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Regional employment growth, shocks and regional industrial resilience: A quantitative analysis of the Danish ICT sector

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Abstract

The resilience of regional industries to economic shocks has gained a lot of attention in evolutionary economic geography recently. This paper uses a novel quantitative approach to investigate the regional industrial resilience of the Danish ICT sector to the shock following the burst of the dot-com bubble. It is shown that regions characterised by small and young ICT service companies were more adaptable and grew more than others, while diversity and urbanisation increased the sensitivity to the business cycle after the shock. Different types of resilient regions are found: adaptively resilient, rigidly resilient, entrepreneurially resilient and non-resilient regions.

Keywords

Resilience; Regional economic growth; ICT sector; Business cycle; Shocks

JEL codes

R11 O18 E32 L86

1. Introduction

The evolution of industries is often found to be uneven across regions. The regional stock of inputs such as knowledge, skills and natural resources in combination with the initial size and composition of an industry are found to have an effect on the growth of that industry across regions (BOSCHMA and van den KNAPP, 1999; BRENNER, 2004). However, these studies of the spatial evolution of industries often disregard the impact of shocks in the business environment on this growth. In such cases, as the business cycle suddenly shifts, some firms go bankrupt while other firms adapt to the changes. The consequence of these shocks varies across regions; an industry can appear to be unaffected in some regions and declining or booming in other regions. Economic systems are continuously confronted with recessionary shocks and other sudden changes. 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 their responsiveness to shocks. Thus, growth and resilience are two important qualities that influence the evolution of an industry in a particular region.

Regional industrial resilience is the adaptive capability of a regional industry to make changes to overcome internal or external shocks and still function. It thus includes the ability to resist shocks, the ability to make small or large changes and either recover or re-orientate and the ability to completely transform itself (see also WALKER et al., 2004; MARTIN, 2012). Various types of shocks exist, such as economic recessions; technological shocks e.g. the introduction of new disruptive technologies; institutional shocks e.g. the creation of free trade areas; environmental shocks e.g. natural disasters and organisational shocks, such as the sudden closure of one or more key companies in a region. Therefore, regional industrial resilience is the resilience of an industry in a particular region to different shocks. Resilience is a population level concept (WALKER et al., 2004). It is not required that all firms survive a shock for the population to be resilient. A population with very high entry and exit rates could very well be resilient if the high rates are associated with high adaptation, or the continuous adaptation of products, services, organisation and technology at the population level. Regional industrial resilience is also an important ability in the evolution of industries and might affect future growth. Specifically, 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 support the growth of an industry in a specific region, while the sources of regional resilience only have been analysed sparsely. Notable exceptions are MARTIN (2012) and FINGLETON et al. (2012). MARTIN (2012) analyses the resistance and recovery of 12 UK regions following a recessionary economic shock by investigating how employment in the regions was affected by the national recession and its post-recession growth. FINGLETON et al. (2012) employs more advanced econometric techniques in the analysis of the impact of economic recessions on future employment growth in 12 UK regions (NUTS 1). They do find differences in the post-recession employment growth rates, but they cannot explain why these differences occur or how the regional industrial structure affects the result. MARTIN (2012) argues that adaptive resilience depends on factors such as the level of new firm formation, the firms' innovativeness, firms' willingness to change, diversity of the regional economic structure and availability of skilled labour but does not have the data to investigate it. Therefore, econometric evidence is still missing on why the regional resilience differs within the same industry and which types of industry structures and employment characteristics might be a source of regional industrial resilience. Regional industries with large firms might be more resistant to economic shocks, while regional industries with a high start-up rate or many small firms might be better to adapt. Furthermore, while there is a large amount of literature on growth and urban externalities, localisation externalities and diversity, there is no research on the relationship between regional industrial resilience and these externalities.

The purpose of this paper is to analyse the regional industrial resilience of the Danish ICT sector to the shock following the burst of the dot-com bubble and economic recession of 2000-1. The ICT sector grew faster than the rest of the economy during the 1990s, but this ended in 2000. The growth rate of the ICT sector at the national level was negative for several years after the burst of the bubble, while the regional industries performed quite differently. This indicates different levels of regional industrial resilience. The ICT sector has experienced rapid growth and increasing economic importance over 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 rapid technological change and international competition. Thus, it exhibits a high degree of uncertainty and change, and skills become outdated quickly. The focus is on a single industry that faced a very symmetrical shock in order to make a comparable analysis of the specific factors of regional industrial resilience and to avoid the fact that some economic recessions hit specific sectors or regions harder than others.[i]

This study contributes to the literature in several ways. First, by using more comprehensive data than previous studies it is possible to analyse sources of regional industrial resilience in more detail. Furthermore, it is analysed how differences in regional industrial structure and human capital affect resilience. Third, it uses a novel and a more focused approach to the study of regional industrial resilience by including the business cycle variable and interaction effects between the latter and different types of externalities. This study also adds to the literature on regional economic evolution by showing that regional industries respond quite differently to shocks which might affect their growth path.

This paper takes its point of departure in the factors that lead to yearly regional growth of the Danish ICT sector. These growth rates vary by region and over time. It then compares the differences in the patterns of growth before and after the year 2000 in order to identify which regional industry characteristics affect regional industrial resilience and how specific characteristics promote the different dimensions of regional industrial resilience. The empirical analyses are based on register data from Statistics Denmark that contain detailed information on all employed individuals and all Danish firms in the period 1992-2006. Therefore, it is possible to create precise longitudinal variables for Danish functional urban regions and business cycle indicators at any level of aggregation based on real revenue.

It is found that there is no relation between growth in the regional ICT industries before and after the burst of the bubble. Some regions are resistant to changes in the business cycle, others decline, some stagnate and some continue to grow. Regional ICT industries characterised by small and young ICT service companies grow more than others before the shock and also after. After the shock the regional industry structure significantly affects the sensitivity to the business cycle. Urbanized regions are more sensitive to the changes in the business cycle. As a result they are hit harder by the shock but also benefit later when the demand for ICT goods and services picks up again. Based on the theoretical models of innovative activity proposed by Schumpeter, two archetypes can be defined; a Schumpeterian Mark II industry structure characterised by large established firms and a Mark I industry structure characterised by many small young firms (FREEMAN, 1982). Regions with a Schumpeterian Mark II industry structure or a diverse industry structure are also found to be pro-cyclical to the business cycle. Therefore, regions that had overall growth in the period 2000-6 have a resistance type of resilience and are characterised by low level of urbanisation, a Schumpeterian Mark I industry structure and a slightly above medium level of diversity. The regions that grew most during the boom were also more sensitive to the business cycle after the shock. However, urbanised regions with a Schumpeter Mark I industry structure performed much better than less urbanised Schumpeter Mark II regional ICT industries.

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

2.1. What is resilience?

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 from the outside (HOLLING, 1973; GUNDERSON and HOLLING, 2002; WALKER et al., 2004). WALKER et al. (2004) defines the resilience of a system as "*the capacity of a system to absorb disturbance and reorganise 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. 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. Engineering resilience is a measure of inertia. It is the ability of a system to remain in equilibrium and to return to equilibrium whereas ecosystem resilience is a property of a system far from equilibrium. When studying systems outside of equilibrium and which are evolving in a space with multiple potential attractors engineering resilience is of little use. Ecosystem resilience, on the other hand, describes the size of the domain in which the system can evolve and remain viable (FOLKE et al., 2004; HOLLING, 2009). Engineering resilience is thus a concept describing the elasticity, in a physical sense, of a stable situation. Elasticity is used in a similar sense in economic analysis, where it is generally recognised as the ratio of one proportional change to another. In traditional economic analysis such ratios describe the short run sensitivity of an equilibrium, though the speed of return to equilibrium is not necessarily considered. Economic elasticity comes close to engineering resilience, but it is at most related to one aspect of ecosystem resilience (WALKER et al., 2004; HOLLING, 2009).

