LUND UNIVERSITY

Development blocks and the second industrial revolution - Sweden 1900-1970

Enflo, Kerstin; Kander, Astrid; Schön, Lennart

2006

Link to publication

Citation for published version (APA):
Enflo, K., Kander, A., & Schön, L. (2006). *Development blocks and the second industrial revolution - Sweden 1900-1970*. (CIRCLE Electronic Working Paper Series; No. 10).
http://www.lu.se/upload/CIRCLE/workingpapers/200610_Kerstin_et_al.pdf

Total number of authors:
3

General rights
Unless other specific re-use rights are stated the following general rights apply:
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.
• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: https://creativecommons.org/licenses/

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Download date: 19. Sep. 2024

J Evol Econ
DOI 10.1007/s00191-007-0070-8

REGULAR ARTICLE

Identifying development blocks—a new methodology

Implemented on Swedish industry 1900–1974

Kerstin Enflo · Astrid Kander · Lennart Schön

© Springer-Verlag 2007

Abstract The paper specifies a quantitative methodology for exploring development blocks. The concept of 'development block' was a major contribution to the historical analysis of industrial transformation by the late Erik Dahmén, but development blocks have mainly been analyzed by qualitative methods and indirect indicators and not statistically identified. In this paper, development blocks are identified by means of a combination of co-integration analysis and Granger causality. Using these techniques, we are able to identify two partially overlapping development blocks in the Swedish economy, formed around the electricity generating sector: one with metal, metal goods, machinery and railways; and another with pulp and paper, chemicals, and machinery.

Keywords Development block · Electricity · Co-integration · Granger causality

JEL Classification $O_0 \cdot N_5$

1 Introduction

The concept of 'development block' stresses the co-evolution of parts of the economy. At the core of a development block there is some central innovation(s) around which complementary activities are formed. There have been two major empirical studies of Swedish industry using the 'development block' approach. One is Erik Dahmén's (1950) formative study of Swedish entrepreneurial activity in the interwar period, performed primarily on a micro and branch level. The other is

K. Enflo · L. Schön
Department of Economic History, Lund University, P. O. Box 7083, 220-07 Lund, Sweden

A. Kander (✉)
Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE),
Lund University, P. O. Box 117, 221-00 Lund, Sweden
e-mail: astrid.kander@circle.lu.se

Lennart Schön's (1990) study of electricity and industrial development that *inter alia* connects the use of electricity to innovative structural change and to the growth of relatively knowledge intensive industries. Our ambition is to bring the development block analysis one step further by describing and implementing a methodology to determine, through a quantitative analysis, what the core development blocks were in Swedish industry during the period 1900 to1974.

We argue that 'development blocks' should in principle be possible to identify by means of cointegration analysis. Cointegration techniques enables identification of long-run relations between variables, in this case value added or gross production at constant prices in different sectors of Swedish industry.[1] A *first* reasonable expectation is that sectors that form a development block would be cointegrated, i. e. their long run growth trends will show a systematic co movement. If electricity is an innovation that is at the core of development blocks, the electricity-producing sector should be cointegrated with every other sector of the block. *Second*, in the *short-term*, the fluctuations in value added of the sectors should be marked by many mutually reinforcing connections within the development block, rather than one sector preceding the other, since a basic idea of the development block is that activities are complementary.[2]

Third, if electrification is a central kernel in a development block that drives growth, it should be possible to detect long and short-run linkages between the electricity use of an industry and its growth rate with the same cointegration techniques. However, energy plays very different roles in sectoral production, some sectors being heavy energy users and others light users. Thus it is not the electricity intensity (electricity divided by value added) but rather the electricity share of total energy use that would affect the growth rate of the sector.

Recently, Moser and Nicholas (2004) used historical patent citations in order to evaluate whether electricity was a general purpose technology. The method used here is also quantitative, but rather than tracing patent links, it traces the links between the value added of sectors, and is thus a different method, but with the aim of answering a related question to that of general purpose technologies: are there any development blocks around electricity?

The outline of the paper is as follows: Section 2 gives a theoretical description of the concept of development blocks and their growth implications in relation to the second industrial revolution. Section 3 presents the dataset we use to test the idea of development blocks centered on electrification. Section 4 explains the method of cointegration analysis and Granger causality. Section 5 shows our identification of development blocks. Section 6 sums up the discussion.

---

[1] Cointegration techniques are common time series econometrics tools to identify long-run relations between non-stationary variables. If there exists a linear relationship between two or more non-stationary variables that produces a time series which is stationary, the variables are said to be cointegrated. For a more detailed description, see Section 4 in this paper.

[2] In order to determine the direction of short-term time series fluctuations among the sectors we use Granger-causality tests, specified at the first difference-level of the variables. If two sectors are cointegrated and appear to Granger-cause each other, we take this as an indication that they are mutually interdependent in the short-run and thus part of a development block. See Section 4 for a more detailed description of the Granger-causality tests.

2 Theory

2.1 Development blocks and growth

The concept of development blocks was first formulated by Dahmén (1950, 1970, 1988). Innovations stimulate entrepreneurial activity in blocks of complementary activities, structuring the Schumpeterian process of creative destruction (Carlsson and Henriksson 1991). Thus, innovations and complementarities are the two central elements of the development block. Innovations create new complementarities—i.e. they create new dependencies between specific functions or properties within the production process or between production and infrastructure or institutions. New competencies, new firms and new branches come to the fore. It takes time, however, to bring forth the complementarities and in this process bottle necks and imbalances appear that, in turn, may stimulate further investments, accelerating the transformation and structural change of the economy. When the complementarities are complete, the factors within a block mutually increase their marginal returns and productivity is enhanced. The development block approach is evolutionary in the sense that growth is not an even process but rather discontinuous over time, involving a struggle between new and old combinations or blocks in the economy—a struggle that intensifies in periods of creative destruction.

New technologies in the fields of communication and transportation are of particular importance in their ability to create development blocks with a wide societal impact (Schön 1990, 1991, 1994, 2000a,b). Electrification of industry provides a good starting point for an analysis of industrial growth in the long-term perspective. Electricity has been central to Swedish industrial development and electrification constitutes a development block with strong potentials and complementarities. The electrification of industry required large investments in the generation and distribution of electrical power and in the development of the electro-technical industry and of industries consuming electricity. This had to be achieved simultaneously. Furthermore, electrification was complementary to urbanization and to the concentration of goods, labor and knowledge. Thus, the concept of development block provides the framework for the analysis of this pattern of electrification, focusing on the inter-relations of power generation, the electro-technical industry and industrial development, leading to shifts in supply and demand functions for electricity.

