LUND UNIVERSITY

Department of Economic History

Josef Taalbi and Jonas Ljungberg

Innovations and Economic Growth in the Swedish Engineering Industry, 1914-2013

Work in progress!! Await forthcoming versions for citation!

Paper for the *Eleventh Conference of the European Historical Economics Society*, Pisa 4-5 September, 2015

1 Introduction

Are innovations developed as response to burgeoning opportunities in growing markets or as responses to waning economic performance? The temporal pattern of innovation has been a matter of controversy since Kuznets (1940) questioned the hypothesis advanced by Schumpeter (1939) that innovations appear in clusters. After a period of quiescence on the matter, a revival of Schumpeter's hypothesis of clusters of innovation came with Mensch (1979), igniting a debate on whether innovations cluster during periods of crisis or growth (Clark et al 1981; Freeman et al 1982; Kleinknecht 1990; Silverberg 2002) and whether innovation finds its driving forces in demand, new opportunities or waning profitability. To date there is no consensus of whether and how patterns of innovation are linked to economic cycles or how economic incentives contribute to technology shifts.

The present paper investigates the patterns of innovation for the Swedish engineering industry during the years 1930-2007[1] using a new database (SWINNO) of innovation output. Based on an analysis of more than 4,000 significant innovations in Swedish manufacturing (and software) in the period 1970-2007, Taalbi (2014) traced the driving forces of innovation in the third industrial revolution. It was shown that economic, social and technological problems, subsumed under the label ‘negative transformation pressure’, together with new technological opportunities or ‘positive transformation pressure’, can be seen as major causes of about two thirds of the significant innovations.[2] It can be assumed that ‘institutionalized search’ of big

[1] The aim is to cover 1914-2013 but data collection is not completed.
[2] The notion of "transformation pressure" stems from the work of Erik Dahmén (1950).

corporations accounts for a substantial share of the remaining third, besides having a role also for innovations that responded to transformation pressure of different kinds.

This paper extends the analysis by focusing on innovation in the engineering industry back into the interwar period. How does innovation during about 80 years relate to business cycles and patterns of economic growth and crisis in the Swedish economy? And which were the driving forces of innovation? What problems and opportunities have been major determinants of innovation activity?

2 Cycles and innovation[3]

The link between innovation and economic activity has primarily been understood as a phenomenon of long duration, in terms of long waves or Kondratiev waves. The question concerns whether innovations are spurred by crisis or boom: do innovations cluster during long wave downswings or during long wave upswing? Like other long-lasting disputes, it all began with a dataset and a bold conjecture. Nicolai Kondratiev observed recurrent movements of approximately 45-60 years of duration, in prices, foreign trade, production and consumption, which he thought to be explained endogenously by the replacement of fixed capital, noting however that such movements applied to technology as well: "during the recession of the long waves, an especially large number of important discoveries and inventions in the technique of production and communication are made, which, however, are usually applied on a large scale only at the beginning of the next long upswing" (Kondratiev, 1935, p. 111). Schumpeter elaborated on a similar view, arguing that technological shifts take place by significant discontinuities, radical innovations that spur further innovation and investment activity: "innovations do not remain isolated events, and are not evenly distributed in time, but [...] on the contrary they tend to cluster, to come about in bunches, simply because first some, and then most, firms follow in the wake of successful innovation" (Schumpeter, 1939, p. 100). This "bandwagon" of innovations brings about a period of prosperity, the expansionary phase of the cycle. Herein lies however, also the seed to the recession phase: as more firms imitate innovations, entrepreneurial profits erode and when technological opportunities are exhausted, investment decreases, prices fall and the rate of interest falls. In Schumpeter’s model, rather than clustering in long wave downswings, innovations are the prime movers of business cycles, clustering in the equilibrium situation that follows upon the long wave down swing. It is however important to stress that Schumpeter recognized that, as the rate at which innovations are diffused may differ, several cycles may coexist. Schumpeter mentioned three: the Kitchin inventory cycle, the Juglar machinery investment cycle of 7-11 years, and the above-mentioned Kondratiev waves. The Kuznets cycle or long swings, of about twenty years, is a fourth possibility.

[3] This section draws on chapter 2 in Taalbi (2014).

The hypothesis of innovation driven economic cycles re-emerged in the wake of the crisis of the 1970s. Gerhard Mensch (1979) suggested a 'depression-trigger' mechanism of basic innovations that explained the transition from depressive to expansive stages of the long wave. He observed that basic innovations were bunched in periods of depression (the 1820s and 1830s, the 1880s and the 1930s), and that during such periods the time-lapse between invention and innovation was shortened. Though obtaining support from Kleinknecht (1981), this was a controversial claim. Clark et al (1981) and Freeman et al (1982) argued that the data used by Mensch stretched the evidence. Instead, they advanced a view closer to Schumpeter's original view, namely that the bunching of innovations first of all "arises from the imitation and diffusion process and from the bunching of technically related families of innovations and inventions" (Clark et al, 1981, p. 321). Second, innovations were suggested to follow profit expectations, thus more likely to take place not during depressions but during the recovery and boom. Mensch had "been looking at the wrong 'swarms'" (Freeman et al, 1982, pp. 66-67).

Regardless of the controversy about where in the cycle innovations cluster, the notion that waves of innovations follow upon major technological breakthroughs has however obtained ample support. This notion is supported by descriptions of technology shift processes as General Purpose Technologies, Technological Revolutions and Development Blocks. Perez (1983) suggested the concept of 'technological styles' (also used and developed by Tylecote, 1992), later rephrased as "techno - economic paradigms", to describe the successive technological revolutions brought about by sets of radical innovations (Freeman and Louça, 2001; Perez, 2002). According to this line of research there has been five Kondratiev waves based on the diffusion of radical innovations (Freeman and Louça, 2001; Perez, 2002). In each wave there has been a set of "key inputs", such as microchips, produced by "motive industries" (Perez, 1983; Freeman and Perez, 1988). Moreover, Freeman and Louça (2001) and Perez (1983, 2002) connect the waves to particular branches of the economy that have implemented the key inputs, so-called "carrier" or "leading" branches.

