LaGrange multiplier test for joint significance of the interaction and the focal variable (*Sales*) confirm the significance. To study the meaning of the interaction the marginal effect of *Sales* on the dependent variable conditional on the respective mediating variables are plotted in Figure 3. The top panel refers to model 3_1 while the bottom panel refers to model 3_2. The dashed black lines pertain to 1993-9 while the solid red lines are for 2000-5. The horizontal axes correspond to the ranges of *Metro* and *District* respectively. Both variables have mean zero and standard deviation of one so the horizontal axes also act as indicators of skewness and kurtosis. The plotted lines vary in length according to the variation in the two subsamples (pre and post burst years).

The interaction effects are only significant in when estimating the models for the later years but from Figure 3 it seems that the two moderators *Metro* (top) and *District* (bottom) also mediate the relationship between sales growth and the growth rate of regional ICT employment in 1993-9 (dashed lines). Comparing the dashed and solid lines indicates that the mediating effect of *Metro* is more or less the same in two periods and that the change in the effect of *Sales* on ICT employment growth is more of a level effect. Comparison also indicates that the mediating effect of *District* changed drastically: from higher values of *District* working to dampen the effect of *Sales* on employment to higher values magnifying the effect. But it must be kept in mind that neither the intercept nor the slope of the dashed lines is significant.