With the advent of the IT-revolution, many economists noticed the occurrence of radical innovations and technological shifts, and in the mid-1990s the concept of General Purpose Technologies, GPTs, was launched (Helpman 1998; Bresnahan et al. 1999).[3]

The development into a GPT is, however, a drawn-out process that may stretch over generations. The concept of development block, which combines the characteristics of the innovation with economic relations, captures the main dynamics of this process. The basic innovation enters into different development blocks over time on its path to becoming a GPT. Fulfilling a development block with

[3] Radical innovations tend to develop into GPTs. The GPT as drastic innovations characterized by pervasiveness in use and innovational complementarity has recently been integrated in endogenous growth models, for instance by Petsas (2003) and Carlaw and Lipsey (2006).

radically new complementarities is a time consuming investment process. Breakthrough periods of new important development blocks—periods of industrial revolution really qualify in this respect—are characterized by severe imbalances in growth, bottlenecks that may direct investments and strong tendencies towards divergence both between sectors and between regions in growth performance.

Furthermore, in the breakthrough period, or period of structural transformation, the positive contribution to productivity from technical change tends to be hampered by these bottlenecks in the economy. Complementarities are insufficiently provided for (Schön 1991). A productivity paradox, i.e. rapid technical change coinciding with slow productivity growth, appeared not only with the computer in the 1980s but also with the breakthrough of electricity in industry (David 1990; Schön 1990).

The evolutionary growth perspective, with some sectors taking the lead and interacting with others in a complementary way, has been examined for Sweden for the period 1968 and onwards (Lundquist et al. 2005, 2006). Strong empirical support for the idea of complementarities in growth processes in time and space has been found simply by characterizing the growth rates of value added in a broad number of sectors in different periods.

This paper takes on the challenge of investigating Swedish economic growth according to the development block ideas in the period 1900–1970 and uses advanced time series analysis, called cointegration analysis, to trace such linkages in the economic growth process with specific emphasis on the role of electrification. The epoch under investigation here is the growth period initiated by the second industrial revolution.

2.2 The second industrial revolution

The *Second Industrial Revolution* (or the Big Wave, Gordon 1999) refers to the period from the 1890s up until the late 20th century. At the heart of the Second Industrial Revolution was a series of innovations that went through a marked acceleration in their diffusion during the 1890s with far-reaching repercussions on growth and society (Schön 2006). In the midst of this group of innovations were new power-machines—the electric motor and the combustion engine.

The breakthrough of the electrical motor and the combustion engine liberated economic growth from a set of constraints that in the course of the 19th century had become more inhibiting with industrial expansion. These constraints concerned the supply and price of energy, the localization of industry and the organization of the industrial work process (Schön 1990). The breakthroughs of the electrical dynamo and the combustion engine as forceful power technologies widened energy supply and infused new optimism.

The power machines did not stand alone, though. The appearance of a radically new steel technology in the last decades of the 19th century created new opportunities for industrial growth. For one thing, the use of steel of higher qualities and in larger quantities made machine technology more competitive and pervasive, particularly in conjunction with new power machines. Steel also became the new material in construction, in infrastructure, in vehicles and vessels—i.e. there were wide potentials in power machines and steel as kernels in new development blocks. Alongside the new steel technology, a new organic chemistry, mainly based on coal, arose. Scientific knowledge in chemistry became an input in the production of steel and paper as well as of fertilizers, dyes, pharmaceutical drugs etc. In information technology, the advent of the telephone and the wireless radio made communications much more flexible than before. In all, this swarm of innovations strengthened modern economic growth, and industrialization became a more encompassing social adventure and a more attractive path to follow.

To assess the full economic impact of these new technologies in quantitative terms is impossible, because they are so complex. The direct growth effects that stem from the growth of industries and sectors involved with production of the new engines and related systems of energy and communication may not justify the term industrial revolution, but the indirect effects on growth are substantial.

The indirect growth effects of the technologies of the second industrial revolution were at least fourfold. First, the new engines in sea, land and air transportation implied increasing market integration with concomitant specialization and economies of scale, which increased overall economic efficiency and growth. Second, the new engines established a growing production apparatus that augmented the motive power at the workers' disposal. The stock of machinery grew incrementally and brought about a long-term growth of industrial production. Third, the new engines enabled more efficient organization of production. This was particularly so with electric engines when applied to group-drive or unit-drive. Fourth, the new technologies went hand-in-hand with human capital development, since there was a skill-technology complementarity especially in the electricity production and manufacturing of electro-technical equipment (Goldin and Katz 1996).

This paper focuses on one of the two radical innovations of the second industrial revolution: electricity. Our aim is to analyze how specific development blocks formed at the sectoral level, and we expect that sectors that were early adopters and producers of electricity should have taken a lead of the evolution and been mutually connected within certain development blocks. If electricity was an important factor in driving growth after 1890, we should be able to find evidence of strong development blocks around electricity and the rapid growth of electrifying sectors.

3 Data

The data set we use consists of a total of 14 time series of value added for 12 industrial sectors plus the railway sector and the electricity-producing sector from 1900 to 1974 in Sweden. In addition, it consists of annual electricity consumption and fuel consumption for all the industrial sectors from 1936 to 1974. For the railway sector, we have energy series from 1915 to 1974. Series of production volumes and energy use in the industrial sectors were constructed and presented in Schön (1990). All industrial series are measured as gross value added, whereas the electricity and railway sectors are measured in gross production expressed in 1969/1970 constant prices (millions of SEK; Fig. 1).

4 Materials and methods

We use cointegration analysis to trace long-run relations between sectors and variables and Granger causality to trace the short-run relations. We define a

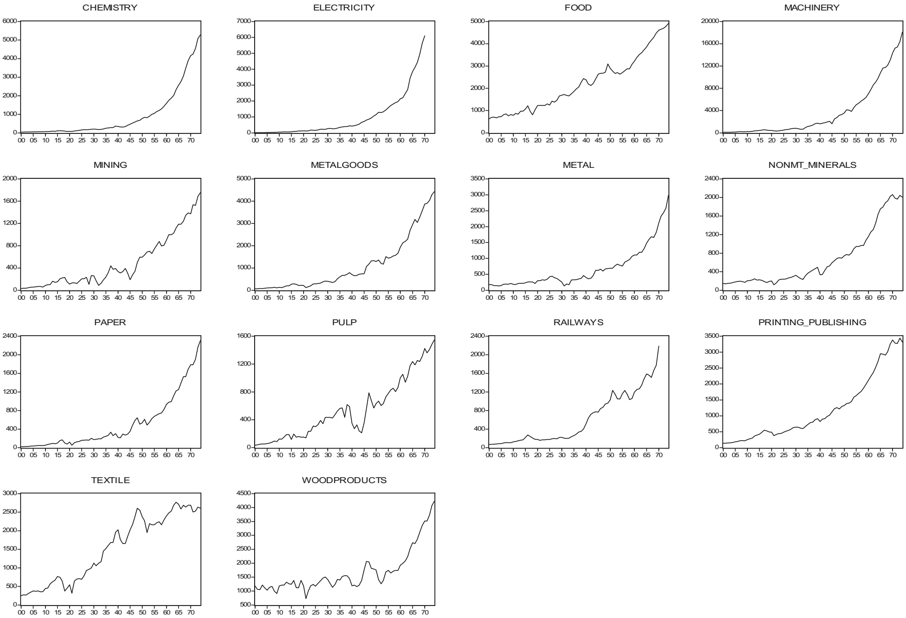

Fig. 1 Value added in all 14 sectors, millions of SEK, constant prices, price level 1969/1970

