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Martin Henning, Kerstin Enflo and Fredrik NG Andersson

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Keywords: economic history, economic geography, regional growth, wavelet analysis, Sweden

JEL Classification: N9; O14; R11; C22.

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Trends and cycles in regional economic growth.

How spatial differences formed the Swedish growth experience 1860-2009.

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1. Introduction

It is widely recognized that economic growth often is characterized by spatial heterogeneity. Over longer periods, such growth differentials have immense implications for regional distribution of employment and welfare. The outcomes of sustained spatially differentiated growth can be seen in economies worldwide, with some spectacular examples in the 'old' industrial regions of continental Europe (Birch *et al.*, 2008). Drastic examples of growth and relative decline could be found in northern Europe, too. Growth in the 'Swedish Klondike', a Swedish regional success story based not on gold but wood, attracted workers from all over the country to the middle and north of Sweden during the mid-1800s. In 1870, as many as 150 sawmills were located in only one of these fairly peripheral provinces (with 135,000 inhabitants). Already in the 1870s, however, the growth of wood-related business was reduced to more conventional growth rates (Schön, 2010). Today, the development of many of these early booming regions can at best be described as stagnant.

In fact, scholarly interest in long-term regional growth has recently increased dramatically. Pioneering quantitative works by Rosés (2003), Crafts and Mulato (2005, 2006), Kim (1999) and Wolff (2005) have investigated the role of factor endowments and market potential for industry location during the early phases of industrialization. Also, a growing literature has found evidence of considerable heterogeneity in regional business cycles after 1980 in the United States (Owyang *et al.*, 2005; 2009) and in Italy after 1950 (Mastromarco and Woitek 2007). Accessibility to long-term regional empirical datasets is also improving, for example by the collection regional GDP data for many countries (Geary and Stark, 2002; Crafts 2005; Martinez-Galagarra *et al.*, 2009; Felice, 2009; Buist, 2009). Still however, the insights about how shifting factor dependencies, market integration and structural change have influenced regional GDP growth over longer time spans remain limited. Turning this around, little is known about which regions share common growth experiences.

This article is specifically concerned with commonalities in, and differences between, historical regional growth trajectories, and how the balance between communalities and differences change over longer periods of time. More specifically, we aim to investigate if the degree of differentiation in regional growth is connected to the characteristics of the Industrial Revolutions, and whether the degree of differentiation in regional growth is connected to the characteristics of shorter cyclical swings in the economy. To address these issues, we use a new dataset of Swedish regional GDPs for

24 provinces (broadly corresponding to NUTS-level 3) in ten-year intervals 1860-2009. Distinguishing trends from cyclical patterns of growth and investigating commonalities in regional long-term growth patterns entails major methodological challenges. We take advantage of recent advancements in Wavelet Analysis and Principal Component Analysis (PCA). We find that the First Industrial Revolution profited a few resource-intensive regions, while the Second Industrial Revolution and the 'record years' or Swedish growth in the 1960s and early 1970s was characterized by growth in virtually all parts of Sweden. Regional growth in Sweden was spatially distributed after the Second Industrial Revolution, and not concentrated to a few industrial districts like in many other industrialized countries (for example in the case of the emergence and persistence of the manufacturing belt in USA, Krugman, 1991). This growth trend was however interrupted with the major structural crisis in the late 1970s. After this, a period of divergence started as Stockholm, the largest metropolitan region in Sweden, became the prime engine of growth. This strong urban growth surge had no previous counter-part in history. We also find evidence of strong counter-acting cyclical tendencies between growth in the major metropolitan regions and peripheral regions.

The paper is organized as follows. Section 2 discusses our interpretative framework, and in section 3 we provide a broad-brush sketch of the national Swedish growth experience since 1860. Section 4 describes how the long-term regional GDP data was constructed, and features a short descriptive analysis of GDP per worker growth in Swedish regions. Section 5 explains the main analytical tools used for analyzing the regional growth trajectories, while section 6 describes the empirical results obtained with these tools. In section 7 we discuss the results, and some conclusions are highlighted in section 8.

2. Trends, cycles and long-term regional economic growth

After previously having been the interest of a limited group of historians and economic geographers, an expanding literature now investigates how long-term regional growth is created, sustained and varies over time. Economic historians with regional interests have sought inspiration from Heckscher-Ohlin (HO) and New Economic Geography (NEG) models to investigate the shifting roles of endowments, market potential and agglomeration forces for the long-term development of regional economies in different countries (Rosés, 2003; Crafts and Mulatu, 2005; Wolf, 2005; Kim, 1999; Tirado *et al.*, 2002). In the 'evolutionary economic geography' literature, a slightly different approach has focused on studying qualitative change in the production structures of regional economies (Boschma and Frenken, 2007).

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In many of the evolutionary accounts, long-run economic growth is seen as a constant out-of-equilibrium process characterized by swings, spikes and discontinuities around the growth trend. Such arguments are closely related to the prepositions of Schumpeter (1939), who argued that capitalist economies are characterized by eras or sequences of economic development, where high-impact innovation bundles exert a decisive influence on aggregate growth patterns in particular sequences. Though largely dormant for a couple of decades, this tradition of historical research into the fundamental sources and characteristics of cyclical economic growth was later revived in a number of versions.[1] Perez (1983) and Freeman and Perez (1988) used their 'techno-economic paradigms' approach to argue that economic impacts of innovations and technological change can be categorized into distinct classes. These range from incremental innovations to entire changes in techno-economic paradigms (Freeman and Perez, 1988).

Arguably, the last category of technological revolutions possess what Freeman and Perez call 'pervasive' effects on most parts of the economy, and is based on the implementation of a whole range of different, but often related, innovations. While the first techno-economic paradigm of the capitalist economies was characterized by breakthroughs in the use of key factors such as cotton and pig iron, the second was characterized by the importance of innovations around coal and improvements in transport technology. The third paradigm was especially connected to innovations related to the usage of steel, the fourth by oil and energy, and the fifth by the computer chips and micro-electronics. Many other authors have used similar categorizations of structural eras in economic history. More recently, Lipsey *et al.* (2005) have used the concept of General Purpose Technologies (Breshnahan and Trajtenberg, 1995) to explain the pervasiveness in the technological dynamics involved in the Industrial Revolutions. Generally, these studies suggest that economic growth takes place in a sequential manner, where the growth primarily centers on the new dominating technologies and their complimentary applications.