Broadly similar with the picture of the long wave literature, yet based on the comprehensive historical national accounts, Schön (1994, 1998, 2012) has proposed a generalization of the Swedish pattern of economic and technological development in two phases of roughly 20 years of duration based on two types of investment behavior of firms. Investments towards renewal increase in the phase of transformation, while investments towards efficiency dominate during the rationalization phase. Together these phases form a structural cycle of about four decades. In this view, innovations have evolved in an interplay with economic growth and structural change. The process of transformation takes place in terms of development blocks (Dahmén 1942, 1950), sets of complementary activities that are built up around innovations. Following the structural crises of the late 1840s, 1890s, 1930s and 1970s, major development blocks, have been formed around coal, steel and railways, electrification, the combustion engine and automotive vehicles, and micro-electronics. In this perspective, the underlying inventions may have been developed earlier but the structural crises have broken down obstacles to the implementation, diffusion and further development of such technologies (Schön, 2006, p. 82). The technological and economic development then follows a pattern in which investment is first directed towards overcoming obstacles and enabling the exploitation of new technologies. During the period of transformation domestic markets have become central. Transformation crises, such as the Korea recession 1951/1955 and the crisis of the 1990s, have followed upon such periods of renewed technological development and have according to Schön led to a strengthening of the orientation of growth in existing structures. In the cases where such transformation crises were successful they have meant that economic growth in the new trajectories has been invigorated (Schön 1994, pp. 64-6).When the technology matures a wider diffusion is made possible, reaching final consumers. Culmination crises, typically mild, have occurred at the culmination of transformation. These crises have led to phases of intensified competition and focus towards rationalization, such as in the 1960s when factory automation became intensified. In Table 1, Schön's periodization is given among with core development blocks underlying the expansion from the structural crisis.

Table 1. Development blocks and structural cycles in the Swedish economy (Schön, 1994; 2012)

Development blocks (example)	*Structural crisis*	*Transformation crisis*	*Culmination crisis*
Steam engine, railways	1845/1850	1865/1870	1875/1880
Dynamo, electric motor, electricity	1890/1895	1905/1910	1915/1920
Automotive vehicles	1930/1935	1950/1955	1960/1965
Micro-electronics, biotechnology	1975/1980	1990/1995	2000/2005

The theories of long waves and the historical framework of structural cycles described above have yet to be confronted with systematic long-term data on innovation output. In an international context, despite several studies on long-term data on patents and basic innovations (Solomou, 1986; Kleinknecht, 1987, 1990; Silverberg and Lehnert, 1993; Silverberg, 2002; Kleinknecht and van der Panne, 2006; de Groot and Franses, 2009), there is to date hardly a consensus about the existence of clusters in innovation activity, or if so, when in the long wave cycle such clusters would appear. However, we note that positions are possible in which waves of innovation are not mechanically linked to periods of economic crisis or growth. Rather, it is very likely that, at any datum, innovation activity simultaneously finds driving forces both in positive factors such as new technological opportunities and profit expectations, and negative factors such as economic or technological problems and imbalances, and pressure to transform occasioned by competition and decreasing returns. If there are waves of innovation, they rather result from a process in which innovations are interdependent, spurred by the opportunities, tensions and problems that are created in the process of economic development and technology shifts.

The Swedish data (SWINNO) suggest that since 1970 innovation activity in Sweden has developed in two waves, culminating around 1980 and 2000, respectively (Sjöö, 2014; Taalbi, 2014). A closer look at the innovations indicates, firstly, that both positive and negative transformation pressure interact to produce patterns of innovation over time that appear to be of longer duration than the ordinary business cycle, rather being similar to a Kuznets cycle/long swing (Taalbi, 2014). Secondly, it also indicates that innovation is not exogenously driven but endogenously related to economic activity. In this paper the aim is to extend the investigation of innovation activity backwards in time (and, in next version, also forwards) in order to see if the pattern can be generalized. The first question is then: how do patterns of innovation relate to the chronology of industrial development and transformation and economic cycles? The second question is: over time, what factors, positive or negative, have prompted the development of innovation?

3 Methods and data

Usually R&D and patents are taken as proxies for technological progress and innovation. These indicators are, however, not necessarily telling about the actual output of innovation. R&D is rather an input to innovation and only with an assumption of a linear relation over time and across countries can it be used as an indicator of innovation. Patents are not necessarily realized as innovations, that is, brought to the market. Moreover, patent regimes vary over time and across industries and countries why comparative analyses must be careful (see, e.g. Granstrand 2005). An alternative is to collect observations of actual innovations reported by trade and technical journals according to the so called Literature Based Innovation Output (LBIO) method.

This method is employed for the construction of the SWINNO database which contains not only observations of when innovations were commercialized but also a large set of variables characterizing each innovation (Sjöö, Taalbi, Kander and Ljungberg 2014; Sjöö 2014; Taalbi 2014). The LBIO method has been applied in different ways (see Kleinknecht and Bains 1993) but for the SWINNO database it is important that observations are only taken from edited articles. The argument is that the collected innovations should be significant and not just randomly skimmed. The edited articles are usually based on a selection made by journalists with some expertise in the field. In other words advertisements and notification lists, based on press releases of firms, should be ignored.

The SWINNO database for the period 1970-2007 was based on 15 trade journals covering the Swedish manufacturing industry. More than 4,000 innovations in manufacturing and some IT-related services, commercialized by Swedish firms, are listed and described with a large number of characteristics. To study innovation patterns over a longer period of time, the data series of the present paper is based on two of these journals, namely *Teknisk tidskrift* and *Verkstäderna*, the first more general and the latter particularly for the engineering industry. Actually, these two journals reported about 40% of the total number of innovations during the period 1970-2007. For the comparability over time, the quantitative exploration in this paper rely on only these two journals for the whole period, while the more qualitative discussion of cases could also refer to other journals. *Teknisk tidskrift*, started in 1871, was published by the Swedish Association of Technologists (Svenska Teknologföreningen), and continued under the name *Ny Teknik* from 1967, published by the Swedish Association of Graduate Engineers (Sveriges ingenjörer). *Tidningen Verkstäderna* was founded in 1905 as the organ of the engineering industry's employer's association (Sveriges Verkstadsförening).