development block as consisting of a number of sectors that share a common long-run trend (i.e. are cointegrated) and are linked to each other by mutually reinforcing Granger causality. The expectation of mutually reinforcing linkages in the short term is due to one of the main ideas in the theory of development blocks: complementarity. This econometric approach to studying sectoral linkages is different from the conventional input–output method that assumes an instantaneous relationship between the sectors of the economy. Instead, we use time series data to capture the dynamic relations between various industrial sectors, both in the long and in the short-run. This econometric approach has been utilized in earlier studies to assess the linkages from particular sectors, such as the financial sector (Odedokun 1996) or the construction sector (Chan 2001) to the rest of the economy. To the best of our knowledge, this approach has not yet been used as a means to identify development blocks among several sectors.

4.1 Cointegration

The concept of cointegration can be defined as a systematic co-movement between two or more non-stationary variables over the long run. A variable is said to be non-stationary when its mean, variance and covariance are time dependent, meaning that any shock to the variable will have a permanent effect, as the variable does not revert back to its mean. If two non-stationary variables are regressed upon each other, the result is likely to be spurious (Granger and Newbold 1974), and therefore econometricians used to opt for taking differences and logs in order to transform non-stationary variables into stationary ones that can enter into traditional regressions. A variable that becomes stationary after taking its first differences is said to be integrated by order one, I(1). The problem with this approach is that the differencing procedure removes all long-run properties from the series. However, Engle and Granger (1987) showed that there may exist a linear combination between two non-stationary variables which produces a time series that is stationary. If we are able to detect such a linear combination, the two non-stationary time series are cointegrated, which means that they may drift from their original means, but they follow the same stochastic trend so that they never drift too far apart in the long-run. Thus, if X_t and Y_t are non-stationary but cointegrated, there exists some value, β, such that $Y_t - \beta X_t$ is stationary.

In order to find out whether our variables are cointegrated, we use the Vector Auto Regression (VAR)-based trace test for cointegration developed by Johansen (1988, 1991). Since this test is sensitive to the choice of length of the time lag in the original VAR, we use a combination of information criteria and lag exclusion tests to determine the appropriate lag length, before testing for cointegration.[4] Since the asymptotic distribution of the test statistic for cointegration depends on the assumptions made with respect to deterministic trends in the data series and in the cointegration relations, we need to make an assumption regarding the underlying trends in our data. All specifications include the intercept in the cointegration relation, but we only include trends if the variables appear to be trend stationary and if the trend turns out to be significant.[5]

4.2 Vector Error Correction (VEC)

The Granger representation theorem (Engle and Granger 1987) states that if a set of variables are cointegrated, there exists a valid error correction representation of the data. If X_t and Y_t are cointegrated, we can therefore write the following Vector Error Correction Model (VECM) of lag order p:

$$\Delta Y_t = \sum\nolimits_{i=1}^{p} \Phi_{1,i}\Delta Y_{t-i} + \sum\nolimits_{i=1}^{p} \Phi_{2,i}\Delta X_{t-i} + \alpha_1(Y_{t-1} - \beta_1 X_{t-1}) + \varepsilon_{1,t}$$
$$\Delta X_t = \sum\nolimits_{i=1}^{p} \theta_{1,i}\Delta X_{t-i} + \sum\nolimits_{i=1}^{p} \theta_{2,i}\Delta Y_{t-i} + \alpha_2(Y_{t-1} - \beta_2 X_{t-1}) + \varepsilon_{2t}$$

where Δ is the first-difference operator, Φ and θ are the coefficients of the first-differenced terms (the short-run parameters) and the α:s measure the speed of adjustment of each variable to the cointegration relationship. The cointegration relationship is represented by the expression within parentheses, in which the β:s are the cointegration coefficients. The ε:s are serially uncorrelated error terms.

In order to discern short-run linkages between industrial sectors, we use the Granger causality test. The test was proposed by Granger (1969) and is a general approach to detect whether past values of a series X can be used to determine current values of Y. The test is usually carried out in a VAR-framework, but in the presence of a cointegration relationship between X and Y, Granger causality can be determined within the framework of the VEC as specified in the above equations. With respect to this system, there is one-way Granger-causality running from X to Y

---

[4] Additional information about VAR-specification is provided in the Appendix.

[5] We also check the robustness of our findings for different specifications, and it turns out that our tests are robust to alternative specifications.

if the Φ_2's are jointly significantly different from zero in the first equation, but the θ_2's not jointly significantly different from zero in the second. In parallel, there is one-way Granger causality from Y to X if the θ_2's are jointly significantly different from zero in the second equation, but the Φ_2's in the first equation are not. Mutually short-run links are defined as the two-way Granger causality that occurs when the Φ_2's in the first and the θ_2's in the second equation both are jointly significant from zero. The two-way Granger causality describes a scenario in which past values of X determine current values of Y and past values of Y simultaneously determine current values of X, which means that the two series are mutually reinforcing. The tests are carried out using the Wald-test for the joint null hypothesis of the above-specified parameters being equal to zero in each equation.

In the absence of a long-run relationship between X and Y, there may still exist short-run linkages. In that case, we have employed the Granger causality test in a VAR with variables in their differenced form to investigate these linkages.

5 Results

5.1 Long-run relations

The Phillips-Perron test shows that the value added-series in all 14 sectors are non-stationary and I(1).[6] Therefore, we proceed by investigating whether we can find any long-run relationships between pairs of sectors during the long period of the second industrial revolution. Since there are 14 sectors, each one can maximally share long-run relationships with all of the other 13 sectors. The results are presented in Table 1. In general, there are quite many long-run relationships between the sectors, which is perhaps not very surprising given that they are part of the same macroeconomic system. The highest number of cointegration relationships is found between the printing and publishing industry and 12 other industries, with most industries showing 9 to 12 common trends with others, indicating strong long-run linkages between most industries in the Swedish economy. However, the exceptions are the textile and the food industry which only share six and four long-run relations, respectively, with other industries and consequently seem to be less integrated into the economic system.