Apart from these longer swings or technology shifts, reoccurring fluctuations of shorter time span have also been suggested. The most prominent of those are probably the Juglar fixed investment cycles and the building- or Kuznets cycles. Juglar cycles (named after the French economist Clement Juglar), are connected to investment behavior of firms. They are also known as the business cycle of 7-11 years (Juglar, 1862). The 20-year Kuznets cycles relate to demographic factors (Kuznets, 1952, Abramovitz, 1956). The logic behind these is that demand for labor increases during prosperous economic times, which induces upward pressure on wages. In turn, the improved economic

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[1] We are admittedly selective in our review. Accounts not treated here include, for example, Mensch (1978) and van Duijn (1986).

environment causes an increase in new family formations, sparking the demand for new housing units.

These different Industrial Revolutions, paradigm and cycle approaches suggest several hypotheses of interest to researchers concerned with spatial characteristics of long-term economic growth. Some accounts in economic history argue that factor endowments and direct adjacency to energy sources were especially important in the era of coal and iron (Crafts and Mulato, 2006). Later improvements in transport technology and the availability of modern energy sources that followed the Second Industrial Revolution 'released' firms from their earlier location constraints. This fostered urbanization and made factors such as population density and closeness to market increasingly important from the Second Industrial Revolution onwards.[2] In the most recent era centering on computers, micro-electronics and other R&D intensive industries, research results repeatedly identify the dramatic concentration of growth in advanced and high-productivity industries to the metropolitan regions (Svensson Henning, 2009).

Generally, since 1860 the integration of regional labor and goods markets has been a considerable force in Swedish economic growth. Following the predictions of the neo-classical Solow-model, market integration could be a process driving convergence in GDP per worker, but it may also drive agglomerations and increasing regional divergence as predicted by New Economic Geography models.

These long-term processes of structural change and market integration are not the sole structural forces in the economy that can be assumed to have geographical implications. The shorter term cyclical movements of the economy, such as the Kusnetz or Juglar cycles, may have varying effects in different regions creating regional lead-lag growth relationships. Recently, scholars have drawn attention to the fact that regions do not always move synchronized with the national business cycles (Owyang *et al*. 2005; 2009, Mastromarco and Woitek 2007). Similar to the findings of Owyang *et al*. (2009) we might rather expect that co-variation in regional cycles may be related to both industry mix as well as non-industry variables, such as agglomeration and neighbor effects.

To our knowledge, few empirical studies address the issue of differentiated regional growth over extensive time periods and for all regions in a country. Some studies have investigated regional economic success over the Industrial Revolutions by focusing on the dynamics of selected individual regions (see for example Glaeser, 2005) or industries (Boschma and Wenting, 2007; Buensdorf and

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[2] Rosenberg and Trajtenberg (2004) argued that urbanization was fostered already with the adoption of the Corliss steam engine in the US economy from the late 19th century. In the Swedish case, the steam engine was never such a prominent source of energy. Instead, hydropower played a major role before it was largely replaced by electricity during the era of the Second Industrial Revolution.

Klepper, 2009). Most economy-wide quantitative studies of historical regional growth do not cover an extensive enough time span to analyze growth over the Industrial Revolutions. Rather, they focus on specific and more limited periods, often related to the break-through of industrialization (Geary and Stark, 2002; Martinez-Galarraga, 2009). An exception is Buyst's (2009) study of the Belgian economy that covers the period 1896 to 2000. Although the spatial aspects of the First and Second Industrial Revolutions are highly interesting viewed separately, systematic comparisons of spatial growth patterns during all Industrial Revolutions are still, to our knowledge, scarce.

Given the arguments from the literature above, we form the following expectations for our data analysis:

E1: During the first Industrial Revolution, growth benefited primarily regions rich in natural resources.

E2: During the Second Industrial Revolution, industries were released from some of their previous locational constraints, leading to a reallocation of growth centers closer to regional markets.

E3: During the Third Industrial Revolution, growth has so far benefited primarily urban centers and metropolitan regions.

E4: There are shorter cycles in regional development that reflect temporary regional lead-lag relationships in growth.

3. A broad-brush empirical sketch of Swedish national growth since the First Industrial Revolution

The First Industrial Revolution, which in Sweden dominated economic growth from about 1850 (consequently later than in the UK), was dominated by very early industrialization efforts primarily concentrated around wood, steel and paper (Schön, 2010). The agricultural sector still employed a high share of all workers (roughly 60% in 1890, Krantz and Schön, 2007). From the 1850s and onwards, a liberalized and integrated labor market was formed and labor migration became increasingly common phenomena (Lundh 2006). Market integration was boosted by the construction of canals in the 1830s, and the initiation of the railroad construction in 1856. In the framework of the Industrial Revolutions, this era reached its downturn with the economic crisis in the end of the 1870s.

From the upswing of 1880 on, quite a different set of industries dominated growth patterns. The Second Industrial Revolution opened up to a strong expansion of industrialism, especially connected to the increased sophistication of mechanical engineering, electric motors, and later the

development of the combustion engine (Schön, 2010). More traditional and heavily natural resource dependent industries were no longer expanding at the same rates as before the 1890s. The structural change from agriculture to manufacturing also continued. Though interrupted by periods of crises (most notably the one in the 1930s), the Second Industrial Revolution allowed for the establishment of important high-growth industries, for example in mechanical engineering, that dominated growth patterns in Sweden all the way up to the 1970s. After the Second World War, once again booming export markets benefited Swedish growth, together with a strong expansion of the public sector and the Swedish welfare system. This period is often referred to as the 'record years' of Swedish industrialism. Moreover, with the further development of road infrastructure and general motorization, the integration of regional markets proceeded at increasingly high speed.

As in many early industrialized countries, the late 1970s saw a slow-down of economic growth in the Swedish economy. Starting with the crises of the mid- and late 1970s, most of the 1980s were marked by comparatively low growth rates. Increasing growth of the 1990s and onwards, however, has sometimes been called the 'Third Industrial Revolution', centering on electronics, telecom and biotech applications.

A broad-brush description of the evolution of structural change in the Swedish economy can, as many aggregate accounts of this kind, be expected to obscure major differences in regional growth. The analysis of such regional patterns requires the construction of regional GDP data. How this dataset was constructed for the Swedish case for this article is described in the next section.