For the period since 1970 the editorial policies of the journals have been broadly unchanged (Sjöö et al 2014). However, further back in time, especially before the 1950s, *Teknisk Tidskrift* had less character of a newspaper and the longer articles, written by specialists, provided more an overview of the state of technology in a certain line of production with innovations highlighted more in passing. Innovations launched “on the market these days” were also reported in shorter items. More frequent in such shorter items were, however, innovations abroad, demonstrating a commitment to report technical novelties. We therefore assume that the journals in a broadly consistent way over time has reflected innovative activity but a more definitive assessment has to await the finishing of data collection.

4 Innovation and growth of the Swedish economy

The history of the Swedish engineering industry , written from the perspective of historical national accounts and price data, tells a story of the rise and decline of manufacturing, the alternating episodes of rapid transformation driven by entrant firms and renewal, and episodes of rationalization, consolidation. From the mid-nineteenth to the mid-twentieth century Sweden made the journey from a poor country, measured with GDP per capita and in comparison with other countries in Europe, to one of the richest. Actually, in 1950 it was on level with Denmark and Britain and only behind Switzerland. This catch-up has usually been ascribed to successful manufacturing industries, capable of not only adopting frontier technology but also itself advancing to a frontier position in several fields. It has recently been pointed out that before WWI, productivity of Swedish industry was not remarkable, and still lagging Denmark, and that the nineteenth century catch-up was much due to structural change (Ljungberg and Schön 2013). That is, progress in agriculture made possible a large scale release of labour to industry and services with higher productivity. However, while structural change continued to be important (Schön 1998), from around the turn of the century 1900, innovation and technical change within manufacturing increasingly became a major factor in economic growth. Table 2 is a hint to this interpretation.

Table 2. Growth and its sectorial contributions, Sweden 1870-2010

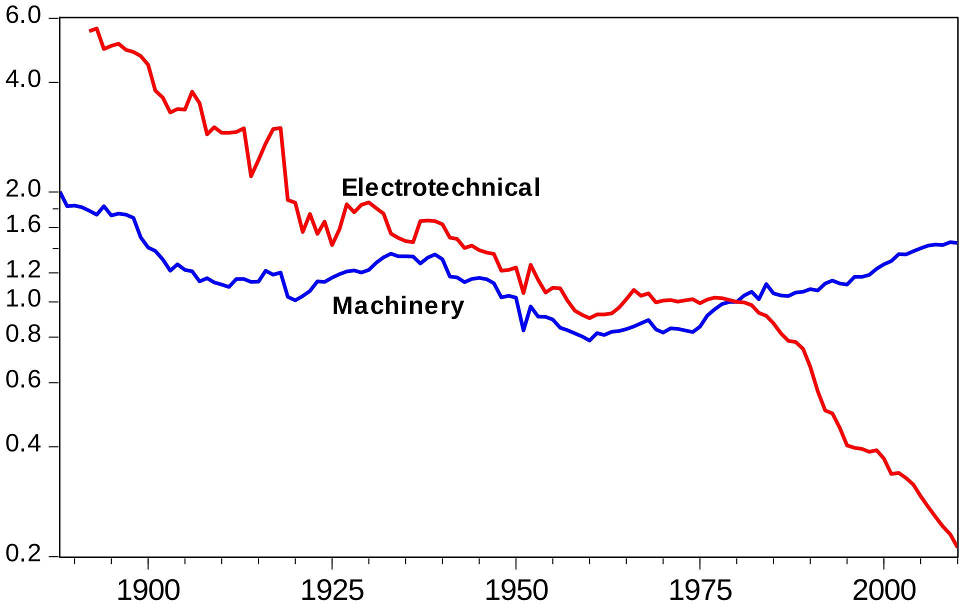
	Agriculture	Manufact.	Construct.	Transp. Communic.	Private services	Public services	GDP*
Panel A: annual rate of change, per cent							
1870-1910	0.94	4.70	1.64	3.46	2.61	1.63	2.32
1910-30	0.41	2.80	2.40	3.01	2.77	1.77	2.18
1930-50	-1.31	4.57	2.81	4.68	1.50	5.42	3.00
1950-70	-0.37	4.83	4.09	3.62	3.93	3.31	4.04
1970-90	0.21	1.50	0.07	3.29	2.63	2.18	1.96
1990-2010	0.08	3.48	-0.84	1.56	3.09	-1.07	2.69
Panel B: contribution to growth of GDP*, per cent							
1870-1910	20.5	38.0	4.3	8.7	25.1	3.4	100
1910-30	5.3	46.3	8.0	11.9	25.8	2.7	100
1930-50	-1.3	56.6	5.9	15.9	16.9	6.0	100
1950-70	-0.3	56.7	5.8	11.8	21.1	4.8	100
1970-90	1.1	35.8	0.9	27.8	29.1	5.3	100
1990-2010	-0.6	60.7	-1.8	14.4	29.0	-1.8	100

Note: * GDP is exclusive of (the imputed) services of dwellings; rates of change are approximations since they are (still) in logs. Calculations on Schön and Krantz (2012).

Panel A gives the growth rates which are dependent on both the within productivity change and the sectorial reallocation of resources. Until the period 1950-70, employment in manufacturing increased but then the so called deindustrialization began. This is a well known "truth" and applies to all advanced countries in the last half-century. However, the figures for Sweden show that the contribution of manufacturing to total growth nevertheless, in the last period, increased to a somewhat higher level than in the golden age. It could be objected that aggregate growth rates were higher in the periods 1930-1970 but they were not conspicuously so. The obvious inference is that output of manufacturing has continued to grow, even in the advanced countries, and since this is despite less input of labour it could be due to more capital but also to technical change leading to higher labour productivity.