As we discussed in Section 2.2, the electric motor, three-phase alternating current and new transmission technique in the technology of electricity were core innovations in a series of innovations that went through a marked acceleration in diffusion during the Second Industrial Revolution. Our prior knowledge about the nature of technologies driving the Second Industrial Revolution makes us focus on development blocks around thise particular industry that supplied the current of the new technology. The identification of development blocks and especially what constitutes the core of such blocks in this paper is thus not a random search, but is driven by our previous understanding. We test the hypothesis that the electricity industry is at the core of one or more development blocks and that it interacts with

[6] All unit root tests are reported in the Appendix.

Table 1 The number of cointegration relationships for each sector

Print.	Chem.	Pulp	Metal goods	Machinery	Paper	Rail-ways	Electricity	Mining	Metal	Non-metal mineral	Wood Prod.	Textile	Food
12	10	10	10	10	10	10	9	9	9	9	9	6	4

several other industries in a mutually reinforcing way. In the electricity industry, we detect nine cointegration relationships, namely between the electricity and metal industries; chemistry; pulp; metal goods; printing and publishing; machinery; railways; paper and wood products industries. This seems intuitively correct as all of these industries are dependent on electricity to a high extent, whereas the industries that do not share long-run relations with electricity (non-metal minerals, food and textile) are not. The only exception is the mining and quarrying industry, which does not share a long-run trend with electricity, although we know that it is both energy intensive and was early in adopting electricity as a new technology.

It seems that electricity was an integrated part of the Swedish economic system from the second industrial revolution onwards, but the number of long-run relationships per se cannot help us in identifying specific development blocks between sectors. To be able to identify such inter-linkages, we must investigate the short-run relationships and possible complementarities between the industries.

5.2 Short-run linkages

Short-run Granger causality is tested either by running the bivariate VAR in differenced form or, in the presence of cointegration, by running VEC-regressions between all possible pairs of variables. Since there are 14 variables in the system, we start by running 91 regressions to test if lagged values of any variable in the system can significantly explain the current dependent variable. If a sector's past values can be used to explain another sector's current value, we define this relationship as a forward linkage. Similarly, we define a backward linkage as a sector whose current value added is significantly adjusting to the past values of another sector. If both variables' past values can be used mutually to explain each other, we consider this an indicator of short-run complementarity between the two industries. The fact that we are running a large number of tests obviously risks leading us into mass significance, since testing on the 5% level theoretically means that every 20th test can be significant even under a correct null hypothesis, so some caution should be adopted when interpreting the results.

In Table 2, we have ranked the industries with the most significant forward and backward linkages to other sectors. As there are 14 variables in the system, each variable can at most Granger cause 13 variables and be Granger caused by 13 variables, meaning that the maximum number of linkages for each sector is 26.

The sector with the highest number of total linkages is the machinery industry, followed by the chemical industry and the electricity industry. At the level of 12 linkages, we find the metal goods and the wood products industry. The railways, mining and quarrying and the metal industries share ten short-run linkages to other

Table 2 Number of total, forward and backward linkages

	Total	Forward	Backward
Machinery	17	7	10
Chemistry	14	5	9
Electricity	13	8	5
Metal goods	12	4	8
Wood products	12	8	4
Mining	10	3	7
Metal	10	9	1
Railways	10	3	7
Non-metal minerals	9	5	4
Pulp	9	6	3
Paper	9	5	4
Printing and publishing	7	3	4
Textile	7	6	1
Food	2	0	2

industries. The only industry that is an outlier at the bottom of the scale is the food industry, with only two linkages.

If we look at the relative distribution of industries with many forward linkages (Granger-causing other variables), it appears that the metal industry is outstanding in this respect. It Granger-causes nine other variables and is only adjusting to one other variable. The machinery and the electricity industries Granger-causes seven other variables each, but whereas the machinery industry adjusts to ten other variables, the electricity sector only adjusts to five other variables. If we look at railways, we find that its main linkages run through the adjustment to other variables, as it shows a total of ten linkages with other industries, with only three of them being forward linkages. (This could be interpreted as the industry mainly responding to the short-run fluctuations of other industries, rather than causing them.) It is also clear that the resource based industries—the metal industry and the wood product industry—Granger-cause growth in other sectors, but are not being Granger-caused by other sectors. Both these industries are dominated by exports and tend to lead the Swedish business cycles. It is, however, typical that linkages in these industries run one-way rather than being mutual, since the metal and wood products industries are primarily influenced by the timing sequence of the business cycle rather than forming a core of mutual complementarity in any development block.

5.3 A development block formed around electricity

In order to explore further the linkages between certain sectors, we look for dependencies between sectors we expect are closely interlinked in so-called development blocks. As stated earlier, we expect that industries that form a development block should be driven by the same long-run stochastic economic trend (i.e. they are cointegrated). But in addition to sharing the same long-run trend, we also expect strong short-run mutually reinforcing linkages within the development block. Although the electricity industry does not have the most forward linkages in total, it actually Granger causes all industries to which it is in turn adjusting (apart from non-metal minerals and wood products). This suggests that there are strong mutual short-run dependencies between the electricity industry and the other sectors and that the electricity industry is likely to form a core in a development block.

Table 3 summarizes the *p* values from the Granger causality tests in the VEC or the VAR as explained in Section 4.2 between the 14 sectors. The dependent variable is displayed on the horizontal axis, and a value below 0.05 indicates that the null hypothesis of the sector on the vertical axis *not Granger causing* the sector on the horizontal axis can be rejected. When the null hypothesis is rejected, we conclude that there is a significant forward linkage running from the sector on the vertical axis to the sector on the horizontal axis.[7]

The short-run linkages between the electricity industry and the other 13 industries are found in the first column and row of the table. Since our main interest is to identify the development that arose around electricity during the second industrial revolution, we start by examining the nine industries that formed long-run relationships with the electricity sector (metal, chemistry, pulp, metal goods, printing and publishing, machinery, railways, paper and wood products). We find mutually reinforcing short-run linkages between electricity and the following sectors: metal, chemistry, metal goods, machinery (at 7% significance) and railways. In addition to being interlinked with electricity, these sectors show a large number of mutual linkages, which further strengthens our hypothesis that these industries are signified by strong complementarities.