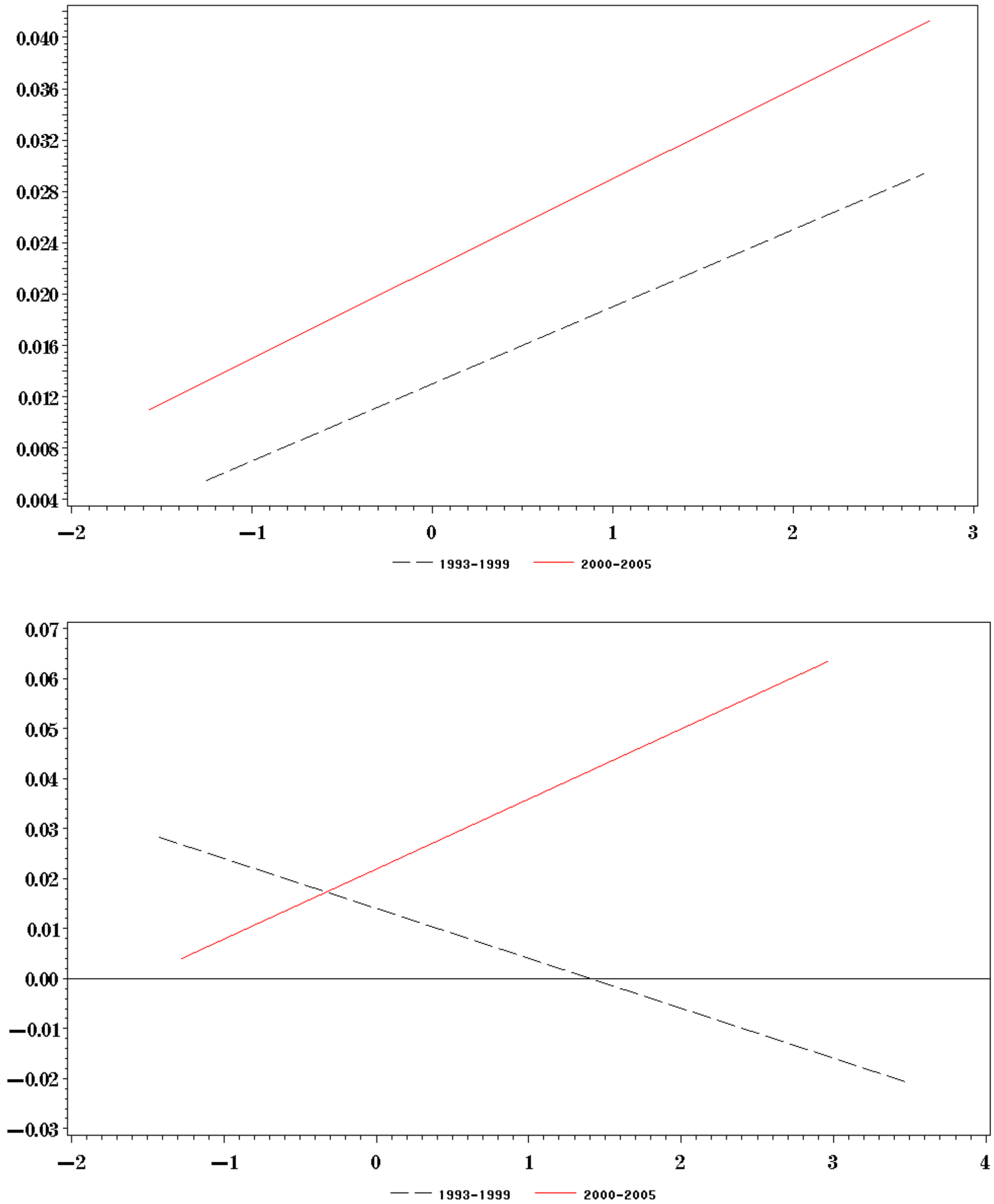


Figure 3 – Marginal effects

The effect of sales growth on regional ICT employment growth varies quite a lot for different values of *Metro* in 2000-5. For the most metropolitan regions, those with a *Metro* score of almost 3 standard deviations above the mean, a standard deviation change in sales growth translates into about a 4 percentage point change in ICT employment growth. At the other end of the spectrum the least metropolitan regions only suffer approximately a 1 percentage point change in employment growth for each standard deviation change in sales growth. These marginal effects are of course the extreme cases but serve to highlight the differences in sensitivity to sales caused by differences in *Metro*. The bottom panel of Figure 3 shows that *District* also mediates the effect of changes in sales during 2000-5. For regions with an ICT industry structure along the lines of Marshall's industrial districts sales growth barely has an effect on employment, while in regions with the opposite ICT industry structure (a relatively small ICT sector dominated by small service plants) a one standard deviation change in the growth of sales means a 6 percentage point change in employment growth. As with the mediating effect of *Metro* this is the hypothetical extreme predicted by the model but it serves to highlight the differences in sensitivity to changes in sales growth caused by differences in industry structure.

The concept of resilience that is developed in the current paper describes the ability of a regional industrial system to adapt in the face of external change. That is, to adapt so that the industry can take advantage of opportunities that arise but also to adapt in times of crisis and evolve into a structure that allows it to continue to survive and grow under the new conditions. This is a very complex concept and the econometric analysis has focussed on the responsiveness of employment to changes in sales growth and the difference in impact across Danish regions of the burst of the ICT bubble. The results of the econometric analysis are summarized in Table 5.

		Metro	*Districts*	*Hetero*
1993 to 1999	Growth	**-**	**0**	**(+)**
	Resilience	**0**	**0**	**0**
2000 to 2005	Growth	**-**	**-**	**(-)**
	Resilience	**+**	**+**	**0**

"Resilience" here refers to mediating the effect of activity change

Table 5 – Result overview

Over the whole period being studied, 1993-2005, the ICT industry structures associated with employment growth were low *Metro* structures. The new conditions prevailing after the burst of the bubble meant that low *District* structures were associated with growth. This is consistent with a trend over the whole period where the industry diffuses to more peripheral regions of Denmark and where conditions in the later period favored small service plants in particular. Some of the estimation also indicates a complex relationship between *Hetero* and growth: regional ICT industries with a diversity of young plants grew more strongly than other in the '90s but grew weaker than others after the burst. Some of this effect, however, is likely to be explained by the fact that there are fewer service subsectors and thus less scope for diversity when the industry shifts from manufacturing towards services.

In the '90s there is no evidence that industry structure affects the responsiveness of employment to sales growth and, indeed, there is no evidence that employment responds to sales growth at all. But in the first half of the '00s, on the other hand, employment responds positively to sales growth and this responsiveness is mediated by industry structure. Regional ICT industry structures scoring high on *Metro* and/or on *District* are more responsive to sales growth.

Two questions that arise when looking at these results in a policy perspective are: What is, then, the most resilient region in Denmark and what must a region do to increase its resilience? The analyses here are a first attempt of an empirical study of resilience and can answer neither. Resilience is an evolving capability: A region may have just the right industry structure at just the right time to exploit e.g. technical change but fail to maintain the lead as the conditions for growth changes. Industry structure itself is dynamic in the sense that an industry cannot grow without changing structure and so high growth in one year may translate into a radical change in structure. Even if policy makers could direct the evolution of industry structure, ex ante knowledge of the "optimal" structure is hard to come by and industry structure is mostly slow to evolve. Even finding the most resilient region of Denmark ex post is not possible based on the results here, as plots of the regions according to industry structure is strongly affected by the year chosen for the plot.