Successful manufacturing firms, emerging during the second industrial revolution before WWI, and led by entrepreneurial 'geniuses' have been emphasized in the economic history literature on Sweden (e g, Gårdlund 1942; Glete 1987; Schön 2012). This view is also broadly corroborated by the development of relative prices in manufacturing. There are two basic factors making innovative products fall relatively, if not absolutely, in price. First, emerging new products are commonly burdened with development costs and small numbers also imply high costs. With larger scale of production, costs are reduced and prices follow unless the producer has a technological monopoly or faces extraordinary demand. Second, initially the innovating firm can draw on being the lone producer but with imitators, or incremental improvements by followers, competition reduces prices. A look at the long-term development of relative prices reveals a periodical pattern indicating when innovations could be assumed to be more frequent. Figure 1 shows relative prices of the machinery industry and the electrotechnical industry, two branches of manufacturing for which technical change has been particularly important.

Figure 1. Prices of electrotechnical equipment and machinery relative to prices of all manufactures, 1888-2010

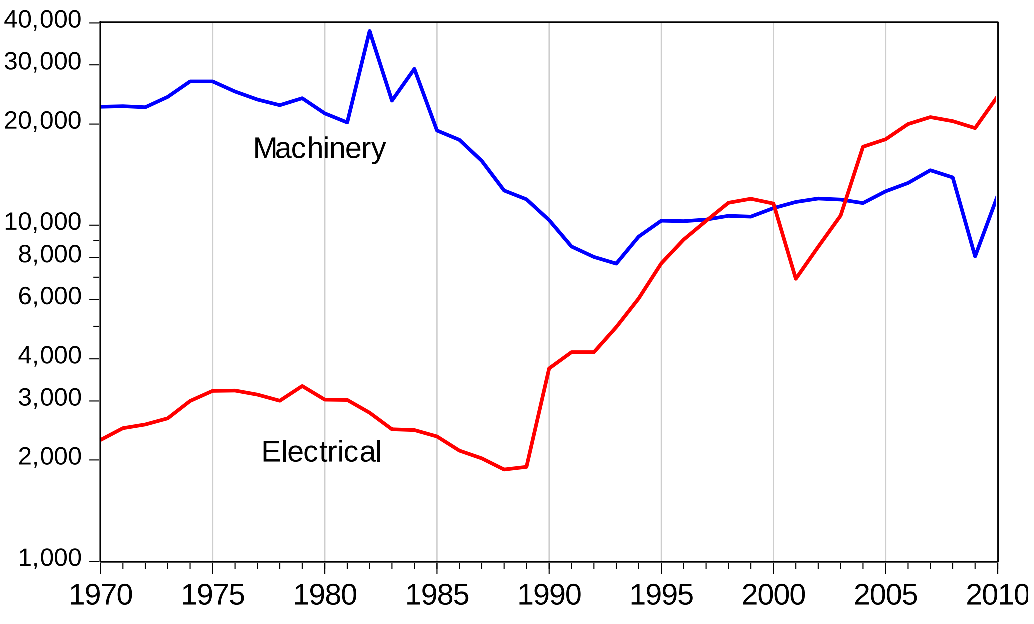


Note: Prices of all manufactures are represented by implicit deflator for manufacturing (Schön and Krantz 2014); prices for the branches are from Ljungberg (1990, 1999) and implicit deflators in national accounts (SCB).

Both industries, and particularly electrotechnical equipment, had distinctly falling relative prices in the two decades down to WWI. In this period electrical generators and motors, cables and lamps were rather new products and improvements by different producers created a competitive market and pressed prices. New or improved agricultural machinery, including separators, and combustion engines also had falling prices. Maybe monetary factors with a general deflation in the 1920s contributed to the change of the trend, but such an impact cannot be traced from the 1930s onward, with the variations of deflation and inflation. It is reasonable to see the pattern of relative prices of machinery as a support for the structural cycles in the Swedish economy, as outlined by Schön (e.g. 2012). In line with the structural cycles, falling relative prices signify periods of transformation, while moderately falling or even rising relative prices signify periods of rationalization. Although rationalization implies efficiency seeking it is a struggle against rising costs and there are less of shifts in technology and markets that allow for a reduction of prices. This is usually also reflected in the growth of production volumes, which are less differentiated in periods of rationalization implying that emerging scale economies have less impact on relative prices.

In general and over the long-term, relative prices of electrotechnical equipment show the most pervasive decline. From the 1980s, this is further emphasized by the third industrial revolution, in the Swedish case in particular driven by telecommunications. Machinery, on the other hand, charged higher prices in contradiction to what the structural cycles, at first sight, would predict. However, the industrial composition of the structural cycles are changing and it seems that machinery in Sweden became a mature industry. In this perspective the development is as expected and was reflected in the relation relative prices/relative volumes. Hence, over the long century shown in figure 1, typically change in relative prices have been negatively correlated with the change in output volumes. Falling relative prices have been connected with rising (relative) volumes, and vice versa (Ljungberg 1990). Figure 2 illustrates this phenomenon with the two actual industries. Since 1970 output of machinery has even

Figure 2. Output volumes of machinery and electrotechnical industries, 1970-2010 (million SEK in prices of 1991)



Note: No official comprehensive series of value added over this period exist, which, e.g., make KLEMS take resort to a +1.3% link 1992-1993 in current prices for both these industries, despite machinery fell about 4 and electricals increased about 15%. Here value added in 1991 has been extrapolated forwards and backwards with shorter series and some of which are output gross values (from various official statistics, some not public).

declined in absolute terms while electrical equipment, driven by telecommunication equipment, has grown. Even apart from the effects of the structural crisis with the decline in the 1980s, machinery grew slowly after 1990. Over the period 1990-2010, manufacturing as a whole grew with 3.5% annually (see table 1) but electrotechnicals grew with an annual rate of 8.9% and machinery with 1.9%, the latter thus displayed a relative decline. It could however be conjectured that a more disaggregate analysis would show a complex pattern of growth, with a strong decline of machinery standard products and a growth some specialized and advanced machinery.[4]

In sum, the record of growth and transformation in the Swedish engineering industry gives us reason to inquire about two things. First, did innovation activity decrease since the 1970s or has innovation activity recovered as ? Second, evidence from relative prices and Schön's work on historical national accounts would suggest that innovation activity should have followed upon structural crises. How can innovation activity be linked to Schön's periodization (see Table 1) in general, or episodes of declining relative prices (Figure 1)?