The development block displayed in Fig. 2 confirms earlier research that has shown a close timing in the development of the infrastructure of electricity and in the structural transformation of industry (Schön 1990). Thus, great advances were made in the electricity infrastructure during the 1910s and from the late 1930s to the 1950s. A national grid was integrated and the technology of high voltage transmission developed that made it possible to supply industries with electricity at lower prices, in large quantities and with great regularity. Furthermore, this development of the infrastructure was simultaneous with a more rapid growth of new sectors. In particular, the machinery industry supplied new generations of electrical motors and machinery as a complement to the supply shift of electricity, and the motors were, in turn, dependent upon new qualities of metal and metal goods. This is certainly relevant for the electrification of railways. Electrification was first introduced in the 1910s, but it was more forcefully followed from the 1930s. In this connection, the Swedish company ASEA (ABB), as a main supplier of equipment to electricity utilities, also developed the electricity traction technology in new locomotives. These linkages between electricity, machinery, metal, metal goods and railways have been traced quantitatively using our proposed methodology, but, in addition, we also detect a strong mutual relationship between electricity production and the chemical industry that calls for further analysis.

5.4 Linkages between electricity use and growth of an industry

In order to explore the role of the electricity share and the effect on growth in value added of the sectors, we first use a basic linear trend analysis to see whether sectors

[7] The VAR or VEC specifications and choices of lag lengths can be found in the Appendix.

Table 3 *p* values for granger tests on short-run linkages

	El	Mining	Metal	Non-met.	Chem	Food	Pulp	Mt goods	Print.	Mach.	Paper	Rail-ways	Wood Prod.	Textile
El		0.41	**0.00**	0.86	**0.00**	0.26	0.46	**0.02**	**0.00**	**0.00**	0.06	**0.02**	**0.02**	0.78
Mining	0.77		0.08	0.18	**0.00**	x	0.14	0.31	0.81	0.08	**0.00**	**0.00**	0.17	x
Metal	**0.01**	**0.04**		**0.00**	**0.02**	0.13	0.36	**0.00**	**0.00**	**0.00**	0.71	**0.05**	**0.03**	0.79
Non-met.	**0.00**	**0.01**	0.57		0.21	**0.00**	0.25	0.12	0.55	0.17	0.51	**0.03**	0.48	0.81
Chem	**0.04**	0.56	0.16	**0.01**		0. 07	0.07	**0.00**	**0.01**	**0.04**	0.27	0.77	0.20	0.31
Food	0.95	x	0.41	0.65	0.09		0.39	0.43	0.81	0.59	0.52	x	0.85	0.12
Pulp	0.15	0.26	0.73	**0.00**	**0.05**	0.05		**0.00**	0.27	**0.03**	**0.00**	**0.01**	0.74	0.76
Mt goods	**0.00**	**0.02**	0.70	0.60	**0.02**	0.10	0.21		0.70	**0.01**	0.07	0.10	0.48	0.63
Print.	0.29	0.21	0.91	0.74	0.51	0.59	0.07	**0.01**		**0.00**	0.14	**0.00**	0.40	0.74
Mach.	0.07	**0.01**	0.94	0.51	**0.01**	0.28	**0.05**	**0.02**	0.11		**0.00**	**0.02**	**0.00**	0.89
Paper	0.31	**0.00**	0.16	0.39	**0.00**	**0.00**	0.64	0.21	0.56	**0.01**		0. 00	0.02	**0.02**
Rail-ways	**0.00**	**0.04**	0.07	0.35	0.11	x	0.07	0.08	0.53	**0.04**	0.26		0.25	x
Wood prod.	0.81	**0.01**	0.10	**0.00**	**0.01**	0.07	**0.00**	**0.00**	**0.04**	**0.00**	**0.00**	0.06		0.15
Textile	0.85	x	0.28	0.05	**0.02**	0.43	**0.02**	**0.00**	0.21	**0.02**	0.14	x	**0.03**	

p values below 0.05 suggest a significant short-run linkage. Dependent variable on horizontal axis.

of high electricity shares have grown faster than sectors with low electricity share. Next, we use cointegration analysis to detect long and short-run inter-linkages between electricity shares and growth patterns. Lastly, we use the results to modify our previous understanding of development blocks around electricity.

Since energy plays different roles in different sectors, some being heavy energy users and others light users, we do not use the electricity intensity (electricity divided by value added) but rather the electricity share of total energy use as the hypothesized driving force of growth in the industrial sectors. In Table 4, we have ranked all 13 industrial sectors (after 1936 we are able to split up the metal industry into non-iron metal and iron/steel industries, thus increasing the number of industrial sectors to 13) according to their electricity share in 1970.

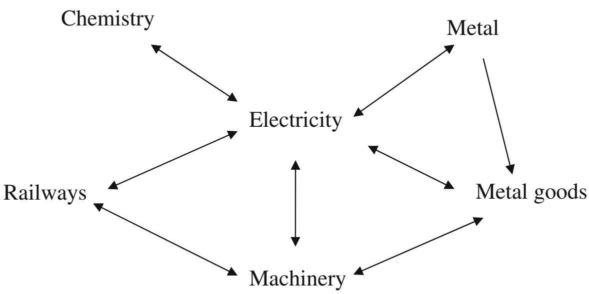

Fig. 2 Development block around electricity

Table 4 Sectors ranked according to their electricity share (of total energy use) in 1970

	1936	1970	Change in electricity share 1936–1970
Railways	0.15	0.78	4.20
Non-iron metal	0.09	0.61	5.70
Chemistry	0.23	0.43	0.90
Mining	0.24	0.32	0.33
Wood products	0.11	0.31	1.82
Paper	0.17	0.31	0.90
Metal goods	0.12	0.29	1.39
Machinery	0.18	0.26	0.43
Pulp	0.14	0.25	0.74
Printing and publishing	0.21	0.23	0.08
Iron / steel	0.12	0.19	0.62
Textile	0.09	0.15	0.58
Food	0.05	0.15	2.01
Non-metal minerals	0.03	0.09	2.44

As seen from Table 4, railways, followed by non-iron metal industry, had the largest electricity share in 1970 and also display the highest growth of the electricity share since 1936. The non-iron metal is the energy intensive part of the metal industry, since it contains the aluminum industry. The chemical industry started off with one of the highest electricity shares in 1936, but still managed to increase this share substantially until 1970. Mining and quarrying and the printing and publishing industries were relatively dependent on electricity already in 1936, but did not increase this share so dramatically until 1970, whereas paper, pulp, wood products and metal goods started from rather low levels and nearly doubled their electricity shares. The machinery industry showed a similar development, although it started from a higher share. The iron / steel, textile, non-metal minerals and food industries were not very dependent on electricity in 1970, although some of these industries increased their shares from very low levels in 1936.