5. Conclusions

In this paper a model of the regional growth rate of ICT employment was first constructed. This was based on a reading of earlier contributions and the current paper to some extent confirmed these earlier results. Diversity promotes growth under some set of external conditions (i.e. the '90s) and so does entry (which in this paper was captured by the share of workers working at plants set up in the current or previous year) though this effect was found to be opposite under different external conditions (e.g. the '00s). It was also shown that urbanization, human capital intensity and a large share of white collar workers, captured by the *Metro* factor, had a negative effect on the growth rate of employment over the whole period. This does not mean that the jobs that were created were in low education blue collar jobs. It means that jobs were created in places were the number of low education blue collar jobs was relatively high. It is possible that the new jobs were high education white collar jobs and that the process uncovered was one of catching up.

The analysis also uncovered that certain characteristics of the regional ICT industry will affect the way in which the growth rate of regional ICT employment depends on the business cycle. The business cycle was captured by the growth rate of sales measured by real ICT revenue at the national level. ICT employment was generally not responsive to sales growth in the '90s while sales growth had a significant effect on employment growth after the year 2000. In the later years industry structure had a mediating effect on the relationship between sales growth and employment growth: industry structures consisting of large manufacturing plants in regions with a relatively large ICT industry were more sensitive to sales growth and so were industry structures in urban regions with a relative dominance of highly educated white collar workers.

Whether or not it is beneficial for regional ICT employment to be dependent on the evolution of industry sales at the national level of course depends on whether sales are growing or not. But, as this paper has shown, there are aspects of industry structure that affect both growth and resilience. A regional ICT industry structure that is able to transform growing sales at the national level into employment growth (i.e. a metropolitan structure and/or a structure along the lines of Marshallian districts) is the same structure as is associated with generally sluggish employment growth.

6. References

Andersen, A. K. (2000): "*Commuting Areas in Denmark*". AKF Forlaget.

Beardsell, M. and Henderson, V. (1999): "Spatial evolution of the computer industry in the USA." *European Economic Review* 43: 431-456.

Boschma, R. and Knaap, G. A. v. d. (1999): "New high-tech Industries and windows of locational opportunity: The role of labour markets and knowledge institutions during the industrial era." *Geografiska Annaler* 81 B(2): 73-89.

Brenner, T. (2004): "*Local Industrial Clusters: Existence, emergence and evolution*". London and New York, Routledge.

Elmeskov, J., Duval, R. and Vogel, L. (2007): "Structural policies and economic resilience to shocks". *OECD Economics Department Working Papers*, no. 567, OECD Publishing.

Eriksson, C. M. (2006): "The dynamics and organisation of the Swedish ICT industry 1990-2004". *Department of Technology Management and Economics*. Gothenburg, Chalmers University of Technology: 140.

Farber, S. (1995): "Economic resilience and economic policy". *Ecological Economics*, vol. 15, pp. 105-107.

Feldman, M. P. and Audretsch, D. B. (1999): "Innovation in cities: Science-based diversity, specialization and localized competition." *European Economic Review* 43: 409-429.

Florida, R. (2002): "*The Rise of the Creative Class*". New York, Basic Books.

Frenken, K., van Oort, F. G. and Verburg, T. (2007): "Related variety, unrelated variety and regional economic growth". *Regional Studies*, 41(5): 685-697.

Gunderson, L. H., and Holling, C. S. (eds.) (2002): "*Panarchy: understanding transformations in human and natural systems*". Washington D.C ., Island Press.

Hanson, G. H. (2000): "Scale Economics and the Geographic Concentration of Industry." *NBER Working Paper Series* (8013).

Henderson, V., Kuncoro, A. and Turner, M. (1995): "Industrial Development in Cities". *The Journal of Political Economy* 103(5): 1067-1090.

Hill, E. W., Wial, H. and Wolman, H. (2008): "Exploring regional economic resilience". *UC Berkeley: Institute for Urban and Regional Development Working Paper Series*, no. 2008-04.