5 Problems and opportunities in innovation activity

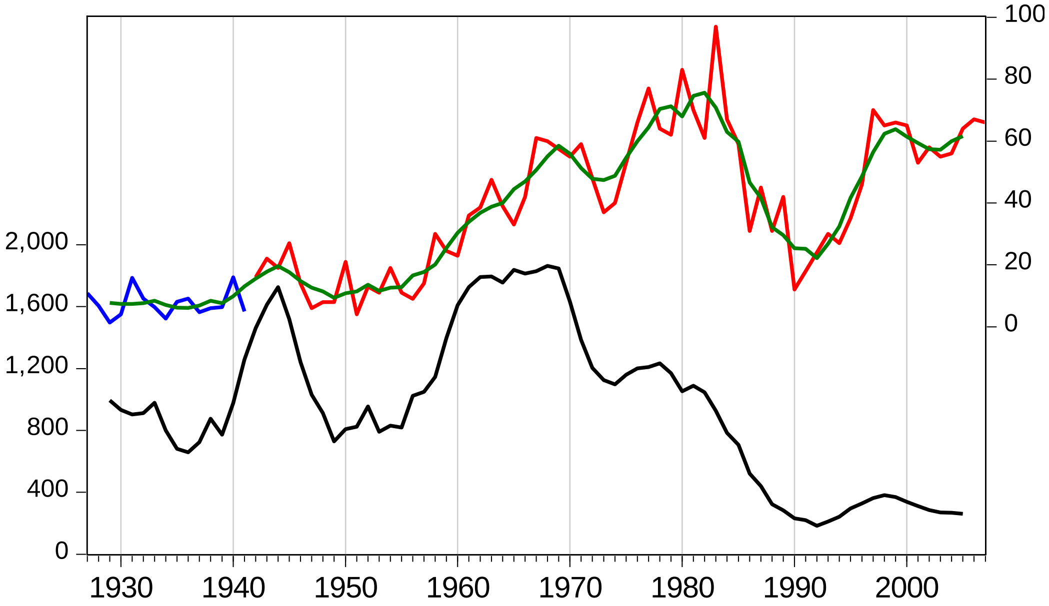
The long-term variations in relative prices and growth of different products could, as in the model with the structural cycle and phases of transformation and rationalization, entail different conditions in terms of positive and negative transformation pressure. Transformation pressure, or incitement for technical and institutional change, is according to the structural cycle not constant over time but fluctuating. Being of both positive and negative kind, transformation pressure does not have a linear relation to the ordinary business cycle. Hence, it is in the origins of the individual innovations that we can trace the contribution of positive opportunities and negative problems. This section begins with an overview and discussion of the number of significant innovations in the Swedish engineering industry over the years 1927-2007, and then zooms in on individual innovations and the historical incentives to innovation that can be observed in the database. Engineering industry includes for example automotive industry and shipbuilding, besides the two industries discussed in the previous section. Output of the whole engineering industry was, over the actual period, 'a good double' of the output of machinery and electrical equipment. The look at individual innovations is qualitative and also follows a more conventional historical periodization than the structural cycle suggests. In the conclusion, we will see if the two perspectives can be combined and complement each other.

What is striking, at a first look in figure 3, is the rising trend in the number of significant innovations over the postwar years, which is broken by a sharp fall after

[444] This must not necessarily be reflected in prices for the specialized products, if producers have a kind of technological monopoly. Historical cases in Sweden are ball bearings and, from about 1930, stainless steel, for which prices were sustained by strong export demand (Ljungberg 1990). A more recent case is specialized lifting machinery (Roubert 2009).

1983 and until 1990. The recovery in the 1990's did not fully bring the number of innovations back to the level of the mid-1980s. Before 1950, the significant innovations seem to have stayed on a low level, however, before 1940 the comparison is not valid because we have only skimmed one of the two journals. The investigation of the long-term pattern, if it has any connection with the structural cycle therefore has to wait on the completion of the data collection. What seems clear, though, is the

Figure 3. Significant innovations in the Swedish engineering industry, 1927-2007: absolute number and relative to human capital



Note: Annual figures and five-year centered moving averages. Before 1940 *Verkstäderna* (the second journal) has not been searched why the number before this year is expected to be higher in a later version of this paper. Human capital is here limited to the average years of higher technical education in the population aged 15-65 (Ljungberg and Nilsson 2009)

connection of the surge in the 1970s-80s with the structural crisis at that time. Both negative and positive transformation pressure played a significant role in innovation activity at this time. Problem solving innovations, or negative transformation pressure, accounted for a significant part of the surge in these years. The oil crisis spurred a large number of innovations aimed to replace or economize on oil based fuels and energy sources, in terms of renewable energy technologies, emission control technologies and electric cars (see below). Strikes and organizational problems led to innovations across the engineering industries, dealing with the problems of industrial noise and vibrations, asbestos and toxic welding fumes. The crisis also played a role in redirecting innovation activity towards the opportunities provided by the breakthrough of microelectronics. Crisis struck firms and industries were quite often able to diversify their production activities towards growing segments (Taalbi, 2014).

The surge in the 1990s, on the other hand, was sustained by positive transformation pressure and innovations as response to opportunities provided by IT (Taalbi 2014; see also Sjöö 2014).