We find that all sectors that were part of the development block identified in Section 5.3 showed strong increases in their electricity shares from 1936 and had among the highest electricity shares in 1970 (railways: 0.78; non-iron metal 0.61; chemistry: 0.43; metal goods 0.29 and machinery 0.26). Besides these industries, paper and pulp also exhibited strong electricity growth and high electricity shares, which make them interesting from the point of view of development blocks around electricity. From the Granger causality tests in Table 3, we also found significant short-run linkages from value added in paper to pulp as well as mutual linkages between the chemical industry and pulp, and a significant link from paper to chemistry. This inter-connection further strengthens our belief that the paper and pulp industries may form a part of a development block around chemistry.

In Table 5, we show the ranking of these industries in terms of growth of value added and we see that the linear economic growth trends coincide rather well with electrification. In general, sectors with high electricity shares and large increases of that ratio between 1936 and 1970 also grew substantially in value added. To explore whether this is only a coincidence, we turn to long-run cointegration analysis and short-run Granger causality.

Table 5 Industries ranked according to their growth of value added

	Growth of Value Added 1890–1936	Average annual growth 1890–1936		Growth of Value added 1936–1970	Average annual growth 1936–1970
Machinery	85.0	0.09	Non-iron metal[a]	18.2	0.08
Pulp	72.3	0.09	Chemistry	14.9	0.08
Paper	36.8	0.08	Machinery	10.6	0.07
Metal goods	32.8	0.07	Railways	9.6	0.07
Printing and publishing	27.1	0.07	Paper	5.7	0.05
Mining	20.7	0.07	Metal goods	4.8	0.05
Textile	11.1	0.05	Iron/Steel[a]	4.3	0.05
Railways	10.5	0.05	Non-met min	4.1	0.05
Chemistry	8.3	0.05	Printing and publishing	3.3	0.04
Non-met min	6.5	0.04	Mining	3.3	0.04
Food	5.4	0.04	Pulp	1.5	0.03
Metal[a]	2.7	0.03	Food	1.3	0.02
Wood products	0.70	0.01	Wood products	1.3	0.02
			Textile	0.7	0.01
Value added total industry	5.1	0.04	Value added total industry	3.6	0.04

[a] Note that the metal industry was split up into non-iron metal and iron/steel after 1936.

5.5 Long-run relations between value added and electricity

In order to investigate whether electrification is a central force that drives industrial growth, we proceed by using the Granger test as explained in Section 4.2. Our hypothesis is that we should be able to detect a long-run (cointegration) relationship between value added of electricity-dependent industries and their electricity share. We also expect that an increase in the electricity share should drive increases in value added in the short-run, and not the other way round. We use data from 1936 to 1974 for all industries apart from railways where we have access to data from 1915 to 1974.

The second column in Table 6 displays the bivariate VAR specification in first differences between the electricity share and value added in the 13 industries. Whenever we find a cointegration relationship between electricity share and value added, we proceed by estimating a VEC. Again, we find cointegration relationships between the electricity share and four of the five industries in the development block defined in Section 5.2: chemistry. machinery, metal goods and railways. However, we cannot find any long-run relationship between electricity use and the metal industry (which we have now divided into non-iron metal and iron and steel) that also are part of the development block, which is at odds with our expectations. We do, however, find a fifth long-run relationship between the electricity share and value added in the pulp industry, which was not part of the pervious development block.

5.6 Short-run linkages between value added and electricity

In addition to finding long-run cointegration between electricity shares and value added in five industries, we also discover that electricity use seems to have short-run

Table 6 VAR:s and VECM:s between the 13 sectors and the electricity share

Industry 1936–1974	Specification	EL → VA	VA → EL
Chemistry	VEC (3)	0.04	0.00
Non-metal minerals	VAR(0)	x	X
Food	VAR(0)	x	X
Printing and publishing	VAR(0)	x	X
Iron / Steel	VAR(3)	0.00	0.17
Machinery	VEC(5)	0.04	0.20
Metal goods	VEC (0)	x	X
Mining	VAR(0)	x	X
Non iron metal	VAR(1)	0.73	0.02
Paper	VAR(3)	0.02	0.22
Pulp	VEC(3)	0.01	0.72
Textile	VAR(0)	x	X
Wood products	VAR(1)	0.98	0.26
Railways 1915–1974	VEC(0)	x	X

Comment: Values within the brackets of the VAR or VEC specification refer to the number of lags in first-differenced specifications.

relationships with several industries, apart from the above-mentioned. The third column in Table 6 exhibits the probabilities from testing the null hypothesis of the electricity share *not Granger causing* value added growth, whereas the fourth column refers to the null hypothesis of value added growth *not Granger causing* increases in the electricity share. Whenever the lag length was determined to be 0 and we do not have a short-run relationship between the variables, the column is denoted with an x. Table 6 displays that short-term changes in the electricity share Granger cause fluctuations in iron/steel, paper and pulp, while we find mutual linkages between the electricity share and value added in the chemical industry. In the non-iron metal industry, we find that fluctuations in value added seem to drive the short-term evolution of the electricity share. Increased production in this heavy electricity using industry may have led to bottle necks that caused expansionary investments in the electricity supply with further price reductions—such links are basic to the development block approach.

None of the industries with low electricity shares (i.e. food, textile, non-metal minerals) show any long-term or short-term relationship between value added and electricity shares. Industries that were rather electricity dependent already in 1936 (printing and publishing industry, mining and quarrying), but had fairly constant electricity shares up until 1970, do not exhibit any short or long-run relationship either (Tables 7 and 8). This could be explained by the fact that both mining and quarrying and the printing and publishing industry were early in adopting electricity as a source of energy and had adapted well to the electricity using technology already in 1936, therefore exhausting the major growth advantages from increasing the electricity share that lay ahead of the majority of the other industries.

5.7 A modified development block

With the additional information obtained from the cointegration and Granger causality tests between the electricity share and value added, we may modify our initial development block somewhat. It seems that the qualities of complementarity between electricity and innovative behavior in the leading sectors of the second industrial revolution (machinery, chemistry, metal products and railways) were a driving force behind long-term growth. In addition, the cointegration relationship between the electricity share and value added in the pulp industry suggests that this sector should be added to the development block around electricity. The pulp industry is likely to be more closely related to the parts around the development block formed around electricity and the chemical industry, since the production of pulp developed in close connection with the chemical industry.

In addition to confirming the long-term structure in the development block found in Section 5.3, the short-term analysis shows that changes in the electricity share also drove short-term fluctuations in those sectors that increased their electricity share during the time period (machinery, chemistry, paper, pulp and iron/steel). It therefore seems that we could add the paper industry to the second development block formed around electricity, chemistry and pulp, especially since we found close mutual short-run linkages between paper and pulp and pulp and chemistry in Section 5.3, indicating complementarities between these sectors.