In a more policy oriented line of research, the term resilience is used in relation to external change in a manner similar to engineering resilience: It connotes both the ability of a regional economy to remain in the current state and to return to the previous state (ROSE, 2004; ROSE and LIAO, 2005; HILL et al., 2008; CHAPPLE and LESTER, 2010; TREADO, 2010). This form of resilience is somewhat misleading, referred to as "regional economic resilience", or 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. Another concept of resilience is used in traditional economic research by ELMESKOV et al. (2007) and WANTANABE et al. (2004). The former uses the term to describe the size and duration of business cycle fluctuations across the OECD, whereas latter 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 close to economic elasticity.

These different uses of the term resilience have led to a critique arguing that such ubiquitous use of the term creates ambiguity (HASSINK, 2010; PIKE et al., 2010; SIMMIE and MARTIN, 2010). Consequently, MARTIN (2012) tries to develop a more precise notion. He argues that there are three main interpretations of resilience: ecological, engineering and adaptive resilience. He also claims that resilience has four different dimensions: resistance, renewal, recovery and re-orientation. Resilience is affected by how someone or something reacts to a shock. Since resilience is a population level concept, it is necessary to be precise in delimiting the population, and this in turn affects the four dimensions. E.g. the paths to recovery of a regional industry might differ from the recovery of the overall regional economy. In addition, the notion of resilience becomes more complex since various types of shocks exist, such as economic, technological, institutional, environmental or organisational shocks. The level of resilience might also change over time as the regional industry grows, because of reduced heterogeneity of accessible knowledge (MENZEL and FORNAHL, 2009), increased connectedness and interdependencies between firms (MARTIN and SUNLEY, 2011) or a reduced industrial diversity (ESSLETZBICHLER, 2007). However, this paper offers an interpretation of the term for use in studies of the evolution of industries. Regional industrial resilience is an adaptive capability of the regional industry to make changes to overcome internal or external shocks and still function. Thus, it includes the ability to resist shocks, the ability to make small or large changes and either recover or re-orientate, and the ability to completely transform itself. The latter is the regional industry’s ability to make large shifts, but still retaining its function and identity as a particular industry. Therefore it is not the region’s ability to make new industries grow, while old industries decline.This interpretation draws on the concept of ecosystem resilience. MARTIN (2012) and SIMMIE and MARTIN (2010) suggest a similar approach for evolutionary economics, though the concept employed in the current paper is just as close to that suggested by PIKE et al. (2010) in that it focuses on the adaptability of regional industries in the face of sudden change.

2.2. Evolution of industries and resilience

Many studies of the growth of various sectors across regions discuss the importance of location-specific externalities related to localisation, diversity or urbanisation. That is, the growth of an industry in a particular region depends mostly on the initial relative size of the industry, the diversity in the industrial activities or the overall size of the region. The empirical results indicate that location-specific externalities exist and influence the spatial evolution of economic activities. However, often multiple types of externalities are found to be important for the regional growth of an industry, and critics state that these externalities vary 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, such as differences in size, age or the level of human capital of the firm. Industries evolve differently across regions. Some regions provide better conditions for the growth of an industry, while other regions are not able to provide the industry with the needed environment (BOSCHMA and van den KNAPP, 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 (HENDERSON et al., 1995; BEARDSELL and HENDERSON, 1999; FELDMAN and AUDRETSCH, 1999). However, these studies have largely overlooked the effect of shocks on the regional evolution of industries. Regional industries react differently to these shocks and the outcome depends on regional industrial resilience, which might be affected by location-specific externalities.

MARSHALL (1920) was among the first to observe that firms within the same industry often co-locate in some regions based on three kinds of externalities: (i) economies of specialisation caused by a concentration of firms being able to attract and support specialised suppliers; (ii) economies of labour pooling, where the pool of labour with particular knowledge attracts firms; and (iii) technological externalities, where ideas and information flow more easily between local actors than over long distances. Marshall argues that these localisation externalities allow small firms to achieve similar advantages as large companies through external economies of scale. Similarly, BRENNER (2004) argues that three types of interactions shape 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 both positive and negative location specific externalities. Brenner finds that when an industry in a particular region reaches a large size in terms of firms or number of employees, the positive externalities create positive feedback mechanisms that induce further growth in that industry, while other regions with a low level of industrial activity or insufficient positive feedback mechanisms remain lagging behind. *Therefore, regions with large ICT industries benefit from localisation externalities and are more resilient to shocks than less agglomerated regions.*

However, FRENKEN et al. (2007) argues that while specialisation enhances employment growth, it also creates greater vulnerability to external shocks. Therefore, regions that have a more diverse industry structure might experience less growth, but they are also more resilient to external shocks. If the industry is specialised, it draws heavily on the same resources, which results in higher wages and other negative congestion effects. Having a more diverse regional industry can mitigate some of these problems and provide a variety of employment opportunities if the employment in one part of the sector faces a shock. ESSLETZBICHLER (2007) also finds that diversity in the industrial structure increase the stability of the regional growth. In the analysis of cluster life cycles MENZEL and FORNAHL (2009) argues that as the cluster grows it becomes more technologically focused and the heterogeneity of knowledge shrinks. This makes the cluster lose its capacity for renewal. Similarly, MARTIN and SUNLEY (2011) argues that as a cluster grows it accumulates resources that increase the connectedness and interdependencies between the firms. This reduces the resilience of the cluster unless the cluster is able to constantly mutate trough innovation and avoiding strong networks. These complicated and, in some cases, conflicting effects of specialisation and diversity mean that several measures that are conceptually similar may need to be considered at once (e.g. BISHOP and GRIPAIOS, 2011). Thus, related diversity is diversity within the ICT sector, while unrelated diversity is the diversity of the overall regional economy. Diversity creates a greater variety in the knowledge base and thus a greater source of cross-subsector knowledge spill-overs and opportunities for the emergence of new activities (JACOBS, 1969; van

OORT and ATZEMA, 2004). *Diversity will be a source of resilience since diversity within the ICT sector will make it more readily capable of exploiting new opportunities, while diversity in the overall region provides a richer source for such opportunities and cross-fertilisation of ideas.*

Diversity externalities are closely related to urbanisation externalities. 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: good infrastructure, the availability of highly skilled workers, a large local market and a short distance to customers and suppliers. Universities and other research organisations are located in the cities, which creates and attracts highly skilled workers and creative talented people (FLORIDA, 2002), making such regions relatively adaptable. Firms in urban regions often have higher human capital intensity and are therefore more likely to be innovative, which can create localised knowledge spill-overs (AUDRETSCH and FELDMAN, 1996). While many new activities emerge and initially experience high growth in the large cities, they might later on diffuse to other regions (HENDERSON et al., 1995). Large cities have a much greater chance of attracting highly skilled workers and less chance of losing them (BEARDSELL and HENDERSON, 1999). *The urban externalities can be a source of resilience for the regional ICT sector by supplying factors that increase the sector's adaptability.*

The size distribution of the firms in a regional industry also affects its resilience. Entrepreneurial activity is an important source of economic change and growth (SCHUMPETER, 1934). 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; however, start-ups also create variety (ESSLETZBICHLER, 2007; NEFFKE, 2008; DAHL and SORENSON, 2012). The Schumpeterian industry structure has two archetypes: Mark I with small entrepreneurial firms and Mark II with large established firms (FREEMAN, 1982). Small entrepreneurial firms can make a region more adaptable, while large firms often invest more in research and development and have greater financial capital to withstand changes in the business cycle. *Thus, regions with a high level of entrepreneurial activity will be adaptable, while large firms create more resistance to shocks.*

3. Data and methodology

The analyses are based on the IDA database. IDA is maintained by Statistics Denmark and contains personal information on all persons employed in Denmark, such as their region and sector of employment, level of education and occupation. The remaining data come from the General Firm Statistics database, from which firm level data on revenue are used to create the indicator for the business cycle.