Holling, C. S. (1973): "Resilience and stability of ecological systems". *Annual Review of Ecological Systems*, vol. 4, pp. 1-23.

Jacobs, J. (1969): "*The Economy of Cities*". New York, Vintage Books.

Marshall, A. (1920): "*Principles of economics*". London, Macmillan.

Maskell, P., Eskelinen, H., Hannibalsson, I., Malmberg, A., and Vatne, E. (1998): "*Competitiveness, Localised Learning and Regional Development - Specialisation and Prosperity in Small Open Economies*". London, Routledge.

Neffke, F. (2008): "*Time-Varying Agglomeration Externalities in UK Counties between 1841 and 1971*." Mimeo.

Pedersen, C. Ø. R. (2005): "*The Development Perspectives for the ICT Sector in North Jutland*". PhD thesis, Aalborg University.

Rose, A. (2004): "Defining and measuring economic resilience to disasters". *Disaster Prevention and Management*, 13(4): 307-314.

Rose, A. and Liao, S.-Y. (2005): "Modeling regional economic resilience to disasters: a computable general equilibrium analysis of water service disruptions". *Journal of Regional Science*, 45(1): 75-112.

Schumpeter, J. A. (1934): "*The Theory of Economic Development*". Cambridge (MA), Harvard University Press.

Simmie, J. and Martin, R. (2010) "The economic resilience of regions: towards an evolutionary approach". *Cambridge Journal of Regions, Economy and Society*, 3(1): 27-43.

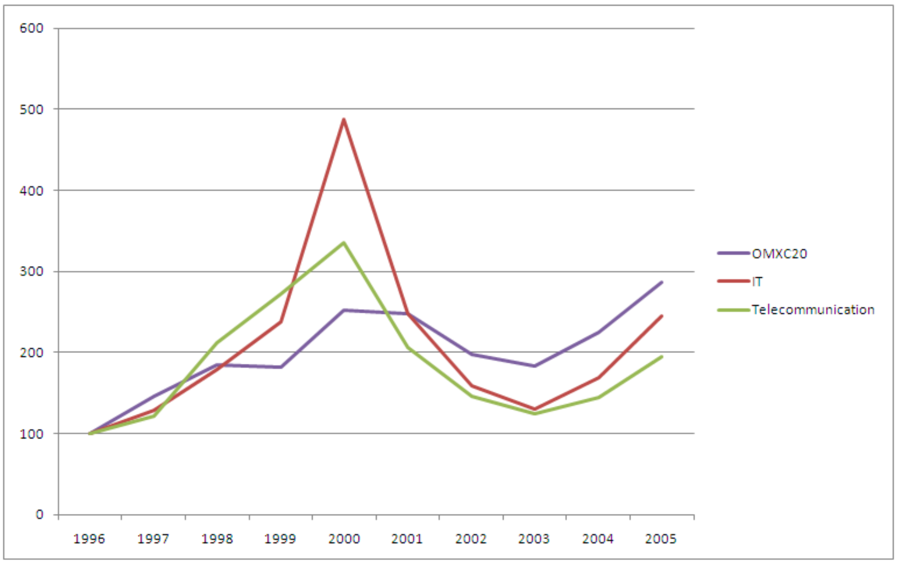
Sorenson, O. (2003). "Social networks and industrial geography". *Journal of Evolutionary Economics*, 13(5): 513-527.

van Oort, F. and Atzema, O. A. L. C. (2004): "On the conceptualization of agglomeration economies: The case of new firm formation in the Dutch ICT sector". *The Annals of Regional Science*, 38:263-290.

Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004): "Resilience, adaptability and transformability in social-ecological systems". *Ecology and Society*, 9(2):5.

Wantanabe, C., Kishioka, M. and Nagamatsu, A. (2004): "Resilience as a source of survival strategy for high-technology firms experiencing megacompetition". *Technovation*, 24: 139-152.

APPENDIX



The figure shows three stock market indexes. OMXC20, which an index of the 20 most traded stocks on the Copenhagen stock exchange and indexes for IT and telecommunication stocks compiled by Statistics Denmark. 1996=100. Source: Statistikbanken.dk, table MPK13.