4. A New Database on Swedish historical regional GDPs

Long-term regional GDP series are rarely readily available. This has so far also been the case for Sweden. Statistics Sweden only started reporting regional GDP data in 1993. Earlier historical accounts about regional income and productivity differentials have been based on the Swedish Tax Assessments (for example Persson, 1997). The Assessments started in 1911 but do not cover the entire population for the early period. In addition, company taxes were assigned to the head quarter of the firms, and these taxed incomes often give a skewed picture of where production was actually taking place. In 2002, Geary and Stark introduced a method that allows for estimation of historical regional GDPs using a minimum amount of historical data. Versions of this method has been applied by Geary and Stark (2002), Crafts (2005), Martinez-Galarraga (2009), Felice (2009) and Buyst (2009). To estimate the Swedish regional GDPs, we here follow the procedure outlined by Geary and Stark (2002), with slight adjustments. The estimation method requires yearly data on 1) national value

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added disaggregated into a number of industries (usually 3 or 4 broad industries), 2) regional employment for the industries, and 3) information about regional wage differentials for the different industries. We define Y_{it}, the GDP of region *i* at year *t*, as:

(1)

$$Y_{it} = \sum^{j} y_{ijt} \times L_{ijt}$$

where y_{ijt} is the average value added per worker in region *i* and industry *j* at year *t*, and L_{ijt} the number of workers in region *i* and industry *j* at year *t*. Henceforth, we will drop the subscript *t*, as all variables refer to values in a specific year *t*. To be able to obtain historical data of sufficient quality and consistency, we use the 24 Swedish historical provinces (län) as regions, and four different broad industries: agriculture, manufacturing, private services and public services.[3] The Swedish provinces are very different in terms of population (Table 1). The vast majority of the population lives in, and south of, Stockholm. The three largest cities in the country are located in the Stockholm, Göteborg and Malmöhus provinces. This leaves the North of Sweden with vast and comparatively less populated areas, some of which however are endowed with extensive energy and raw material resources, such as hydropower, wood and iron ore. The distance between the southernmost point and northern most point of Sweden is today by car about the same distance as from the south of Sweden to Naples (1900 km). However, almost 65% of this is the distance from Stockholm to the far north of Sweden.

-Table 1 about here-

Normally, all variables in equation (1) are not available for estimation of historical regional GDPs. The Geary-Stark method can offer a solution to the predicaments that arise when there is no available data for y_{ij} (value added per worker on region/industry level, which is intended to take regional productivity differentials into account). In such cases, y_{ij} is proxied using information about output per worker in each industry on national level, assuming that regional differentials in labor

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[3] More detailed industries would not necessarily, in the case that historical records were available, increase the precision of the estimations. It would increase the scope for reclassification errors, with large consequences especially for smaller regions.

productivity in each industry is reflected by the regional industry wage level relative to the national industry wage level (w_{ij}/w_j). In our case, final estimated regional GDP will then be given by:

(2)

$$Y_i = \sum^{j} y_j \left(\frac{w_{ij}}{w_j}\right) \times L_{ij}$$

We use the Geary-Stark method to calculate the regional shares of GDP in ten year intervals.[4] Then we distribute already known historical GDP estimates from the Swedish Historical National Accounts regionally using the estimated shares. In the estimations for this article, we use total Swedish GDP figures per industry from the Swedish Historical National Accounts, employment data from the Censuses, and information about wage differentials from Jörberg (1972), Lundh *et al*. (2004), the Swedish wage statistical yearbooks, and the National Accounts. All historical sources, linking of series and proxies used are described and discussed in detail in Enflo *et al*. (2010). Here, GDP and GDP per capita series for each province can also be found.

To analyze the empirical outcomes of our estimations, we first turn to Table 2. The second column displays the GDPs of the regions in 1855 indexed to the nation (=100). The distribution shows the large regional discrepancies in GDPs per worker at the onset of the industrialization process, as indices range from 166 in Stockholm to only about 70 in Kronoberg (a poor agricultural province with extensive migration to the United States in the 19th century). Regions with a high GDP per worker are mainly the big city regions, regions with very early industrial activity and resource rich regions in the North. The next three columns display average annual growth rates during selected time periods. In the period 1860-1890, growth was already slower in the northern peripheral regions (such as Gävleborg, Västernorrland and Jämtland), and the substantial differences in regional growth rates persisted also into the first part of the Second Industrial Revolution (1890-1930). During the period of generally high growth rates (1930-1980), distribution of growth was more flat as most regions display more or less equal growth rates. In the last period (1980-2009), average annual growth rates were on average substantially lower than in the previous period. One regional feature is especially prominent during this period: growth rates of the Stockholm region were considerably higher than the national average. The second fastest growing region, Göteborg, is also one of the major metropolitan regions. Partly contrary to previous periods, growth of the metropolitan areas is a strong feature of the most

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[4] We construct 10-year benchmark GDPs because of the time structure of the census surveys.

recent period and the Third Industrial Revolution. This dramatic spatial shift in growth has, to our knowledge, no counterpart in Sweden's earlier history since the introduction of capitalism.

-Table 2 about here-

In these overall descriptions of regional growth, we can not rule that there are more long-term trends that are obscured by the ways we analyze data, and that regions embark on individual growth trajectories that are not captured by simple periodical descriptive accounts. As we argued in the theoretical overview, growth processes can be expected to be characterized by both long term trend patterns and various cyclical movements. Since the causes and dynamics of trend growth and cyclical growth also can be expected to be different, there is an analytical need to separate original regional growth data into a trend component and various long and short cycles (see *e.g.* Engle, 1974; Ramsey and Lampart, 1998). We therefore now turn to a more detailed analysis of the long run growth of regions, and the decomposition of the growth effects into a trend and cyclical components.

5. Wavelet transformations and Principal component analysis

We employ a discrete wavelet transform to decompose the regional growth data into cycles and a trend. Whilst it is possible to decompose data using several different methods, there are considerable advantages to be found in using wavelet transformations. Wavelet transform combines both time- and frequency resolution. Frequency resolution makes it easier to identify cycles in the data, compared to common time series methods. Time resolution, on the other hand, makes it possible to account for outliers and structural breaks in the data, which pure frequency domain methods cannot do. In fact, an outlier can yield an erroneous decomposition of the data if it is left unaccounted for, something that would affect the entire analysis (see *e.g.* Percival and Walden, 2006).