Sub-sectors, regions and the business cycle

The main variable 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. Delimiting a sector of an economy requires 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, and the definition used here is based on PEDERSEN (2005) and OECD (2000). The ICT sector is defined as the aggregate of seven manufacturing sub-sectors and three service sub-sectors.[ii] The activity codes used to delimit the sub-sectors are based on the Danish DB93 (DB03 from 2003), which is identical to NACE rev 1.1 codes at the four-digit level. The data contain information on the revenue of firms except for those in telecommunication services. The growth rate of the real national revenue for the remaining nine sub-sectors is used as an indicator of fluctuations in sales for the whole sector. The evolution of the growth rate of employment, real sales (revenue deflated by the price index of the domestic supply of goods) and the number of firms is illustrated in Figure 1.

Figure 1 The ICT business cycle: Growth rates of revenue, firms and employment

Figure 1 illustrates a stylised fact: In terms of employment the ICT sector grew almost explosively during the late 1990s, and it shows negative growth rates in 2000-4 following the burst of the dot-com bubble and economic recession. By 2005 the sector seems to have entered a period of recovery.

In terms of the number of firms the ICT sector as a whole continued to grow each year. There is a clear disruption in 2000 when the yearly growth rate drops from 16 per cent to almost zero in 2002. The aggregate pattern shows the net change in firm population. Therefore it hides regional differences and churn rates.

The responsiveness of employment to changes in sales seems to vary over time. The negative ICT sales growth in 2002 corresponds with the largest drop in ICT employment, but the large growth in ICT sales in 2005 is barely identifiable on employment. This indicates that ICT firms retained some redundant labour during the downturn and thus had spare capacity when demand picked up. Such a strategy means that the firms do not lose knowledge, which allows them to maintain adaptability.

The sales variable in Figure 1 is used as a business cycle indicator in the below analyses ($gSales_t$). 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 real aggregate sales at t is used as explanatory variable for the growth of employment at $t+1$.

Functional urban regions based on HOLM (2011) are used as proxies for regional systems. The 21 regions are shown in Figure 4, and their sizes are listed in Table 5. With 21 regions and 13 observations of growth rates per region (1993-2005 – one year lost through use of lags), the total panel dataset contains 273 observations for econometric analysis.

3.2. Dependent and explanatory variables

The key variable is the growth rate of ICT employment in region i at time t. $Empl_{i,t}$ is ICT employment in region i at time t and $gEmpl_{i,t} = (Empl_{i,t+1} - Empl_{i,t})/Empl_{i,t}$ is the growth rate of regional ICT employment. Notice that the definition is equivalent to lagging all explanatory variables one period.

The regional industry structure can be described by the following nine variables. The first variable is human capital intensity (*HCint*), which is the share of regional ICT employees with at least a master's degree. The master's degree is chosen for the cut-off, as this is the main university degree in Denmark.[iii] Higher human capital intensity is expected to increase the adaptability of the regional ICT sector (FELDMAN and AUDRETSCH, 1999). The second variable is total regional employment (*RegSize*). This is logged so that the marginal effect of the variable pertains to relative changes in the region’s size. The size of the regional employment is expected to be a source of resilience due to urban externalities (BEARDSELL and HENDERSON, 1999; van OORT and ATZEMA, 2004). The third variable is the share of ICT workers in white collar occupations (*White*), which is expected to increase the regional industrial resilience. Variable number four is the regional specialisation in ICT (*ICTspec*) defined as the share of regional employees working in the ICT sector. A relative measure is used instead of an absolute number in order to capture the effects that cannot be explained by size. That is, if a region has a higher share of ICT employment compared to other regions then there is likely to be some localisation externalities in the region that have led to a higher growth (BRENNER, 2004). A higher absolute number of ICT employees in a region also create localisation externalities, but it also creates diseconomies by raising wages and congestion costs. The number of firms could also have been used to measure the possibilities of localization externalities. As the number of firms increase so does the possibilities for cross-fertilization through knowledge spillovers and the chances of new spin off ventures. It also increases the regional industrial resilience by creating variety in the possible responses to a disruption. However, the number of employees is closely linked to the number of firms, but it is more sensitive to changes. Furthermore, the number of firms is used to calculate the Schumpeterian industrial structure. 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 captures specialisation in ICT manufacturing (*Manuf*). The latter is the share of regional ICT employment working within the seven ICT manufacturing sub-sectors. The rapid employment growth in the 1990s and the dot-com bubble were in particular in ICT services because of the creation of the World Wide Web. Therefore manufacturing is expected to be more resistant to the disruption. Variable number seven measures the balance of established firms to new firms (*Estab*) through the share of ICT workers employed in plants that were set up more than one year ago. The variables five and seven relate to the Schumpeterian industry structure. Large firms are more resistant to disruptions because they have more resources than small firms. However, entrepreneurship creates regional industrial adaptability. The last two variables measure diversity in industry structure that is expected to be a source of resilience (ESSLETZBICHLER, 2007; MARTIN and SUNLEY, 2011). *IntDiv* is related diversity within the ICT sector. It is calculated as the Shannon index of diversity[iv] of the regional distribution of ICT employment among the ten sub-sectors. And *RegDiv* is regional diversity measured as the Shannon index of overall regional employment across 22 sectors based on Statistics Denmark's 27-standard grouping excluding the public sector, health, education and unclassified plants. The measure of regional diversity (*RegDiv*) is similar to the measure of unrelated variety suggested by FRENKEN et al. (2007). But the measure of intra ICT sector diversity (*IntDiv*) differs from their measure of related variety, as it only measures diversity within the ICT sector and not weighted within sector diversity for all sectors in the region.

These nine variables for industry structure are likely to have exhibited a trend during 1993-2005, and therefore a linear time trend at the national level has been estimated and subtracted from the observations. The slope coefficients of these nine regressions are given in the bottom row of Table 1 below.[v] Seven of the slopes are statistically significant. There has been a trend towards higher human capital intensity, larger regions, smaller plants, increased specialisation in ICT, more service plants and less diversity both within ICT and at the regional level. There are no linear trends in the white collar occupation and in established plants. The observed trends are closely intertwined. The shift of the ICT sector from manufacturing to services decreases the level of diversity, as there are seven manufacturing sub-sectors and only three service sub-sectors. Service plants are also generally smaller and have more educated workers.

Table 1 shows the mean, standard deviation and matrix of correlation for the dependent variable, the nine variables for industry structure and the business cycle variable.

Table 1 – Descriptive statistics

Variable	*gEmpl*	*gSales*	*HCint*	*RegSize*	*White*	*ICTspec*	*AvSize*	*Manuf*	*Estab*	*IntDiv*	*RegDiv*
gSales	**0.125**	1									
HCint	-0.022	-0.066	1								
RegSize	-0.001	-0.003	**0.772**	1							
White	0.021	-0.018	**0.519**	**0.477**	1						
ICTspec	-0.064	-0.007	**0.712**	**0.572**	**0.268**	1					
AvSize	-0.067	0.088	**0.205**	**0.131**	-0.089	**0.694**	1				
Manuf	-0.039	0.044	**-0.146**	**-0.201**	**-0.485**	**0.339**	**0.695**	1			
Estab	-0.027	**0.173**	**-0.119**	**-0.122**	-0.026	0.073	**0.220**	**0.221**	1		
IntDiv	0.037	0.009	**0.168**	**0.361**	0.024	**0.155**	**-0.171**	**0.150**	-0.028	1	
RegDiv	0.052	0.111	**-0.161**	-0.059	-0.013	-0.055	**0.156**	**0.273**	0.032	**0.126**	1
Mean	0.0203	0.0959	0.0427	11.135	0.4340	0.0241	18.788	0.3581	0.9035	1.5295	2.7465
Std Dev	0.1296	0.0724	0.0385	0.8214	0.1240	0.0176	13.115	0.2278	0.0750	0.2220	0.0581
Time slope	-	-	**0.006**	**0.016**	0.006	**0.001**	**-0.644**	**-0.010**	-0.000	**-0.017**	**-0.007**

Correlations and estimates in bold are significant at 5 percent. gEmpl: growth of regional ICT employment from t to t+1. gSales: growth rate of real sales from t-1 to t. HCint: human capital intensity. RegSize: region's size. White: share of white collar in ICT. ICTspec: regional specialization in ICT. AvSize: average ICT plant size. Manuf: manufacturing share of ICT. Estab: employment weight of established plants. IntDiv: intra ICT sector diversity. RegDiv: regional employment diversity. All variables except from gEmpl and gSales were de-trended before correlations were computed. 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.