As regards the long run trend in innovations, one should not however be misled by the low numbers before 1950. Output of engineering has grown immensely since the mid-nineteenth century and human capital has accumulated as well. A measure of the latter is the average years of schooling in the population of working age, and if we think of innovations in engineering industry as particularly dependent on graduate engineers, the lower curve in figure 3 suggests a different interpretation. Seen in this perspective, significant innovations were as frequent relative to the in mid-1940s as in the 1960s. However, before 1940 the curve may change nature when the collection of data has been completed. The decline, to a persistently (?) lower level with the third industrial revolution is also a challenge . Will it stay at such a low level for an enduring period and is this actually a reflection of the requirements of the new technology? Its maintenance and running is built on a much increased stock of knowledge, which on the other hand does not generate as many entirely new innovations.

Regardless of how one may interpret the long-run trend, it is clear that there are significant variations in the count of innovations, in particular after the 1940s (the period before 1940, being subject to data collection). These variations can be tentatively linked to underlying pressures and opportunities in the process of technology shifts, by describing some of the sources to innovation during the period studied.

5.1 Great Depression and the 1930s

The 1930s has been described as a period of renewal and transformation on the basis of innovations made in the 1920s and a continued development on the basis of the major innovations of the second industrial revolution (Schön, 2012). Pointing to a structural boundary in the late 1920s, Erik Dahmén (1950) claimed that, in comparison with the 1920s "new goods were rare during the 1930s". Dahmén based this proposition on an examination of innovations reported in *Teknisk tidskrift* and *Verkstäderna*. A statistical assessment has to await the completion of our data collection, in the same journals. From an examination of only *Teknisk tidskrift* it seems that product innovations were few during the 1930s, as shown in figure 3. However, this should not overshadow the fact that major breakthroughs were made in the 1930s in several areas, some of which made possible a deeper exploitation of the basic innovations surrounding electric power, the combustion engine and motor powered vehicles. Innovations launched in the 1930s with a particular importance for the Swedish industry were e.g., Fredrik Ljungström's rotating air pre-heater for coal and oil heated electric power plants (commercialized in 1930), metal compound Kanthal (launched 1931), developed from an idea by Hans von Kantzow in 1916, and the Kamewa marine propeller (commercialized in 1937) developed by Karlstads Mekaniska Verkstad.

Notable examples of significant innovations are in particular found in the development block surrounding electrification and the integration of the national electricity grid. Related to this was the electrification of the main trunk railways. The problems faced at this time stemmed from the long-distance transmission of electricity. In the 1890s, it is well known that a break-through had occurred in the medium-distance transmission with the innovation of the three-phase electric power system. In Sweden this was pioneered by Jonas Wenström and formed the basis for the multination corporation ASEA (Schön, 1990). In the 1930s, the development of a nationwide electricity grid required continued problem solving along these lines, something which could be solved with High Voltage Direct Current (HVDC) transmission systems. This method was developed by Uno Lamm in the 1930s, involving several components that solved problems along the way of developing systems for HVDC. An important innovation was e.g. the ion valve, designed to solve the problem with arcs, which tend to occur more often in high voltage electric current (*Teknisk tidskrift* 1946, pp. 969-975; 1947, pp. 307-314; 1952, pp. 620-622; 1954, pp. 301-306). On the basis of the progress in the 1930s ASEA developed the HVDC technology further in the post-war era, bringing it into commercial production in March 1954 as the transmission between Sweden's mainland and the Gotland in the Baltic Sea began (Fridlund, 1997, pp. 30-31).

5.2 WWII (1939-1945)
Other breakthroughs were made in the early 1940s as regards the establishment or strengthening of a domestic industry. Import restrictions during the war prompted domestic production of products, not previously produced in Sweden. This is well known as regards consumption goods but production was also initiated of specialized machine tools and motor vehicles. There are various examples of Swedish firms that due to high import prices and import restrictions, found no better alternative than to start their own production of machine tools to cover their needs. For instance, upon finding that no suitable keyway machine could be acquired, a foundry, Brevens Bruk, decided to construct one on their own, the end-result being so good that they started marketing of the machine tool (*Verkstäderna* 1942, p. 125). Another firm, Stal, together with V. Löwener, developed a universal grinding machine as a response to the lack of similar machines. However, the war gave a particularly strong push towards the establishment of a domestic industry as regards motor vehicles, or a reinforcement of the domestic industry when already present. Before the war Sweden had little domestic capacity to produce military airplanes. While imports of military airplanes were made in the beginning of the war, the Swedish government was eventually forced to call for domestic production. This was a significant boost to the formation of the Swedish airplane industry. SAAB, formed in 1937, having acquired its main competitor ASJA in 1939, started licensed production of airplanes and gained experience to develop its own airplanes, in part continuing experimental development projects of ASJA. Among the independently developed airplanes were "B 18" (launched 1943), "Saab 21 A" (launched 1945) and "SAAB 91 Safir" (launched

after the war). Likewise, AB Flygindustri had licensed production of airplanes, but could develop its first own airplane "Fi 1" during the war (Teknisk tidskrift 1944, pp. 961-964). Swedish motorcycles had been produced since the early 1900s, notably by Husqvarna (since 1903) and Monark Cykelfabriken (since the 1920s). During WWII the Swedish motorcycle industry faced problems due to the restricted imports, but gained from military procurement. In 1942, the Swedish military commissioned a motor cycle, which Albin Motor and Monark Cykelfabriken started to develop ("Monark-Albin m/42") (*Teknisk tidskrift* 1943 "Automobil- och motorteknik", pp. 25-30).