The analysis in this article is based on a special form of wavelet analysis, the Maximal Overlap Discrete Wavelet Transform (MODWT). We have chosen this method because it has superior small sample properties compared to other forms of wavelet transforms (see Percival and Walden, 2006).

The basic idea behind wavelet transforms is straightforward. Wavelet analysis is based on averages[5], and differences between adjacent averages. For example, the shortest cycles are obtained by taking the difference between two adjacent observations. More persistent cycles are obtained by first calculating an average that includes a 'medium' number of time observations, and then taking the difference between two such adjacent averages. The number of observations that are included in the average depends on the cycle of interest. The more observations that are included in the average, the longer is the cycle being considered. Economists and economic historians have of course used averages and moving averages in an *ad hoc* manner for a long time, both to eliminate high frequency fluctuations in the data and to obtain cyclical components. The advantage of using wavelets is that the averages that wavelets use are not *ad hoc*, but determined by the length of the cycles we wish to study. Furthermore, the weights used in most wavelet transforms are chosen in such a way as to obtain desirable statistical properties, such as making the transforms local and orthonormal. These properties make it much easier to work with the wavelet transform, and to interpret the results.[6]

Based on our regional growth data and the properties of the MODWT, we obtain two cyclical components and one trend component. The cyclical component represents cycles of length 10-20 years and 20-40 years. In the following, we will refer to these as short-term and mid-term cyclical movements respectively. The trend that we identify represent more persistent changes in the economy (40 years and beyond).

In a second step, after using wavelet analysis to decompose trend developments and cyclical change in the data, similarities and differences between the regional growth patterns are analyzed by means of principal component analysis (PCA). Scholars have already used both PCA and PCA in combination with Dynamic Factor Models (DFM) (Owyang *et al.*, 2009) or Markov-switching regime models (Owyang *et al.*, 2005) to analyze co-movement of regional business cycles.[7] Principal components is a technique to reduce the dimension of the data set by trying to explain as much of the variation in the data by as few common components as possible. Let y_{it} denote the analyzed variable, where $i = 1,...,I$ denotes the region and $t = 1,...,T$ the point in time. Using PCA the data is decomposed into a function of common components that capture similarities between the regions,

(3)

$$Y_{it} = \alpha_{i0} + \alpha_{i1} f_{1t} + \alpha_{i2} f_{2t} + \cdots + \alpha_{iI} f_{It} \,,$$

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[5] All wavelet transform use a set of wavelet basis functions. Some of these represent averages, while others represent weighted averages. The wavelet filter employed in this paper is the Haar-wavelet.

[6] For a more detailed presentation of wavelet analysis we refer to the works by Crowley (2007), Gencay *at al.* (2001) and Percival and Walden (2006).

[7] DFM:s have also been employed to trace historical business cycles, for example in Uebele and Sarferaz (2009).

where f_k, $k=1,..,I$, are the common components and α_{ij} are the component loadings that show the strength and direction of these relationships. Each common component f_{kt} is orthogonal to all other common components, whereby each component captures unique features in the data.

The common components are estimated in such a way that the first component, f_{1t}, explains the most of the variation in the data, the second component the second most and so on. Because the first couple of components explain most of the variation, we obtain an adequate representation of the original data by using the first $J<I$ components. Thus, instead of analyzing all I regions individually, we can instead analyze J common components. Furthermore, because each component captures joint features between some or all regions, we can use these components to analyze which regions cluster together.[8] Once we have determined the number of common components necessary to represent the data[9] we can define the residual term,

(4)
$$\varepsilon_{it} = Y_{it} - \alpha_{i0} - \sum_{j=1}^{J} \alpha_{ij} f_{jt}.$$

Given that we have captured most of the correlation structure between the regions with the J common components, the residual terms is approximately uncorrelated across regions. If the residuals are uncorrelated we can interpret them as representing an 'idiosyncratic' component capturing a unique growth pattern for each region.

An extension of the model in equation (3) is to make it dynamic (see *e.g.* Brillinger, 1981; Forni *et al.*, 2000; 2004). However, because of both our data frequency (one observation for every 10th year) and because we employ the PCA on wavelet coefficients, we reduce the need for a dynamic model. Consider for example our analysis of the long run trend (40 years and beyond). In this case introducing a lag to the model implies introducing a 40 year lag as each observation represents a 40 year period (see *e.g.* Chow *et al.*, 1999). For shorter time horizons, say a few years, allowing for a dynamic process may be important if the shock is slowly absorbed by the economy. For longer time horizons (our shortest is 20 years) the need for a dynamic relationship is less important as we can assume that the effect of a shock has been fully absorbed by the economy.

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[8] For a more detailed presentation of PCA see *e.g.* Jolliffe (2002).
[9] Due to the nature of the PCA all component loadings depend on each other ensure that the basis is orthonormal. It is thus difficult to obtain confidence bounds for individual component loadings. It is therefore common to determine J by how much of the total variation the Jth component explains (see *e.g.* Jolliffe 2002). To determine whether a particular common component has a significant effect on a particular region we employ the Bayesian information criteria.

The PCA uses the covariance matrix to find common features in the data. To employ the PCA we therefore have to estimate the sample covariance matrix. To ensure that this matrix is stationary such that we do not obtain spurious results due to non-stationarity, we first take the log of all our variables and then the first difference[10],

(5)

$$\Delta \ln(Y_{it}) = \ln(Y_{it}) - \ln(Y_{it-1}).$$

For small changes, these first differences represent approximately growth rates.[11]

6. Commonalities and idiosyncratic patterns in Swedish long-term regional growth

Let us first turn the analysis of regional growth patterns in the long-run trend of the regions, after removal of the two growth cycles. In essence, we now abstract from cyclical changes 40 years or shorter. We interpret this trend as primarily reflecting the impacts of very fundamental factors for the longer term growth of regions. In particular, we expect it to mirror the ways in which fundamental regional location factors such as natural resource accessibility, institutions and infrastructures are aligned with the dominating patterns of technological change. If the trend growth of the regions were completely unrelated to each other and each region only followed its own particular growth path, each component of the PCA would explain approximately 1/24 (4.2 percent) of all variation. However, we find that there is one major long-term trend component that explains 81.4 per cent of all the variation in regional growth rates (we call this component 1). This means that there is a very strong common growth component for all the regions in our dataset during the period that we study. Furthermore, we extract a second trend component that explains 12.8 percent of all regional variation in the data. Together, trend components one and two explain as much as 94.2 per cent of all variation.