With this additional information, we find it possible to discern two partly separate and partly overlapping development blocks, portrayed in Fig. 3. Thus, we have been able to discern two development blocks involving electricity at this level. Apart from the main block around metal, machinery and railways, there is also one with a main link between electricity, chemistry and pulp and paper. Both chemical industries and pulp and paper mills used large amounts of electricity. Electrolytical processes were, e.g., important in chemical industries from the early 20th century onwards, while electricity was important in driving the machinery of pulp and paper mills. These industries were early in constructing hydroelectrical power sites of their own and could later take advantage of their integration into a national grid. Furthermore, there

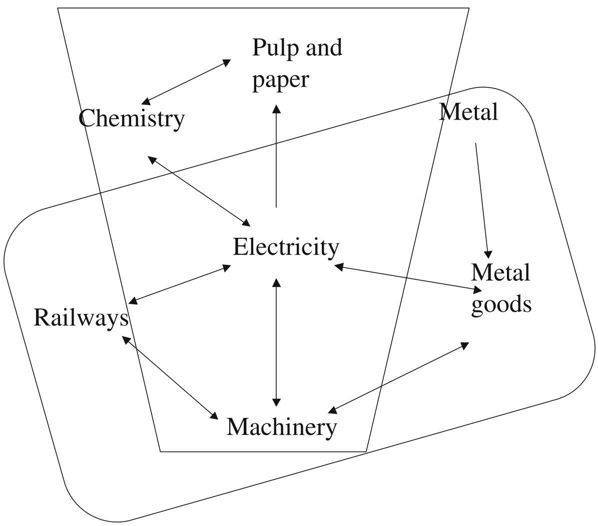

Fig. 3 Two development blocks around electricity

was a close link between the chemical industry and the explosive expansion of the pulp industry in the 20th century, since mostly chemical pulp was produced stimulating the production of chemical ingredients in the process, such as chlorine. Both industries are likelyto be interlinked also with the machinery industries through the adoption of the new technology introduced with electricity. This macro-level picture conforms very well to prior micro-level analyses Dahmén (1950) and analyses of industrial innovative transformation and electricity use, as well as to more qualitative interpretations of the role of development blocks in long-term Swedish economic growth (Schön 2000a).

6 Concluding discussion

The contributions of this paper are twofold. First, we have proposed a method for quantitatively tracing the existence of development blocks in time series data that can be used by other scholars for other countries, datasets and periods. We suggest that cointegration analysis combined with short-run Granger causality tests is appropriate for such investigations. Sectors within a development block should share common long-run stochastic trends *and* be linked to each other with mutually reinforcing links (that is, the direction of Granger causality should go in both ways). This definition comes naturally from the theory of development blocks, which states that sectors within a development block are strongly dependent on each other, so that complementarities are a basic feature. The long-run common trend consists of everything that unites the sectors, and thus captures common technologies as well as influences from the external world (business cycles). For a small open economy such as Sweden, certainly the export markets play a fundamental role for the evolution of those common trends. We therefore find that most sectors share many common trends with other sectors, and that the long-run common feature must be complemented by the short-run mutually reinforcing linkage to become a sufficient criterion for a development block.

Second, we have empirically discerned two development blocks around electricity, allegedly one of the general purpose technologies of the second industrial revolution. The period we study is 1900–1974, and we use 14 sectors for our analyses. Those are the electricity production, mining and quarrying, metal, metal products, manufacturing of non-metal minerals, chemical, food, pulp, paper, printing and publishing, machinery, wood products, textiles and railways.

A first development block was discovered by using data of value added in constant prices comprised of electricity production (center of the system), metal, metal products, machinery, chemistry and railways. A complementary analysis was performed which used data on electricity and energy consumption of the sectors and related the electricity share (electricity/total energy) to the value added. This analysis showed that pulp and paper qualified to be part of the bigger development block around electricity and that it is possible to discern two partly overlapping development blocks around electricity: a first block with metal, metal goods, machinery and railways; and a second block with pulp and paper, chemistry and machinery. These results give a new formulation of development blocks that both deepens and confirms the earlier analysis of the role of development blocks and electricity in Swedish economic growth.

Appendix

Unit root tests

Table 7 Value added in 14 sectors 1900–1970

Level	1st diff						Conclusion
	PP t-stat	*p* value	PP t-stat	*p* value	Trend	Intercept	
Electricity	20.2	1.0	−3.8	0.02	0.0	0.1	I(1) trend stationary
Mining	−0.32	0.98	−7.2	0.0	no	0.02	I(1)
Metal	6.9	1.0	−6.5	0.0	0.0	0.1	I(1) trend stationary
Non-metal minerals	1.5	1.0	−6.5	0.0	0.0	0.22	I(1) trend stationary
Chemistry	38.5	1.0	−4.1	0.0	0.0	0.16	I(1) trend stationary
Food	−0.66	0.97	−6.8	0.0	no	0.0	I(1)
Pulp	1.6	0.99	−7.7	0.0	no	0.05	I(1)
Metal Goods	9.6	1.0	−6.9	0.0	0.0	0.16	I(1) trend stationary
Printing and publishing	2.8	1.0	−6.2	0.0	0.0	0.39	I(1) trend stationary
Machinery	12.1	1.0	−5.9	0.0	0.0	0.02	I(1) trend stationary
Paper	1.9	1.0	−8.8	0.0	0.0	0.15	I(1) trend stationary
Railways	0.48	0.99	−3.7	0.0	0.0	0.38	I(1) trend stationary
Wood prod.	−0.49	0.98	−6.2	0.0	no	no	I(1)
Textile	−2.6	0.24	−7.6	0.0	no	0.04	I(1)

McKinnon one-sided *p* values to the hypothesis of a unit root

Tables 7 and 8 display Phillips-Perron test for the null hypothesis of a unit root in the value added (Table 7) and electricity share (Table 8) series of the 14 industries.

Specifying the VARs

Before applying the Johanssen's test for cointegration, we need to specify the appropriate number of lags in the VAR. Since the cointegration test is sensitive for the

Table 8 Electricity share in 14 sectors 1936–1974

Level	1st diff						Conclusion
	PP t-stat	*p* value	PP t-stat	*p* value	Trend	Intercept	
Mining	−2.0	0.28	−10.3	0.0	No	0.36	I(1)
Iron/steel	−2.1	0.22	−9.1	0.0	no	0.39	I(1)
Non-iron metal	−2.1	0.21	−5.5	0.0	no	0.08	I(1)
Non-metal minerals	−1.0	0.73	−4.6	0.0	no	0.12	I(1)
Chemistry	−0.68	0.83	−9.2	0.0	no	0.01	I(1)
Food	0.73	0.99	−12.1	0.0	no	0.0	I(1)
Pulp	−1.2	0.64	−7.2	0.0	no	0.27	I(1)
Metal Goods	0.31	0.97	−11.7	0.0	no	0.01	I(1)
Printing and publishing	−4.67	0.0					I(0)
Machinery	0.81	0.99	0.81	0.99	no	0.07	I(1)
Paper	−1.1	0.68	−8.4	0.0	no	0.26	I(1)
Railways 1915–1974	−0.07	0.94	−4.1	0.0	no	0.02	I(1)
Wood products	−1.	0.7	−6.2	0.0	no	0.05	I(1)
Textile	1.2	0.99	−9.8	0.0	no	0.03	I(1)

McKinnon one-sided *p* values to the hypothesis of a unit root.