Furthermore, the Second World War brought with it import restrictions, particularly felt in the shortage of gasoline and fossil fuels, which are very rare in the Swedish soil. These difficulties prompted search for alternative fuels and vehicles or generators making possible the use of other power sources, mainly based on firewood. Generator gas emerged as the main but not the only alternative fuel. After Sweden was cut-off from its import of petrol from North and South America in Spring 1940, the response was swift. Several innovations and new constructions were developed aimed to enable the use of generator gas for vehicles. A government owned company (Svenska Gengasaktiebolaget) was started in 1940 to promote the use of generator gas, developing among other innovations a two-cycle engine for generator gas. Already in autumn 1940 Bolinders Fabriks AB had responded to the import restrictions on petrol fuels, developing a wood fuelled gas generator (*Verkstäderna* 1941, pp. 67-68; *Teknisk tidskrift* 1943 M, pp. 37-41). Once the war was over, generator gas however became a historical oddity, as petrol fuels came to dominate both for transport and heating. The shortage of oils also created a problem for the machinery industry as oil was difficult to replace as machine tool lubricants, something which prompted air plane manufacturer AB Thulinverken to develop a replacement "Teveol" based on resin, which unlike other replacements did not dry out. Attempts were also made with electric cars, continuing a longer line of technological development in Swedish corporate group ASEA. SEA (Svenska elektrobilsaktiebolaget) was started as a subsidiary to ASEA to develop electric cars. The electric truck EBV 12-2 was used during the war, but could not compete with its gasoline driven relatives once the war was over (Teknisk tidskrift 1940, pp. 389-393; 1966, pp. 439-446).

5.3 The post-war era 1946-1969

The technological development during the post-war period was marked by the coming to maturity of the development blocks surrounding automotive vehicles and electrification, with the large scale introduction of electric apparatuses into households. New technological opportunities in these fields brought about, especially during the 1960s, strong incentives to innovation. Meanwhile, the development of computers and a burgeoning automation attracted increased interest, culminating in the 1960s before the advent of microelectronic chips led to a full-blown revolution.

Before WWII, producers such as Volvo and Scania-Vabis were focused on large trucks and buses. It was during and shortly after the war that Volvo and SAAB developed the first smaller passenger cars, sold in large numbers to the public. Volvo's manufacturing of cars had begun with the launch in 1927 of "Volvo ÖV 4", but it's first broadly successful car, "PV 444", was constructed during the war and sold in large numbers from 1947 (*Teknisk tidskrift* 1944, pp. 1085-1091). SAAB's development of automotive vehicles and motors drew from the experience made from airplane production during the war. The first SAAB car "SAAB 92" was launched in 1949 with several novel constructions (*Teknisk tidskrift* 1947, pp. 539-540; 1949, pp. 197-202; *Verkstäderna* 1956, pp. 48-53). In the postwar era, the Swedish passenger car industry grew quickly. New cars made by SAAB and Volvo (e.g. "Saab 93" and "Amazon", respectively, both launched in 1956) contained innovations made not only by the car producers. With a network of suppliers of engines and transmissions and other car parts, the Swedish automotive industry formed a development block (Elsässer 1995, Schön, 2012) in which innovations, such as the three-point security belt (invented by Nils Bohlin in 1958), were successively integrated into new car models. Notably, Köping Mechanical Workshop (Köpings Mekaniska Verkstads AB) was a producer of transmissions that collaborated closely on Volvo's car projects (being in 1942 also bought by Volvo). Among its innovations, the firm developed a three speed transmission with synchronized gears (1946) and the first wholly synchronized four speed transmission (1958), used in all Volvo's passenger cars and trucks (*Verkstäderna* 1963:1, pp. 19-22).

The post-war era also saw vast improvement of transportation networks. Motorized vehicles and the expansion of roads and highways enabled not only more efficient transportation but also rational lifting and handling of goods. Judging from the database, the Swedish industries of trucks and lifting machinery were particularly innovative during the 1950s and 1960s, when diesel engines could be integrated into new trucks and mobile cranes to attain increased capacity, e.g. Tornborg & Lundberg AB's mobile crane, the world's largest at the time, launched in 1955 (*Teknisk tidskrift* 1955, pp. 163-164).

A set of innovations were centered on problems emerging in the introduction of freezing and cooling technologies that required solutions in distribution, packaging as well as transportation. In particular innovations were aimed to eliminate obstacles to the wider introduction of frozen food technology. The first quick-frozen food was sold to the public in the US already in 1930 (Bäckström et al, 1992, p. 165). In the 1950s frozen food was introduced on the Swedish market. The introduction of frozen food required packaging innovations, plastic innovations, freezing methods and equipment (Bäckström et al, 1992; Beckeman and Olsson, 2005). Åkerlund & Rausing and Esselte Pac were developing frozen food packaging innovations in the beginning of the 1950s, solving leakage problems in the distribution of frozen food (Beckeman and Olsson, 2005, p. 9). Moreover, transport equipment were developed to overcome problems with the transportation of foodstuff, such as the "Thermo train", a train with built-in freezing equipment (*Teknisk tidskrift* 1952, p. 820). A major innovation was made by Frigoscandia: "Flo-Freeze", an equipment using a uidization process for quick freezing of peas and other vegetables of uniform size that had previously been difficult to freeze (*Teknisk tidskrift* 1965, p. 6; pp. 1096-1097; see also Wallmark and McQueen 1988, 1991). However, there were technical obstacles to the introduction of quick-freezing as regarded liquids or products such as whipped cream, spinache and some sorts of meat. Pellofreeze was developed to bridge this gap (*Livsmedelsteknik* 1971:1, p. 36; 1977:1, pp. 24-25; *Ny Teknik* 1971:2, p. 5). Other problems in the use of quick-freezing technologies pertained to fact that bacteria and other microorganisms thrive in foods being thawed. This problem was the source of another innovation launched by Frigoscandia in 1976 (*Ny Teknik* 1976:35, p. 14).

Needless to say, one of the most important tendencies during this period were also the increased interest in computers and electronics, establishing an industrial basis for the later development blocks surrounding factory automation and computerization. From the beginning of the 1950s both firms and research institutes were active in the development of automated calculators and computers. The first Swedish computers were developed by state owned Matematiknämnden in the early 1950s: BARK (Binär Automatisk Relä Kalkylator), and BESK (Binär Elektronisk SekvensKalkylator) (*Teknisk tidskrift* 1950, pp. 193-194; 1953, p. 1007; 1955, pp. 273-281; 281-292). While the research activities of Matematiknämnden were discontinued, the experience from the construction of BARK and BESK lay the basis of the industrial development of computers. In particular, the firms Facit (Åtvidaberg Industrier AB), SAAB, L M Ericsson, Standard Radio & Telefon AB and AB Addo came to the fore during the 1950s and 1960s. Facit and SAAB developed their own versions of BESK under the names "Facit EDB" and "SARA" respectively. Innovations also involved the development of complementary innovations. In the early development of computers, an imbalance emerged as data processing power increased and increased requirements for memory space. Both SAAB and AB Åtvidaberg Industrier developed magnetic tape memory to overcome this bottleneck and enabled information storage without requiring large physical space (*Teknisk tidskrift* 1958, pp. 1175-1179; *Verkstäderna* 1958:10, p. 356).