More interestingly, however, is how these growth components relate to the overall trend growth over time, which is illustrated in Figure 1. The graph should be interpreted in the following way. The x-axis indicates the time frame, and the y-axis depicts how each component relates to the average trend growth over the entire period. A zero value on the y-axis indicates average trend growth, and positive/negative values indicate above/below average growth respectively. The black line illustrates the first component, and shows that regions dominated by this component followed an accelerating

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[10] Taking the first difference does not affect our ability to analyze the cycles and trends in the data (see *e.g.* Brockwell and Davis, 1998; Percival and Walden, 2006).

[11] A stationarity test on the growth rates shows that they are stationary.

growth path from the 1870s all the way to the 1960s. Thereafter, long-term growth rates associated with this component have leveled off. In the early 21st century it had returned to the same rate as during the early phase of industrialization. Contrasting this, component 2 (indicated by the grey line in figure 1) points to the fact that there are some regions that follow a very different trajectory of long-term trend growth. The regions dominated by this component experienced significantly higher long-term trend growth during early industrialization (up until about 1900), but thereafter much lower growth. After 2000, regions following component 2 seem to have again performed relatively better than the majority of the regions that were following the first trend component.

-Figure 1 about here-

In order to determine which regions actually followed the two different trend components, we consider the component loadings and the variation explained by each component. As described in section 6, the component loadings should be interpreted as weights which could be multiplied with the different components in order to gauge how much each region is affected by each of the components. The component loadings thus measure how much growth in each region varies with the component. By mathematical construction, the component loadings would be 0.204 if all regions were affected similarly by the components.[12] Figure 2 illustrates the extent to which trend growth in each region in Sweden is associated with the first component. We map here the coefficients as indices (multiplied with 100) where (0) marks a non-significant coefficient. Component 1 clearly weights significantly on most region. For regions with an index of over 20, that is the vast majority of regions, variation explained range from 84 to 99 per cent. After 1910 this component turns into an extraordinary strong common growth force. During the 1950s and the 1960s economic growth appears to have been strong and benefited regions virtually all over the country.

But while all regions are almost uniformly affected by component 1, three regions that stand out as being significantly associated also to the second trend component (Figure 3). These regions are Malmöhus in the South (explaining 53 per cent of the variance), Kopparberg in Mid-Sweden (37 per cent) and Norrbotten in the North (99 per cent). These regions have growth trajectories that deviate from the very strong first common component. We will return to the interpretation of these results below.

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[12] By construction $\sum_{i=1}^{I} \alpha_{ij}^2 = 1$ for all j=1,…,I.

However, regions may also have idiosyncratic components, that is, unique traits for particular regions. For the trend growth, these usually explain very small parts of the variation (below 10% for the majority of regions). For Stockholm, however, this unique component is particularly strong and explains 37% of the variation. Since Stockholm appears to follow its own regional growth path, we have plotted its idiosyncratic trend component in Figure 4. Again, the y-axis should be interpreted as representing the national average trend growth in the period, and positive values indicate trend growth above the average. Stockholm had lower trend growth than the nation until 1910, and then fluctuated around the national average with a dip during the 1950s and 1960s. Since 1970, a remarkable new growth pattern emerged as Stockholm's trend growth increased above the national average with 3-10 percentage points per decade.

-Figure 2 about here-

-Figure 3 about here-

-Figure 4 about here-

We now turn to the cycles of shorter time span.[13] In the analysis of cycles, we are especially interested in identifying regional patterns that counteract each other, indicating lead-lag relationships. Such movements would for example show in a situation when one region experiences an upturn in the short or mid-term cycle, and another region experiences a downturn. Of all the variation in the mid-term cycle, the first component only explains 65.4 percent. The second component explains 14.7 percent and the third 6.9 percent. Altogether, the first three components explain 87 percent. Thus, while there is a strong common component in overall trend growth of the Swedish regions, individual regional traits play a much larger role in the mid-term cycles. Figure 5 maps the component loadings for the first component of the mid-term cycle. To varying extent, the first component influenced all regions, but left Stockholm unaffected (not significant). The second component of the mid-term cycles only significantly influenced growth in six regions (Figure 6). While it influences Stockholm, the regions adjacent to Stockholm and Kristianstad negatively, it has a positive component loading for Norrbotten. This result indicates that the central regions around Stockholm follow a counter-cyclical pattern compared to the far north, and that this pattern is

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[13] Using Manly and Rayner's (1987) test of the covariance matrices, we find that each time horizon (10-20 years cycle, 20-40 years cycle and 40 years and beyond) has its own cross-sectional relationship. This underlines the necessity to decompose the data into the two cycles and the trend component and analyze each separately.

strikingly persistent over the period that we study. The third component is significantly positive for Stockholm and Göteborg only, and negative for Jämtland.

We also investigated the regional pattern for the short-term cycles (10-year), and found a similar pattern to the one obtained for the mid-term cycles. Thus, it appeared that Stockholm was left unaffected by the first common component, and that there was a second component in which a significant counter-cyclical pattern between the regions around Stockholm and the most Northern regions was present. These results reinforce the earlier picture that the Stockholm region follows a cyclical component of its own, and that there are counter-cyclical forces between the core regions around Stockholm and the far north of Sweden.

-Figure 5 about here-

-Figure 6 about here-

7. Discussion

Our empirical results can now be readily compared to the expectations formulated in section 2. For the regional growth trajectories compared to the trend, the findings strongly suggest a number of stylized eras of regional growth. The findings are broadly in line with the expectations as formulated from previous literature. According to E1, we expect that growth during the First Industrial Revolution primarily benefited regions rich in natural resources. It is not surprising that especially three Swedish regions performed well during the early industrialization phase (until 1910, see Figure 3). It was precisely in these regions that the Swedish export-led growth took off with oatmeal and agricultural products in the south, mining and steelwork in mid-Sweden and timber, iron ore and hydro-power in the north (Schön, 2010). Although dissimilar in many respects, these three regions share the characteristic of having been particularly successful in Sweden's early industrialization phase. Thereafter, they fell behind and experienced lower trend growth than the rest of the country. These findings strongly serve to corroborate out first expectation.