Table 1 demonstrates that the mean regional growth rate of ICT employment is 2.03 per cent per year and that it is positively correlated with the previous year's growth rate of aggregate real revenue. None of the variables for industry structure are correlated with employment growth. There is a general correlation among the variables for industry structure and were they to be employed in a single regression analysis there would potentially be problems of multicollinearity. However, the variables are all used in factor analysis and only the factors are used in regression analyses. These factors are orthogonal to each other by construction. Larger regions will generally also have more diversity and be centred on the larger cities with relatively educated workers and many white collar workers. The correlation between manufacturing specialisation, regional size, established 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 (van OORT and ATZEMA, 2004; ERIKSSON, 2006).

The nine variables for industry structure are submitted to a principal component analysis in order to condense the number of variables to measures of industry structure in accordance with the discussions in Section 2.

Table 2 shows the results of the principal component analysis after varimax rotation.

Table 2 – Factor analysis results

Variable	Factor 1	Factor 2	Factor 3
HCint	0.940	0.047	-0.058
RegSize	0.875	-0.080	0.209
White	0.759	-0.351	-0.232
ICTspec	0.757	0.592	0.042
AvSize	0.241	0.921	-0.011
Manuf	-0.138	0.832	0.410
Estab	-0.137	0.410	-0.173
IntDiv	0.120	-0.183	0.828
RegDiv	-0.138	0.126	0.579
Label	Urbanization	Mark II	Diversity

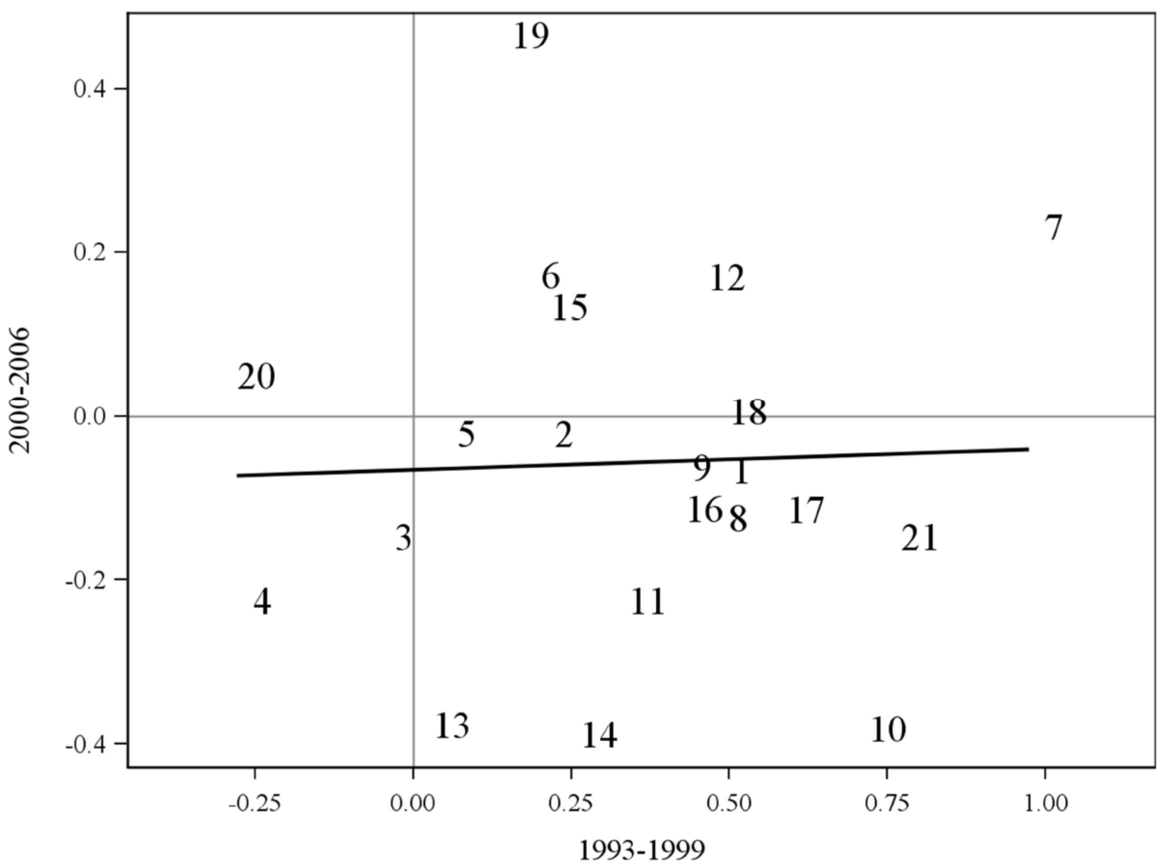
Table 2 shows the three factors with an eigenvalue greater than one after applying varimax rotation. The first factor especially loads positively on the variables for human capital intensity, regional size, the share of white collar workers and ICT specialisation. This factor is labelled Urbanization (*Urban*), as regions scoring particularly high on this factor are the urban regions with high quality workers in high level occupations, and where ICT makes up a relatively large share of the regional industry. The second factor is labelled Mark II (*MK2*). It captures the balance between Schumpeterian Mark I and Mark II industry structures. Regions scoring high on this factor are characterized by having ICT industries of large, established manufacturing plants (Mark II) while regions scoring low have ICT industries dominated by young, small service plants (Mark I). The last factor is strongly correlated with both variables for diversity and is thus labelled Diversity (*Diver*). This differs from the findings of FRENKEN et al. (2007), who does not find a positive correlation between related and unrelated variety, but as mentioned earlier their measure of related variety is different. The three factors fit the theoretical expectations well, except for the relative specialisation of ICT employment in the regions characterised by urbanization. This means that urban regions also tend to be regions where the ICT sector is agglomerated. For all three factors the mean is zero, the standard deviation is one and their correlation with each other is zero. The variable for the growth rate of aggregate real sales is also standardised to mean zero and standard deviation one before being used in the regressions. The dependent variable is not standardised.

All of the regression models are estimated as fixed effects models with fixed effects for regions. There are likely to be regional specificities that we cannot control for, but which affect regional ICT employment growth. Furthermore, these specificities are not likely to be random, that is, they are correlated with the explanatory variables. Thus neither a pooled nor a random effects model is appropriate. Robust standard errors are reported throughout the analyses as the errors are likely not to be homoscedastic. The growth dynamics, not just growth rates, are likely to vary across regions and although care is taken to account for relevant factors of regional industry structure, it is likely that errors will have higher variance for observations pertaining to some regions than for observations pertaining to other regions. Two different models are employed. One relates regional ICT employment growth to industry structure and the business cycle, while the second uses interaction terms to expand on the first model and account for varying regional sensitivity to the business cycle.

4. Results

Figure 2 plots the 21 regions in a 'pre burst growth' by 'post burst growth' space. The horizontal axis is the percentage growth from 1993 to 2000, while the vertical axis is the percentage growth from 2000 to 2006. A regression line is also shown in the figure. The line has a slope of 0.026, and the model has an R-square of 0.0015, indicating that pre burst growth is not at all an indicator of post burst growth. Interestingly, three regional ICT sectors actually shrank during the boom years: Regions 3, (Næstved), 4 (Lolland-Falster) and 20 (Vendsyssel). These are three of the poorest and peripheral regions in Denmark with overall low growth and problems of depopulation.