Table 9 Bivariate VAR lag specification (in differences) and the presence of cointegration between the variables (*Y* Yes, *N* no)

	EL	Min	Metal	Non-met min	Chem.	Food	Pulp	Mt prod	Pri	Mach	Paper	Railw	Wood prod.
EL													
Min	4 N												
Mt	5 Y	4 Y											
Nm	5 N	1 Y	5 N										
Che	6 Y	6 Y	4 Y	1 Y									
Fo	4 N	0 N	4 N	1 N	4 N								
Pu	4 Y	1 Y	4 Y	2 Y	4 Y	2 N							
Mtp	4 Y	3 Y	5 N	1 Y	6 N	1 Y	2 Y						
Pri	4 Y	1 Y	4 N	1 Y	4 Y	1 Y	1 Y	1 Y					
Mac	5 Y	5 N	6 Y	5 Y	3 Y	1 Y	5 Y	4 Y	2 Y				
Pap	4 Y	3 Y	1 Y	3 Y	5 Y	3 N	3 Y	3 Y	2 Y	5 N			
Rail	6 Y	1 Y	4 Y	5 Y	4 Y	0 Y	2 Y	5 N	5 Y	5 N	4 Y		
Woo	5 Y	3 Y	4 Y	2 Y	5 Y	3 N	2 N	1 Y	2 Y	5 Y	5 Y	5 N	
Text	4 N	0 N	1 Y	1 N	4 N	1 N	1 N	1 Y	1 Y	1 Y	4 Y	0 Y	3 N

specification of lags in the VAR, information criteria such as Akaike, Schwarz and Hannan-Quinn were all used to find the appropriate number of lags. We also used the Final Prediction Error and the LR-test for lag exclusion. When different information criterion and tests suggested conflicting number of lags, we have followed the number suggested by most indicators and thereafter checked the robustness of our results to different lag specifications. All VARs were specified with the variables appearing in their differenced form in order to avoid spurious results.

Table 9 displays the different VAR-lag specifications that were chosen using the information criteria next to a letter indicating whether we were able to detect a cointegration relationship between the two variables (Y/N). Since the specification was made in differences, the maximum dependence between two variables is 7 years; however the usual dependence seems to be around 2–3 years.

References

Bresnahan TF, Brynjolfson E, Hitt LM (1999) Information Technology. Workplace organization and the demand for skilled labour: firm level evidence. NBER Working paper W 7136

Carlaw KI, Lipsey RG (2006) GPT-rdriven. Endogenous growth. Econ J 116(508):155–174

Carlsson B, Henriksson RGH (1991) Development blocks and industrial transformation: the Dahménian approach to economic development. Industrial Institute for Economic and Social Research (Industriens utredningsinstitut): Almqvist & Wiksell International

Chan SL (2001) Empirical tests t o discern linkages between construction and other economic sectors in Singapore. Constr Manag Econ 19:355–363

Dahmén E (1950) Svensk industriell företagarverksamhet. Kausalanalys av den industriella utvecklingen 1919–1939. Del I–II. Industriens utredningsinstitut. Stockholm

Dahmén E (1970) Entrepreneurial activity and the development of Swedish industry, 1919–1939. The American Economic Association. Homewood, IL

Dahmén E (1988) Development blocks in industrial economics. The Scandinavian Economic History Review 36(1):3–14

David PA (1990) The dynamo and the computer: an historical perspective on the modern productivity paradox. Am Econ Rev 80:355–361 (May)

Engle RF, Granger CWJ (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica 5(2):251–276
Goldin C, Katz L (1996) The origins of technology-skill complementarity. NBER Working Paper 5657, Cambridge, MA
Gordon RJ (1999) U.S. Economic growth since 1870: one big wave? Am Econ Rev 89(2):123–128
Granger CWJ (1969) Investigating causal relations by econometric models and cross-spectral. Methods. J Econom Soc 37(3):424–438
Granger CWJ, Newbold P (1974) Spurious regression in econometrics. J Econom 2:111–120
Helpman E (1998) General purpose technologies and economic growth. MIT, Cambridge, MA
Johansen S (1988) Statistical analysis of cointegration vectors. J Econ Dynam Control 12:231–255
Johansen S (1991) Estimation and testing of cointegration vectors in Gaussian Vector Autoregressive Models. Econometrica 59(6):1551–1580
Lundquist KJ, Olander LO, Svensson Henning M (2005) Renewal and Obsolescence: An evolutionary perspective on industry growth and regional development in Sweden 1968–2002. Department of Social and Economic Geography, Lund University, Sweden (Report 165)
Lundquist K-J, Olander L-O, Svensson Henning M (2006) Producer services: Boosters or followers. An evolutionary approach to producer services and technology shifts in time and space. Department of Social and Economic Geography, Lund University, Sweden. (Report 167)
Moser P, Nicholas T (2004) Was Electricity a General Purpose Technology? Evidence from Historical Patent Citations. Am Econ Rev 94(2):388–394
Odedokun MO (1996) Alternative econometric approaches to analysing the role of the financial sector in economic growth: time series evidence from LDCs. J Dev Econ 50(1):119–146
Petsas I (2003) The dynamic effects of general purpose technologies on Schumpeterian growth. J Evol Econ 13:577–605
Schön L (1990) Elektricitetens betydelse för svensk industriell utveckling. Vattenfall
Schön L (1991) Development blocks and transformation pressure in a macroeconomic perspective—a model of long-term cyclical change. Skandinaviska enskilda banken quarterly review 3–4
Schön L (1994) Omvandling och obalans. Mönster i svensk ekonomisk utveckling. Bilaga 4 till Långtidsutredningen. Stockholm
Schön L (2000a) En modern ekonomisk historia. Tillväxt och omvandling under två sekel. SNS förlag. Stockholm
Schön L (2000b) Electricity, technological change and productivity in Swedish industry 1890–1990. Eur Rev Econ Hist 2
Schön L (2006) Swedish industrialization and the heckscher-ohlin theorem. In: Findlay R, Heckscher E et al (eds) International trade and economic history. MIT, Cambridge Mass