Our second expectation concerns locational patterns during the second Industrial Revolution, in the Swedish case from 1890 onwards. We expected growth to be more equally spatially distributed, as industries were released from some of their previous locational constraints. Indeed, we find that from 1910 onwards, other regions than the early industrializes were the primary engines of growth. It is likely that increased market integration with railroads and subsequent motorization, as well as the possibility to relocate industries closer to the market and further from the original power and

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raw material source, are parts of the explanation for the dramatic surge that resulted in catch-up of the majority of Swedish regions. Contrary to the experiences of many other European countries, growth following the Second Industrial Revolution in Sweden seems not to have benefited only a few (urbanized) regions specializing in manufacturing, but also a large range of more peripheral countryside locations (see also Söderberg and Lundgren, 1982). In fact, the strength of the commonalities in trend growth that followed from the Second Industrial Revolution and all the way into the 1970s are striking. Rather than favoring a smaller number of industrial agglomerations, the Swedish growth process had remarkable geographical spread during this period. This could poosibly be explained by a well-functioning infrastructure that involved rather evenly distributed access to foreign markets, a larger dependency on electricity than coal and an early connection of a national electricity grid.

However, one could further think of a number of candidate, or complementing, explanations. Beside the effects of the enabling technologies and market integration, the strong commonalities in the Swedish regional growth trajectories during the period after the Second World War might also be connected to regional policy. These policies especially served to promote regional decentralization of manufacturing production. Types of regional support schemes to less fortunate regions in the country included location grants, reduced social fees and employment grants (Nilsson 1995). These encompassing policies resulted in direct employment creation of only 9,000 jobs over the period of 1975-1992 (Nilsson 1995), but it is likely that they had considerably larger indirect employment effects. In 1995 Sweden joined the EU, and entered into a new pan-European regional support structure. However, we do not regard policy as a prime candidate explanation to the results. Of larger importance is probably then the expansion of the public sector from 1950s. Parts of the public sector were also subject to relocation to more peripheral areas during the period (Cederlund, 1995). Government intervention and expansion of the public sector could thus, in this way, have worked to smooth differences in regional production structures that we would otherwise have found.

Towards the end of our investigated period, the strong trend growth of Stockholm suggests an increased growth focus around the metropolitan regions, quite in line with our third expectation E3. This growth could be especially connected to the expansion of R&D intensive manufacturing industries (such as telecom and pharmaceuticals), and the expansion of advanced producer services (Lundquist *et al.,* 2006). While the results about this time period should perhaps not be over-interpreted, they coincide remarkably well with our expectations about the alleged Third Industrial Revolution and the continuing decrease of manufacturing employment in Sweden.

We also formed a very general expectation about the prevalence of shorter fluctuations in regional growth (E4). We indeed identified some such tendencies, but to get a better picture of the contra-cyclical tendencies identified above between Stockholm and the rest of the country, we plot the national average 20-year cycle against that of Stockholm in Figure 7. In fact, the cyclical pattern relates to earlier accounts about Swedish cyclical growth (Schön 2010). After this, there has been an average national upswing in the mid-term cycle. It is striking how Stockholm counterbalances these general tendencies. Only during the boom years of building investments during the 1960s the two (national and Stockholm) cycles coincide. When the rest of the country experienced lower trend and cyclical growth after the oil crisis, Stockholm performed significantly better on both. It is only during the last decade that crowding out of the capital region has involved a cyclical upswing in the rest of the country, with no counterpart in Stockholm. On the other hand, this slowdown is counterbalanced by a strongly positive trend growth in Stockholm (figure 4). In fact, our results suggest a very different growth behavior of the leading metropolitan regions compared to the rest of the regions. Expectation 4 about lead-lag relationships between regions seems to be met, although we acknowledge that this is the least theoretically grounded of our expectations. Future research will have to show if the regional lead-lag patterns arise by virtue of the leading roles of innovation and learning in the metropolitan regions, or if they rather are a result of spatially lagged business cycles.

-Figure 7 about here-

8. Conclusions and further research

This article has analyzed communalities in and individual traits of regional growth rates in Sweden from 1860 until today. The trend growth of regions shows very strong communalities among specific sets of regions. While the period until 1890 was characterized by strong growth in regions benefiting from booming export markets in the wake of the First Industrial Revolution, the period of the Second Industrial Revolution and the subsequent expansion of the welfare state was characterized by a strong surge in trend growth in virtually all regions of the country. This period lasted all the way to the 1970s. The subsequent period has prominently been marked by economically expanding metropolitan regions. The scope for regional variations to the common patterns has however been significantly larger for the mid-term movements in growth. Our investigations also suggest that there are counter-cyclical movements of the metropolitan regions to the rest of the country. In these

shorter movements, regional growth display de-synchronized patterns that are easily disregarded in the analysis of long-term regional growth patterns.

This article contributes to the existing literature on long-term regional growth in several ways. In terms of data, we present new evidence on long-term regional growth based on new GDP series, whereas the literature has earlier favored investigation of other variables, such as employment or taxed incomes. In terms of method, we take advantage of developments in wavelet analysis combined with PCA to explore long-term regional economic evolution in trend growth and cycles. We hope that this method may be used for historical comparative studies in other countries, or even on European-wide level. Empirically, we substantiate, by quantitative analysis, many of the claims that have been made about regional growth in Sweden by means of case studies or analysis of growth proxies.

Most significantly however, we believe that the theoretical implications of the long-term decomposition framework that is presented in this article are of importance. Our findings are strongly suggestive of the fact that traces of the industrial revolutions even can be found in the total growth data on regions, and not only on industry level. In fact, the evidence suggests that historical regional growth is characterized by 'regimes of spatial growth'. The analysis reveals the shifting fortunes of regions from a dominating growth regime based on the access to primary inputs, via a much more distributed growth regime, to a growth regime favoring growth of the metropolitan cities. Also, we show that shorter movements in regional growth are highly desynchronized, forming a pattern of leading and lagging regions, and persistently so over time.