Figure 2 Pre- by post-burst regional ICT employment change, percentages



1: Copenhagen, 2: Slagelse, 3: Næstved, 4: Lolland-Falster, 5: Bornholm, 6: Odense, 7: Svendborg, 8: Sønderborg, 9: Esbjerg, 10: Horsens, 11: Kolding, 12: Vejle, 13:Herning, 14: Holstebro, 15: Randers, 16: Silkeborg, 17: Thy-Mors-Salling, 18: Aarhus, 19: Viborg, 20: Vendsyssel, 21: Aalborg. The slope of the regression line is 0.026 with a *p*-value of 0.867.

The scatter plot in the figure is discussed in relation to the econometric results below. It illustrates that the various regions have heterogeneous growth patterns. Some regions were able to grow both before and after the burst and thus exhibit resilient growth dynamics. These include some of the smallest regions (7: Svendborg, 15: Randers and 19: Viborg) but also the medium-sized Vejle region (12) and the large Odense region (6).[vi] Some show weak resilience by stagnating after the burst while others declined. This is especially true for Region 10 (Horsens) that grew fast during the boom, but lost all the gains after the burst.

The analysis of regional industrial resilience is approached in a stepwise manner. First, a growth model explaining regional ICT employment growth is estimated. Secondly, it will be studied how industry structure mediates the effect of the business cycle. The following model relates regional ICT employment growth to the business cycle and regional industry characteristics:

$$gEmpl_{i,t} = a_0 + a_1 Urban_{i,t} + a_2 MK2_{i,t} + a_3 Diver_{i,t}$$

$$+ a_4 gSales_t + fixed\ effects\ for\ regions + u_{i,t} \qquad \text{(Model 1)}$$

$gEmpl_{i,t}$ is employment growth in the ICT sector of region *i* from year *t* to year *t*+1. $Urban_{i,t}$, $MK2_{i,t}$ and $Diver_{i,t}$ describe the structure of the industry in region *i* in year *t*. The business cycle is captured by $gSales_t$: the growth in national sales of Danish ICT firms relative to *t-1*. $u_{i,t}$ is a classical error term.

The results from fitting Model 1 with OLS are reported in Table 3. The first estimates are obtained by fitting the model to the full panel. To test for a structural break at the burst of the ICT bubble, a dummy is defined to be 1 till and including 1999 and 0 afterwards. By adding the dummy variable and interactions with each explanatory variable to the model and testing for the joint significance of these added terms, it is possible to tell whether the parameters of the model are significantly different from 2000 onwards.[vii] The bottom row of the first column presents the *p*-value for this test. The test has a very low *p*-value, and thus the model has been estimated for 1993-9 and 2000-5 independently. These results are reported in the second and third columns.

Table 3 – Results for Model 1: Effects of the business cycle and industry structure on employment growth

	1993-2005			1993-1999			2000-2005		
Variable	Estimate	Std. Err.		Estimate	Std. Err.		Estimate	Std. Err.	
Intercept	0.170	(0.080)	**	0.415	(0.216)	*	0.416	(0.087)	***
Urban	-0.063	(0.046)		-0.201	(0.126)		-0.244	(0.043)	***
MK2	-0.075	(0.028)	***	-0.178	(0.053)	***	-0.207	(0.029)	***
Diver	-0.030	(0.020)		-0.027	(0.043)		-0.066	(0.032)	**
gSales	0.022	(0.007)	***	0.018	(0.018)		0.011	(0.007)	
n	273			147			126		
Adj. R^2	0.010			-0.003			0.253		
Joint test for structural break	<0.001			.			.		

Estimated intercept and slope coefficients for each regressor with robust standard errors in parentheses. Asterisks denote significance: *: 10%,. **: 5%, ***: 1%. p-value reported for dummy based test for structural break between 1999 and 2000. The model includes fixed effects for regions.

When estimating the model for all years, the slope coefficients for *gSales* and *MK2* are significant. The results show that regions scoring high on Mark II have low growth or, conversely, regions with small, young ICT service plants have relatively high growth rates. The positive estimate for *gSales* shows that the ICT business cycle affects ICT employment. When aggregate sales have grown relative to the previous year, then there will generally be employment growth across the regions over the following year.

When estimating the model separately for the two periods, it turns out that industry structure and the business cycle do not explain growth during the 1990s (negative adjusted R-square) while after the burst of the bubble, the model improves. The effect of *MK2* is still negative for both periods. For the late period, however, the estimates of *Urban* and *Diver* are now also significant and negative. This indicates that regions characterised by low diversity and/or low urbanization and localisation (i.e. small regions with low human capital intensity, relatively many blue collar workers and relatively small ICT industries) experienced above average growth after the burst of the bubble. There are no statistically significant effects of *gSales*. The low adjusted R-squares for fitting the model to the early years and the full panel are likely to be consequences of the idiosyncratic growth dynamics of the bubble years. The theories relating regional growth to diversity, localisation, and other aspects of industry structure do not explain growth under the build-up of a bubble very well.

The growth rate of real national ICT revenue ($gSales_t$) is expected to have a varying effect on the dependent variable depending on industry structure, and thus the business cycle is interacted with industry structure in Model 2. $e_{i,t}$ is a classic error term. The results of estimating Model 2 are presented in Table 4

$$\begin{aligned} gEmpl_{i,t} &= b_0 + b_1 Urban_{i,t} + b_2 MK2_{i,t} + b_3 Diver_{i,t} \\ &+ \left(b_4 + b_5 Urban_{i,t} + b_6 MK2_{i,t} + b_7 Diver_{i,t}\right) gSales_t \qquad \text{(Model 2)} \\ &+ fixed\ effects\ for\ regions + e_{i,t} \end{aligned}$$

Table 4 – Results for Model 2: Effects of the business cycle and industry structure including interaction terms on employment growth

	1993-1999			2000-2005		
Variable	Estimate	Std. Err.		Estimate	Std. Err.	
Intercept	0.396	(0.215)	*	0.446	(0.102)	***
Urban	-0.184	(0.124)		-0.261	(0.052)	***
MK2	-0.161	(0.052)	***	-0.212	(0.031)	***
Diver	-0.024	(0.041)		-0.065	(0.035)	*
gSales	0.018	(0.022)		0.012	(0.007)	*
*Urban*gSales*	-0.012	(0.016)		0.008	(0.003)	***
*MK2*gSales*	-0.024	(0.013)	*	0.007	(0.008)	
*Diver*gSales*	-0.008	(0.014)		0.005	(0.005)	
n	147			126		
Adj. R^2	-0.011			0.243		

Estimated intercept and slope coefficients for each regressor with robust standard errors in parentheses. Asterisks denote significance: *: 10%,. **: 5%, ***: 1%. The model includes fixed effects for regions.