Figure A.1 – The ICT bubble

	Regions	ICT workers in 1992	ICT workers in 2006
1	Copenhagen	46007	61540
2	Slagelse	384	455
3	Næstved	695	615
4	Lolland-Falster	660	343
5	Bornholm	136	138
6	Odense	3330	4275
7	Svendborg	170	357
8	Sønderborg	1380	1756
9	Esbjerg	620	836
10	Horsens	1635	1588
11	Kolding	1477	1480
12	Vejle	1204	1957
13	Herning	1417	934
14	Holstebro	2643	1840
15	Randers	384	468
16	Silkeborg	779	937
17	Thy-Mors-Salling	1141	1878
18	Århus	9060	13234
19	Viborg	317	574
20	Vendsyssel	620	481
21	Aalborg	4260	6701
	Total (Denmark)	78319	102387

Source: IDA

Table A.1 – Regions and their size

Figure A.2.a – 38 regions

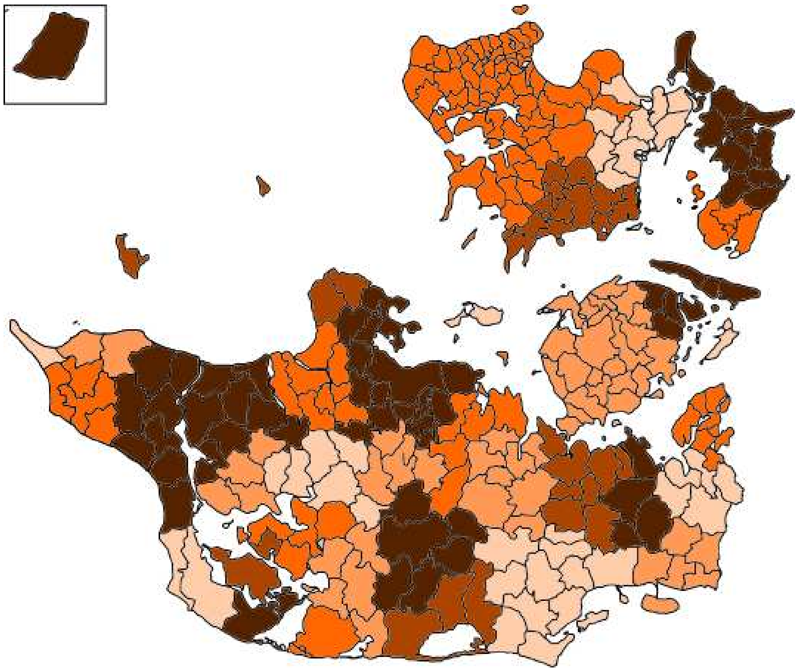
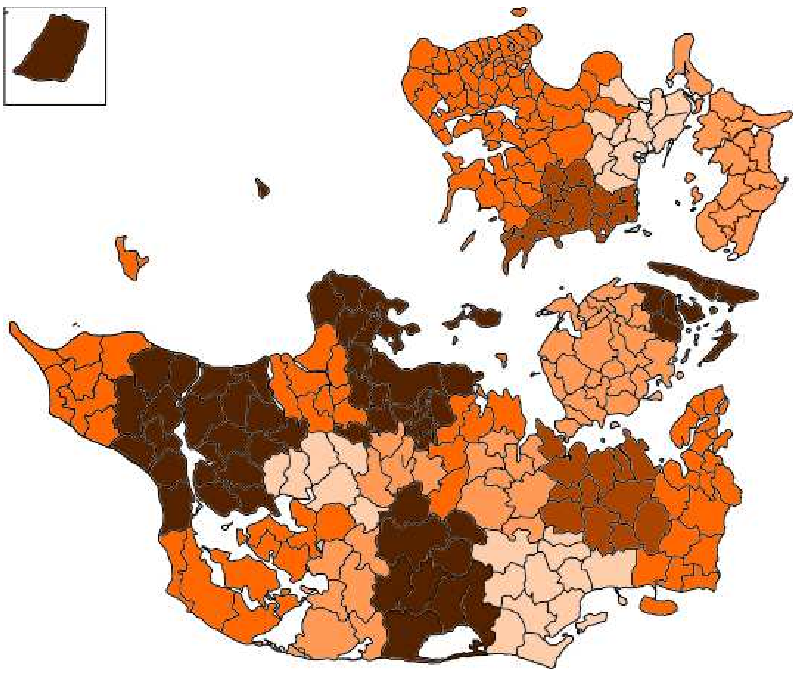