Unfortunately, absence of economy-wide historical census data prevents any estimation of regional GDPs on smaller regional units than NUTS-level 3, at least for the Swedish case. For some manufacturing industries however, there are opportunities for long-term studies using for example cities as the smallest regional unit. Since the total growth of regions may obscure considerable changes in regional specialization, a natural next step on the history-geography research agenda is to investigate how these regional patterns interact to form growth patterns over the Industrial Revolutions. Notwithstanding this, the results in this article suggest that also aggregate data carries quite some information about the spatial dynamics of historical economic processes.

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Tables and figures

Table 1. *The Swedish provinces and their population in 1860 and 2007. Source: own calculations from Statistics Sweden data.*

	Population	
Province	**1860**	**2000**
Stockholms län	234128	1823210
Uppsala län	92536	294196
Södermanlands län	126705	256033
Östergötlands län	240917	411345
Jönköpings län	171011	311180
Kronobergs län	152225	176639
Kalmar län	221029	235391
Gotlands län	50137	57313
Blekinge län	117875	150392
Kristianstads län	209581	289447
Malmöhus län	284430	839977
Hallands län	119578	275004
Göteborgs och Bohus län	214342	793159
Älvsborgs län	269322	446726
Skaraborgs län	222240	271405
Värmlands län	247171	275003
Örebro län	151651	273615
Västmanlands län	103300	256889
Kopparbergs län	166899	278259
Gävleborgs län	136061	279262
Västernorrlands län	116669	246903
Jämtlands län	61218	129566
Västerbottens län	81478	255640
Norrbottens län	69225	256238

Table 2. *Initial GDP per worker (indexed to nation=100) and average annual growth during selected time periods. Source: own calculations from GDP data in Enflo et al. 2010.*

|	1860 GDP/worker, index	Average annual growth			
		1860-1890	1890-1930	1930-1980	1980-2009
Stockholms län	166	0,8%	1,0%	2,7%	2,1%
Uppsala län	124	-0,2%	2,4%	2,6%	1,3%
Södermanlands län	106	0,4%	2,1%	3,2%	0,7%
Östergötlands län	109	0,9%	1,8%	3,0%	1,0%
Jönköpings län	78	0,8%	2,5%	3,2%	1,0%
Kronobergs län	69	1,2%	2,4%	3,2%	1,2%
Kalmar län	81	1,1%	2,4%	3,0%	0,8%
Gotlands län	90	1,1%	2,0%	3,0%	0,3%
Blekinge län	89	0,8%	2,5%	3,0%	0,6%
Kristianstads län	88	0,7%	2,3%	3,0%	1,2%
Malmöhus län	83	1,7%	2,1%	2,7%	1,1%
Hallands län	84	-0,2%	3,1%	2,9%	1,0%
Göteborgs och Bohus län	122	0,0%	2,8%	2,4%	1,5%
Älvsborgs län	79	0,2%	2,9%	3,2%	1,2%
Skaraborgs län	78	0,9%	2,1%	3,3%	1,3%
Värmlands län	95	0,3%	2,5%	3,1%	1,0%
Örebro län	80	0,8%	2,7%	2,9%	1,1%
Västmanlands län	101	0,5%	2,2%	3,3%	0,9%
Kopparbergs län	89	0,8%	2,4%	3,0%	0,9%
Gävleborgs län	133	0,2%	2,2%	2,8%	0,8%
Västernorrlands län	115	0,6%	2,2%	2,7%	0,9%
Jämtlands län	115	0,4%	1,7%	3,0%	1,0%
Västerbottens län	100	0,0%	2,7%	2,9%	1,1%
Norrbottens län	117	-0,1%	2,9%	2,6%	1,0%
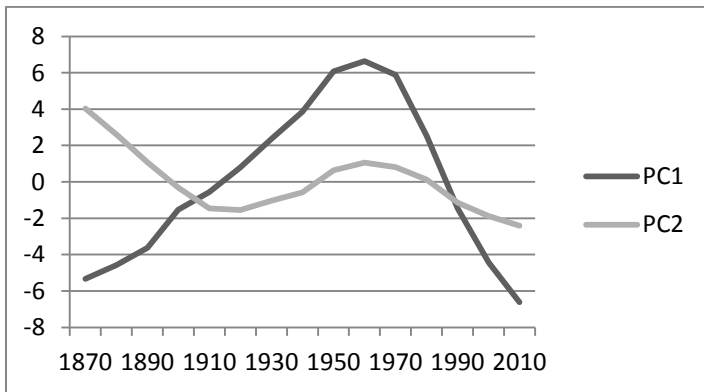
Figure 1. *The two main trend components in the Swedish regions (component 1 represented by the black line, component 2 represented by the grey line).*
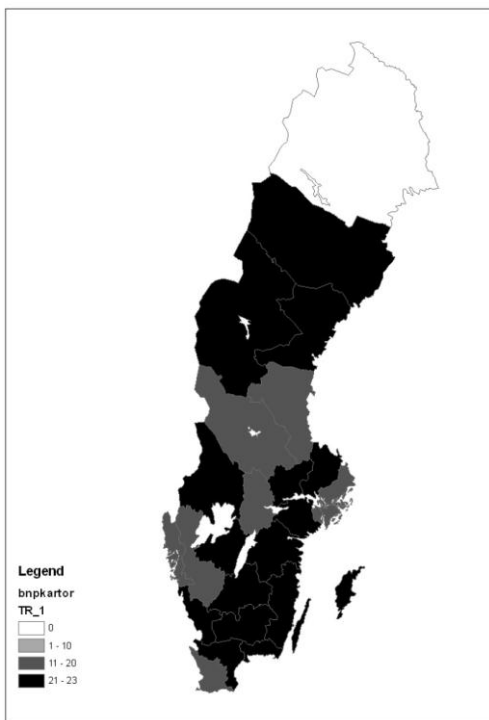