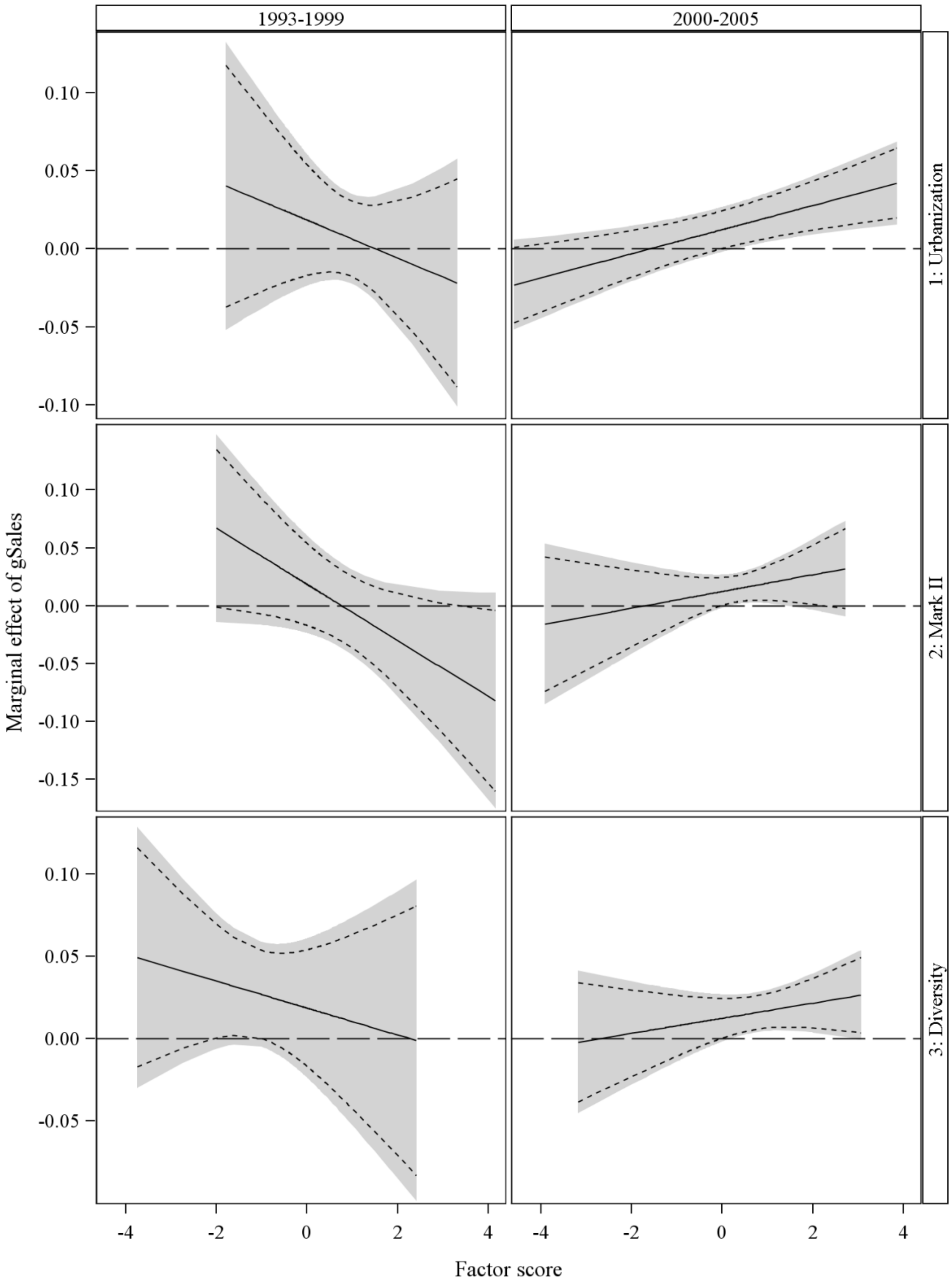
Because of the three interaction terms, the results in Table 4 must be interpreted with care (see e.g. BRAMBOR et al., 2006). The marginal effect of the business cycle is now assumed to depend on industry structure as specified in Equation 1, and it is not sufficient to assess the individual significance of the estimates reported in Table 4.

$$\frac{\partial gEmpl_{i,t}}{\partial gSales_t} = b_4 + b_5 Urban_{i,t} + b_6 MK2_{i,t} + b_7 Diver_{i,t} \qquad \text{(Equation 1)}$$

The overall means of each of the factors for industry structure are zero. Therefore, it is relatively easy to evaluate the marginal effect of the business cycle conditional on one dimension at a time holding the other two dimensions constant at their means. This is shown graphically in Figure 3.

The marginal effects are only plotted for the observed ranges of the respective moderator variables over the periods. The shaded area is a 95% confidence interval, and the dashed lines are a 90% confidence interval. Thus, if the reference line at zero is outside of these intervals, the marginal effect is significant at 5% or 10%, respectively.

Figure 3 Marginal effect conditional on industry structure



Looking at the effect of urbanization, there are no statistically significant effects of the business cycle on regional ICT employment for any values of *Urban* in the period 1993-9 (top left panel). However, after 2000 there is a statistically significant effect for values of *Urban* above the mean (top right panel). That is, the ICT sectors of more urbanized regions were more sensitive to the business cycle. They suffered more from the burst of the bubble, but were also better able to adapt and recover along with the rebound of sales.

The middle left panel shows that there was no statistically significant effect of *MK2* during the early period except for a marginally significant negative effect at the highest level of Mark II (four standard deviations above the mean). From 2000, however, for Mark II levels from the mean to about 1.5 standard deviations above it there is a significant positive effect (middle right panel). Thus, regions with an industry structure that was slightly more of the Mark II type than the average were more sensitive to the business cycle, but regions with an even more pronounced Mark II structure were not. The results for diversity show a similar pattern: There is not a statistically significant effect in the early period (bottom left panel; except for a marginally significant positive effect for low levels of diversity), but after 2000 there is a significant positive effect for values of *Diver* above the mean. The sensitivity caused by diversity is in contrast with the findings of FRENKEN et al. (2007) and ESSLETZBICHLER (2007). However, they study overall regional employment growth, while our study focuses on a single industry.

4.1. Sources and different dimensions of resilience

The results of Model 2 illustrated in Figure 3 show that there was generally no marginal effect of the business cycle on regional ICT employment during 1993-9.[viii] For 2000-5, however, the business cycle had a significant impact on growth in regions with above mean urbanisation, Mark II or diversity – though the effect is not significant for the highest levels of Mark II. The magnitudes of these effects are non-negligible. For each standard deviation above the mean of urbanisation, a region will experience 0.8 percentage points higher yearly ICT employment growth per standard deviation increase in ICT sales at the national level (Table 4). The corresponding numbers for Mark II and diversity are 0.7 percentage points and 0.5 percentage points, respectively.

As was seen in Figure 1, ICT sales rebounded within a few years after the bubble, so presumably it was positive for growth in a region's ICT industry if it was sensitive to the business cycle. The expected marginal effect of the business cycle given the *i,t* combination can be calculated by inserting the estimates in Table 4 into Equation 1. This has been done for each region for 2000-5, and the average marginal effect and the standard deviation are reported in Table 5. Notice that the persistence over time of industry structure is evident from the low standard deviations. The statistical uncertainty of these estimates is considerable, so too much emphasis should not be put on the specific means. However, when comparing the mean estimates with Figure 2, an interesting pattern emerges: Contrary to expectations, the most sensitive regions tend to cluster in the bottom right of Figure 2, while the least sensitive regions are scattered across the top and left parts of the figure. That is, regions where ICT employment growth followed the business cycle were often declining regions.

The position of many non-sensitive regions in the top part of Figure 2 means that most of the regions that managed to grow both before and after the burst of the bubble (small regions with middle sized cities and a small ICT sector; Regions 7, 12, 15 and 19) had little sensitivity to the business cycle after the burst. The exception is the highly sensitive yet resilient Region 6, which is the urbanised university region of Odense. Inspection of the data (cf. Table 5) shows that the sensitivity of these resilient regions was based on above mean diversity scores. Again, there is an exception: Region 19 has the lowest diversity score of the dataset. The resilient regions decoupled from the business cycle, but also had diversity above the mean. Such non-urban, slightly diverse, Mark I structured industries are likely to be adaptable through a multitude of heterogeneous, young, small firms creating and exploiting a variety of opportunities, despite the absence of human capital and other urbanisation and localisation externalities.

However, this does not mean that low sensitivity in general results in resilience. The small and peripheral regions 2, 3, 4, 5, 13 and 20 have low sensitivity to the business cycle and yet low growth. The sources of these regions' sensitivity reveal that they either score higher (Regions 2 and 3) or lower (Regions 5, 13 and 20) on diversity than the resilient regions. That is, these regions were either too diverse or too specialised to be resilient. The observation that a region can have too much diversity to be resilient suggests that there is a curvilinear relationship between diversity and performance. Diversity in knowledge, competences and experiences supports innovation, but if these are too disconnected then it creates conflict and slows down the innovation process (ØSTERGAARD et al, 2011). Thus if regional diversity is very high, then there might only be few possibilities for cross-fertilisation. Similarly if the internal diversity is too high then the firms might have difficulties in learning from each other and receiving localised knowledge spill-overs. Region 4 is an exception: Its industry structure suggests that it should have exhibited resilience, but it suffered from decline even in the boom years. Region 4 is peripheral and one of the poorest regions in Denmark with a persistent, high unemployment rate and a low level of human capital.