Figure A.2.b – 21 regions



Explanatory variables	Model 1a		2a		1b		2b		1c		2c	
Intercept	0.153 (0.048)	**	0.052 (0.043)		0.175 (0.068)	**	0.160 (0.052)	***	0.322 (0.094)	***	0.272 (0.081)	***
Lag of grICT	-0.113 (0.089)		-0.101 (0.077)		-0.282 (0.154)	*	-0.308 (0.152)	**	-0.061 (0.068)		-0.083 (0.075)	
Metro	-0.085 (0.031)	***	-0.017 (0.026)		-0.090 (0.045)	**	-0.065 (0.032)	**	-0.187 (0.055)	***	-0.175 (0.042)	***
Districts	-0.027 (0.018)		-0.012 (0.018)		-0.027 (0.027)		-0.034 (0.031)		-0.133 (0.034)	***	-0.136 (0.033)	***
Hetero	-0.003 (0.011)		0.002 (0.012)		0.016 (0.012)		0.021 (0.012)	*	-0.052 (0.028)	*	-0.048 (0.029)	
Sales			0.024 (0.006)	***			0.014 (0.012)				0.020 (0.007)	***
Years	1993-2005		1993-2005		1993-1999		1993-1999		2000-2005		2000-2005	
n	273		273		147		147		126		126	
R^2	0.2405		0.1158		0.2469		0.2362		0.3975		0.3677	
Adjusted R^2	0.1209		0.0223		-0.0087		0.0707		0.1442		0.2016	
Degrees of freedom	236		247		116		121		96		100	
Fixed effects for	Years and regions		Regions		Years and regions		Regions		Years and regions		Regions	
Test for structural break, p-value	0.0004		0.0010		-		-		-		-	

Dummy based test for structural break between 1999 and 2000. Robust standard errors in parentheses. Asterisks denote significance: *: 10%, **: 5%, ***: 1%.

Table A.2 – Growth models

Explanatory variables / Interaction term:	3_1b Sales*Metro	3_2b Sales*Districts	3_2b Sales*Hetero	3_1c Sales*Metro	3_2c Sales*Districts	3_3c Sales*Hetero
Intercept	0.160 (0.051) ***	0.149 (0.044) ***	0.156 (0.053) **	0.276 (0.082) ***	0.307 (0.092) ***	0.273 (0.080) ***
Lag of grICT	-0.309 (0.149) **	-0.293 (0.155) *	-0.316 (0.154) **	-0.088 (0.077)	-0.122 (0.072) *	-0.080 (0.074)
Metro	-0.067 (0.032) **	-0.057 (0.028) **	-0.063 (0.033) *	-0.177 (0.044) ***	-0.195 (0.051) ***	-0.176 (0.042) ***
Districts	-0.034 (0.031)	-0.027 (0.028)	-0.034 (0.031)	-0.137 (0.033) ***	-0.144 (0.029) ***	-0.137 (0.032) ***
Hetero	0.021 (0.012) *	0.021 (0.012) *	0.020 (0.013)	-0.044 (0.030)	-0.054 (0.030) *	-0.048 (0.029)
Sales	0.013 (0.014)	0.014 (0.012)	0.015 (0.013)	0.022 (0.007) ***	0.022 (0.007) ***	0.021 (0.008) **
"Interaction"	0.006 (0.010)	-0.010 (0.009)	0.009 (0.008)	0.007 (0.004) *	0.014 (0.008) *	-0.002 (0.010)
Years	1993-1999	1993-1999	1993-1999	2000-2005	2000-2005	2000-2005
n	147	147	147	126	126	126
R^2	0.2378	0.2430	0.2422	0.3762	0.3926	0.3683
Adjusted R^2	0.0649	0.0712	0.0703	0.2043	0.2253	0.1943
Degrees of freedom	120	120	120	99	99	99
Fixed effects for	Regions	Regions	Regions	Regions	Regions	Regions
LM test, p-value	0.3005	0.1841	0.1981	0.0015	0.0004	0.0032

LaGrange multiplier test for joint significance of interaction and *Sales*. Robust standard errors in parentheses. Asterisks denote significance: *: 10%, **: 5%, ***: 1%.

Table A.3 – Models with interactions