Figure 2. *Component loadings for the different regions, trend, first component (all components showed multiplied by 100 on the map).*
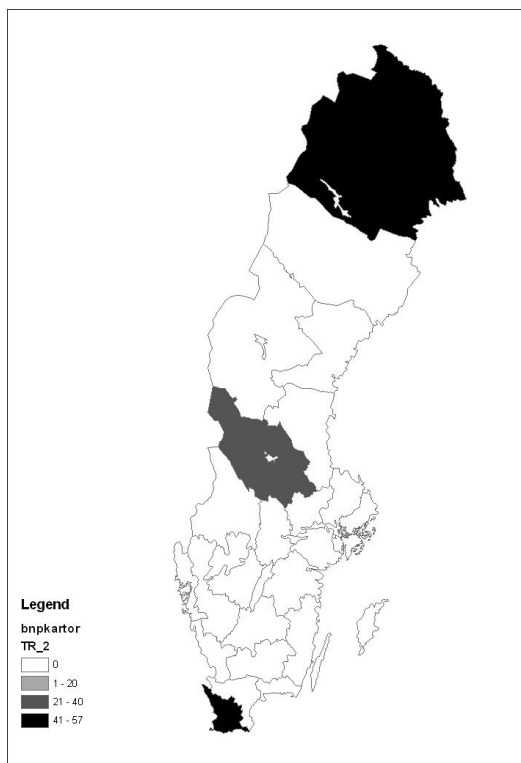
Figure 3. *Component loadings for the different regions, trend, first component (all components showed multiplied by 100 on the map).*
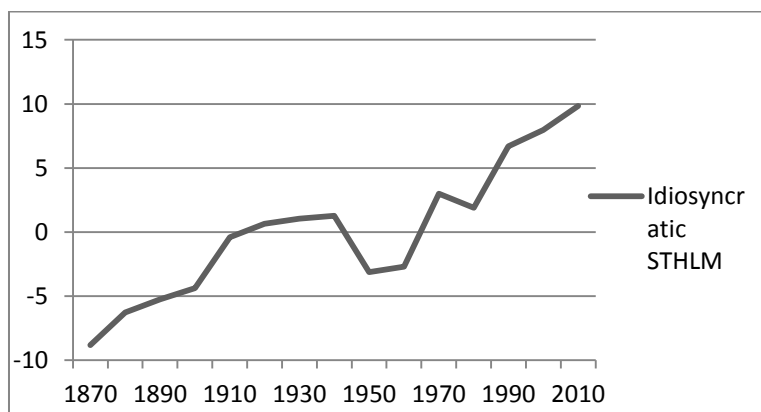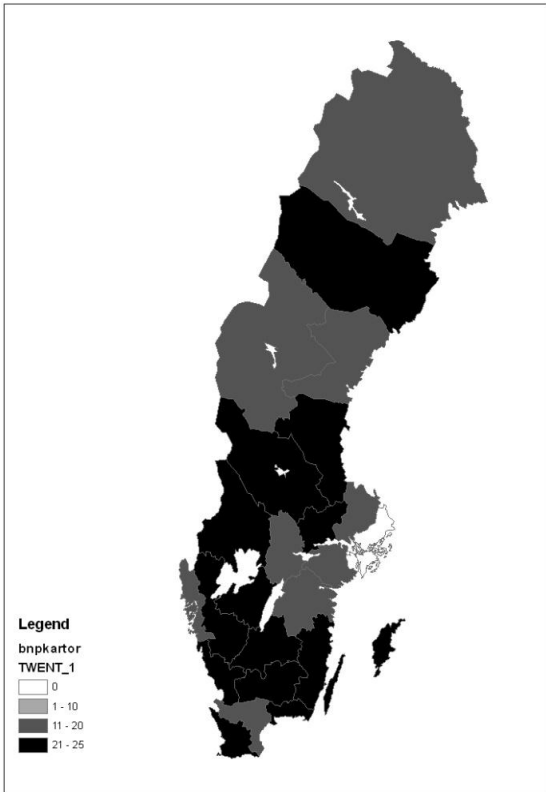

Figure 4. *Idiosyncratic trend component for Stockholm.*

Figure 5. *Component loadings for the different regions, 20-year cycle, first component (all components showed multiplied by 100 on the map).*
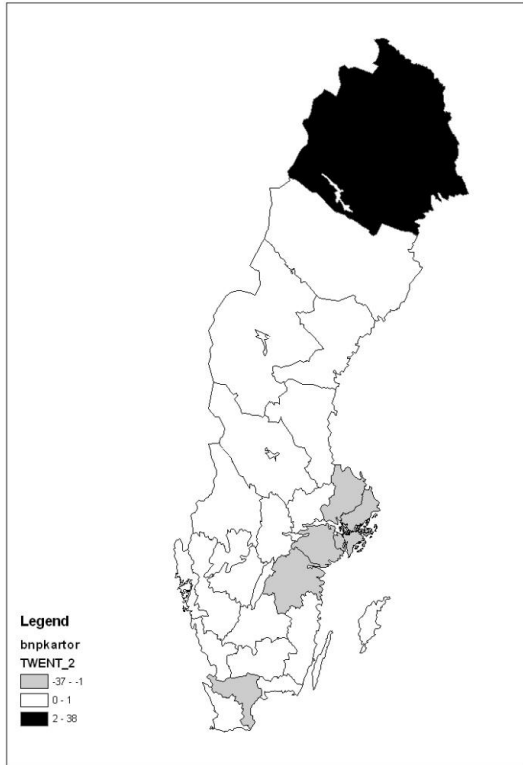
Figure 6. *Component loadings for the different regions, 20-year cycle, second component (all components showed multiplied by 100 on the map).*
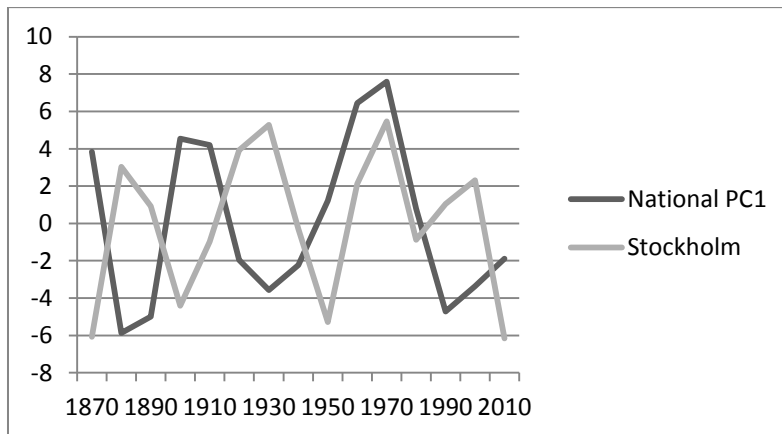

Figure 7. *20-year cycle, national average component one and observed cycle for Stockholm.*