The above mentioned clustering in Figure 2 of the most sensitive regions is also worth considering. It seems that many regions that experienced significant growth in the boom years became sensitive to the business cycle after 2000. In some regions this led to stagnation (Region 18) while in others it led to a steep decline (Regions 10 and 14). Regions 10, 14, 17 and 21 are distinguished by high scores on both the Mark II and the diversity dimension; Region 10 houses Bang & Olufsen, the largest Danish producer of high-end audio and video equipment, while region 14 traditionally had a lot of manufacturing of electronics and one of the oldest Danish technical colleges. Regions 1, 18 and 21 are the three largest city and university regions in Denmark and they score high on urbanisation. In other words, it seems that the most urban and agglomerated regions managed to offset their sensitivity by having low Mark II and low diversity (that is, a specialised Mark I structure) while the diverse Mark II structures became very sensitive and suffered accordingly.

The results can be summarised in the following way: adaptively resilient regions are regions with low sensitivity to the business cycle and some diversity, allowing them to be adaptable and grow after the bubble (Regions 6, 7, 12, 15 and 19). Rigidly resilient regions managed to grow neither during the boom nor after the bubble. They were not affected by the business cycle and had too much or too little diversity to be adaptable (Regions 2, 3, 4, 5, 13 and 20). These regions are generally peripheral regions with a small ICT sector. Non-resilient regions achieved high gains during the boom, but they declined afterwards. These are sensitive to the business cycle through their explicit Mark II industry structure and high diversity (Regions 10, 14, 17 and 21). The last regions are entrepreneurially resilient regions with high growth during the boom but stagnation afterwards. These large urban university regions have high sensitivity to the business cycle offset by adaptability through a somewhat specialised but explicit Mark I industry structure (Regions 1 and 18).

5. Conclusions

The concept of regional industrial resilience that is developed in this paper describes the adaptability of a regional industrial system in the face of a shock. That is, regional industrial resilience involves adapting in times of crisis and evolving into a structure that allows such systems to continue to survive and grow under the new conditions. This was applied in an analysis of the varying effects that the ICT bubble of the 1990s had across regional ICT industries in Denmark. The study is based on more comprehensive and more detailed data than previous studies that allows for a more detailed investigation of the sources of regional industrial resilience. Such resilience is linked to the traditional changes in employment growth when the business cycle suddenly turns. Contrary to the expectations of MARTIN (2012) pre-shock growth does not ensure high resilience when facing a shock. Some of the high growth regional ICT industries examined in this study experienced a steep decline. Region 10 (Horsens) grew 75 per cent during the boom, but employment declined 40 per cent after the shock. Therefore, regional industrial resilience is important for ensuring future growth.

Resilience is an important concept in evolutionary economic geography, but it has been criticised for being ambiguous (HASSINK, 2010; PIKE et al., 2010; SIMMIE and MARTIN, 2010). This paper tries to make the concept more precise by arguing that regional industrial resilience is a population concept on the adaptive capability of a regional industry to make changes in response to a shock. It includes the ability to resist shocks, to make small or large changes and either recover, re-orientate or transform. Furthermore, we have investigated the relationship between employment growth, resilience and shocks and pointed towards the regional industrial characteristics that create resilience. Resilience appears to be a positive quality of regional industries (ESSLETZBICHLER, 2007; MARTIN and SUNLEY, 2011; MARTIN, 2012). However, resistance and transformation are also aspects of resilience. The former could describe strong regional industries unaffected by the shock, but it could also describe a regional industry decoupled from the rest of the industry and economy. In addition, transformation would include a high degree of creative destruction. The existing literature often considers resilience as a generic capability (ESSLETZBICHLER, 2007; MARTIN and SUNLEY, 2011), or a capability with four different dimensions: resistance, renewal, recovery and re-orientation (FINGLETON et al., 2012; MARTIN, 2012). These dimensions focus too much on the outcomes of the regions' response to a shock. This study argues that regional industrial resilience is an adaptive capability to overcome shocks, but the dominating aspects and the sources of resilience are not uniform for all regions. Four general types of regions were identified in the empirical analysis: adaptively resilient regions, rigidly resilient regions, non-resilient regions and entrepreneurially resilient regions. These differ in their response to the shock and following growth performance. High or low levels of diversity create resistance, while a medium level of diversity results in sensitivity to changes in the business cycle as well as adaptability. ESSLETZBICHLER (2007) argues that systems that continuously adapt to the current environment through efficiency might lower their resilience, because they lower their diversity. Low diversity reduces the pre-adaptive features and makes the systems vulnerable to shock, while high diversity reduces the possible synergies between firms. The results from the empirical analysis also show a potentially curvilinear effect of diversity, but contrary to ESSLETZBICHLER (2007) and FRENKEN (2007) diversity does not lead to stability. Diversity makes the ICT sector more sensitive to changes in the business cycle, which worsen the effect of the shock, but speeds up the recovery. Regional ICT industries characterised by small and young ICT companies also tend to be more adaptable. According to this study's findings, the ICT sector in urban and agglomerated regions was sensitive to the business cycle, while the sector in less urbanised regions was resistant. Thus the growth of a regional ICT sectors seems not to reduce the resilience (as expected by MENZEL and FORNAHL, 2009 and MARTIN and SUNLEY, 2011). The ICT sector is agglomerated in the large urban university regions and while these declined after shock, they also grew when the business cycle turned positive. The combination of Schumpeter Mark I industry structure in urbanised and agglomerated regions leads to better performance than Schumpeter Mark II industry structure in less urbanised regional ICT industries.

Resilience has the drawback of not being very policy friendly (HASSINK, 2010; PENDALL et al. 2010). This is also the case in this study. Regional industrial resilience depends on the industrial structure that changes when an industry evolves and also on fairly stable factors, such as the region's size and overall industrial diversity. Therefore, opportunities for policy to support factors that could increase regional industrial resilience are limited and depend on the initial industry structure. This finding is in line with the theoretical arguments by MARTIN and SUNLEY (2011) and MARTIN (2012), which argues that the regional resilience might change over time as the industry evolves. This study has shown that the factors that increased the resistance type of resilience also limited the growth of the ICT sector. It has also shown that diversity and the formation of new firms increased the regional industrial adaptability and growth prospects.

However, this study has several limitations that should be addressed in future studies. It analyses changes in employment in a single sector within particular regions in relation to changes in the business cycle following a major shock. However, the results do not reveal the regions' ability to generate new industries as a response to a shock. Furthermore, adaptability takes place at the micro level. It is the strategy of the organisations and individuals combined with their capabilities that eventually determine the regional industries' response at the population level. Lastly, this paper does not include any outside links the organisations in a regional industry might have that might affect their adaptability and the overall regional industrial resilience.

Future studies should focus on identifying regional sources of resilience, looking at the micro dynamics within regions to determine the adaptability of the firms and analysing why some regions fail to be resilient. Sometimes shock simply leads to the decline of an entire industry and subsequent creative destruction (MENZEL and FORNAHL, 2009; MARTIN and SUNLEY, 2011; MARTIN, 2012) Future studies should study regional resilience for all industries (like the attempts by ESSLETZBICHLER, 2007; FINGLETON et al., 2012; Martin, 2012), but it is important to note that the concept of resilience must also be applicable to regions that are stagnating or declining. In such cases regional resilience depends on how the knowledge and skills of laid off workers are being redeployed in new companies and other existing industries. Thus, it should be investigated how regional resilience change over time and how changes in diversity and specialisation of the industry structure affects resilience that again might lead to changes in the industry structure after a shock.

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Appendix

Figure 4 Map of 21 regions

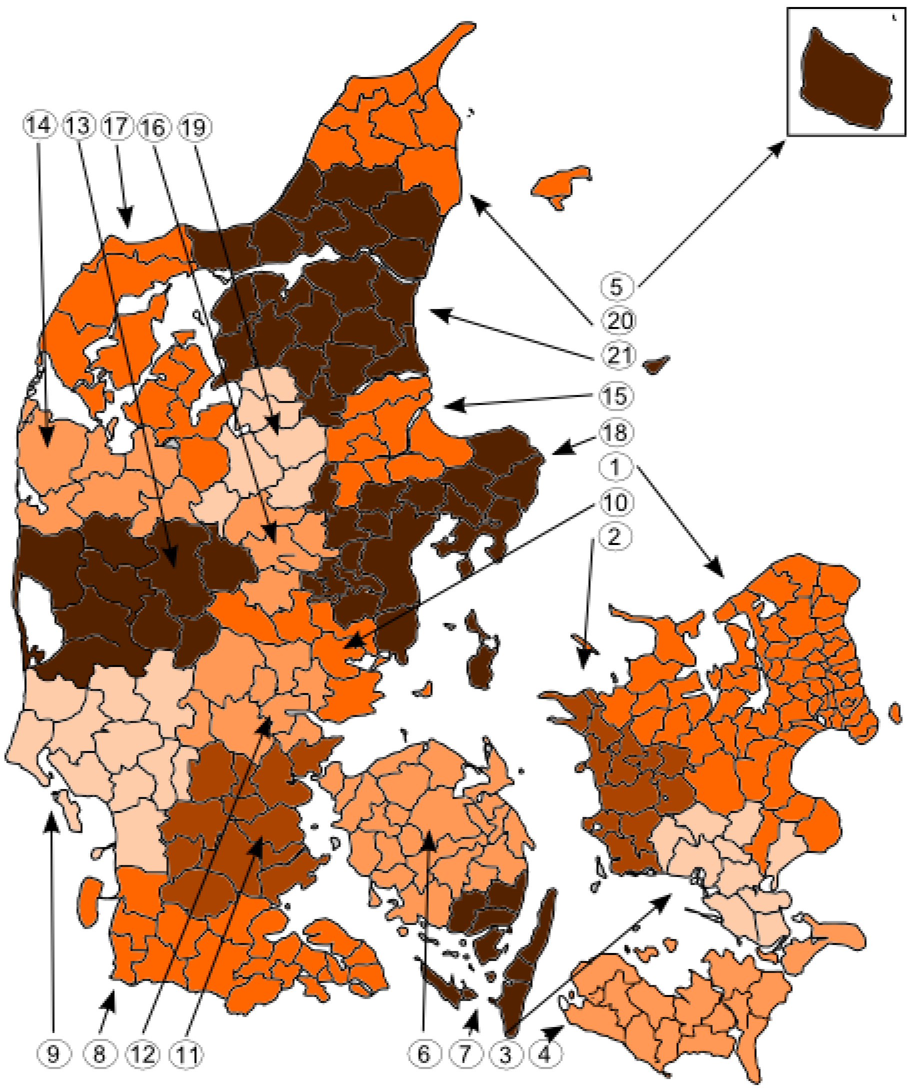

Table 5 – List of regions

	Region	ICT workers in 1993	2006	Average ICT industry structure 2000-5 *Urban*	*MK2*	*Diver*	Marginal effect of *gSales* 2000-5 Mean	Std.dev
1	Copenhagen	44593	61540	2.77	-0.17	-0.20	3.19	0.07
2	Slagelse	388	455	-0.76	-0.82	0.67	0.36	0.32
3	Næstved	762	615	-0.98	-0.16	0.90	0.75	0.32
4	Lolland-Falster	614	343	-1.23	-0.35	0.21	0.07	0.07
5	Bornholm	135	138	-1.35	-0.56	-1.69	-1.12	0.09
6	Odense	3096	4275	0.52	-0.70	0.30	1.28	0.06
7	Svendborg	147	357	-1.15	0.00	0.11	0.33	0.12
8	Sønderborg	1361	1756	-0.13	-0.07	-0.13	0.98	0.09
9	Esbjerg	629	836	-0.88	-0.31	1.66	1.11	0.08
10	Horsens	1493	1588	-0.54	1.30	0.82	2.09	0.25
11	Kolding	1426	1480	0.13	-1.02	0.17	0.67	0.10
12	Vejle	1143	1957	-0.05	-0.22	0.45	1.23	0.16
13	Herning	1454	934	0.19	-0.25	-0.48	0.64	0.26
14	Holstebro	2382	1840	0.14	1.89	0.17	2.73	0.38
15	Randers	340	468	-0.62	-0.74	0.29	0.33	0.10
16	Silkeborg	740	937	-0.31	-0.37	0.89	1.14	0.20
17	Thy-Mors-Salling	1334	1878	-0.76	2.07	1.03	2.56	0.08
18	Århus	8778	13234	2.10	-0.02	-0.09	2.82	0.08
19	Viborg	340	574	-0.38	-0.64	-2.00	-0.55	0.14
20	Vendsyssel	636	481	-0.42	-0.90	-0.18	0.15	0.19
21	Aalborg	4438	6701	1.35	0.17	1.11	2.95	0.21
	Total (Denmark)	76229	102387					

Source: IDA. Marginal effects computed from industry structure by plugging the estimates in Table 4 in to Equation 1 and reported as percentage point effects.

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[i] The recessions in the 1970s were caused by the oil crisis which hit the manufacturing industries harder than services; therefore regions with a lot of manufacturing had a deeper crisis. Likewise the financial crisis was related to the housing bubble which hit regions with a lot of construction employment. It is intended to see if two regions with similar types of industry respond differently to a shock.

[ii] NACE/DB93 codes of the ICT sub-sectors: 1) Manufacturing of office machinery: 3001xx. 2) Manufacturing of computers: 3002xx. 3) Manufacturing of electronic components and wires: 3130xx, 321010, 321090. 4) Manufacturing of telecommunication equipment: 322010, 322020. 5) Manufacturing of consumer electronics: 323010, 323020, 233030. 6) Manufacturing of electro medical equipment: 331020, 331030, 331090. 7) Manufacturing of instruments etc.: 332010, 332020, 332030, 332040, 332090, 333000. 8) Wholesale of ICT equipment: 514320, 516410, 516520. 9) Telecommunication services: 642000. 10) IT services and software: 713310, 7210xx, 7220xx, 7230xx, 7240xx, 7250xx, 7260xx.

[iii] The analyses have also been undertaken with *HCint* defined as the share of regional ICT workers with at least a bachelor’s degree. This has a negligible effect on the econometric results except for a decrease in the p-values for t-tests on the *Urban* factor (see the factor analysis). When using a bachelor’s degree as a cut-off point, about 75-80 per cent of the ICT workers in this variable, have a master’s degree. So a variable defined as the share of regional ICT workers with at least bachelor’s degree would, in fact, primarily be measuring the impact of master’s degrees. Therefore, *HCint* is measured as the share of ICT workers with at least a master’s degree.

[iv] It is computed as $-\sum_r x_r \ln(x_r)$ where x_r is the proportion of category *r*. The Shannon index of diversity is also known as entropy or the Teachman index (HARRISON and SIN, 2006).

[v] There is a break in the data underlying *White* between 1995 and 1996. From 1996 onwards the 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 *White* from 1996 which is accounted for by including a dummy for the years 1993-5 in the estimation of the time trend.

[vi] The size distribution can be seen in Table 5.

[vii] The results from fitting Model 1 with four slope dummies and an intercept dummy are not reported but are available upon request.

[viii] The effects were computed for each dimension of industry structure separately holding the other two constant at their means (i.e. zero). It is technically possible that for example regions combining above mean scores on all factors experience a significant effect of the business cycle on employment growth.