From this experience, especially SAAB was able to continue development of process control equipment, the innovations MTC-6 (launched 1965) and MTC-7 (launched 1967) being especially notable. In the late 1960s several firms in the machine-tool industry had integrated numeric control equipment into new machine tool innovations.

5.4 Structural crisis and transformation in 1970s and 1980s

The crisis of the 1970s brought with it a strong set of incentives towards innovation, both from the opportunities created by the micro-electronics revolution, and from organizational and environmental problems that were made brought to the surface in the structural crisis of the 1970s.

Strong incentives towards product innovation emerged from the opportunities of the new microelectronics based technologies. The diffusion of microprocessor based technology enabled new generations of machinery and instruments for control and measurement with vastly improved performance. At the core of this development lay control systems and computer equipment. Numeric Control (NC) systems had already been introduced into machinery during the course of the 1960s, but predominantly among large firms. Asea was one of the pioneers of the development of commercially available Computer Numeric Control systems (CNC) with its introduction of Nucon 1972 and Nucon 400 in 1977 (Ny Teknik 1972:3, p. 4; Verkstäderna 1977:4, p. 90). Swedish firms also lay at the forefront of the development of robots. ASEA Robotics (ABB Robotics after 1988) was a market leader in this field, launching several notable robot innovations during the period studied. ASEA's IRB 6 launched in 1973, was the first wholly electrical micro-processor controlled robot commercially available.[5] During this period a wave of entrant firms emerged aiming to exploit the new opportunities (for description and examples, see Taalbi, 2014, Chapter 7). Other firms, facing negative performance, were able to diversify towards growing markets in electronics. Sweden's first personal computer called ABC 80 was launched on the Swedish market in 1978 and had been developed by the three Swedish companies Luxor Industri AB, Scandic Metric AB and Dataindustrier AB to meet the difficulties arising from a saturated market in home electronics (TV and audio systems) (Verkstäderna 1978:12, p. 67; 1981:5, p. 40; Ny Teknik 1981:12, pp. 8-9).
.
At the same time environmental problems came to the acute attention of Swedish industry. New environmental legislation, energy policy, and the energy and oil crisis of the 1970s intensified the search for new energy saving production processes and products, as well as alternative fuels and attempts to reduce oil dependency. The introduction of two-way catalysts and emission control technologies contained a broad set of innovations. The introduction of exhaust requirements and legislation in the US had an impact on the introduction of emission control technologies, also in Sweden(Elsässer 1995; Bauner 20007). Saab-Scania and Volvo were two early Swedish contributors. They separately developed three-way catalytic converters (TWC), introduced in new car models for the US market in 1976 (Elsässer 1995; Bauner 2007, pp. 245-55; Verkstäderna 1988:12, pp. 93-94). The energy crisis also spurred a large number of innovations that aimed to reduce the oil dependency or economize on energy costs, such as ventilation apparatus, heating radiators, heating pumps, or ship and automotive engines.
Another set of problems that surfaced during 1970s were related to the working environment in the old industries. This was the case in the forestry, mining and engineering industries in particular. These problems concerned occupational safety, the use of toxic substances (such as organic solvents, asbestos and welding gas) or the

[5] ASEA also began research and development in 1977 of a new robot system based on computer based image processing technology. The result, "ASEA Robot Vision", was commercialized in 1983 (Ny Teknik 1983:37, p. 3; Verkstäderna 1983:13, pp. 44-46).

in-house factory or firm working environment. In both the forestry and mining industries, labour strikes and organizational conflicts may have contributed to increased efforts to deal with these problems. The mining industry struggled with dusting and occupational injuries. The engineering and construction industries had problems with occupational noise and injuries from vibrations in drilling operations. Other work environment problems were related to toxic welding gases and the use of organic solvents and harmful materials such as asbestos.

After SEA had cancelled its production of electric cars in the late 1940s, interest in electric cars did not re-emerge until the late 1960s as a result of the increasing awareness of environmental issues. Noting the development in the US and Japan, in the late 1960s, experimental electric trucks were ordered by Vattenfall (from the US) and Stockholms elverk (from ASEA). Around this time the Postal Service already 1968 used the electric car "Tjorven", produced by Kalmar Verkstad AB (*Verkstäderna* 1968:9, p. 391; *Ny Teknik* 1968:25, pp. 12-13). In the end of the 1970s, Saab-Scania, AGA Innovation AB and the Postal Service developed an electric car with improved battery capacity and driving range (*Verkstäderna* 1977:4, p. 34; 1977:12, p. 39). There was all along an understanding of the critical problem of the battery, why new electric cars and trucks have been developed alongside the research on lighter batteries with increased capacity. Several development projects of new batteries and electric cars were also carried out in the late 1980s and the beginning of the 1990s, all of which were targeting the core techno-economic obstacle of limited life lengths and limited driving range. ABB's sodium-sulphur battery was given much attention as it was thought that it could mean a breakthrough for the electric car. It had an energy-density four times higher than the best lead batteries and enabled increased driving range (*Ny Teknik* 1988:32, p. 5; *Verkstäderna* 1990:10, pp. 75-76; 1992:6-7, pp. 56-58; *Teknik i Transpor*t 1990:7, p. 36; 1990:7, p. 41). Shortly afterwards Catella Generics launched a charging station system in 1992 providing another solution for the limited driving range (*Ny Teknik* 1993:22, p. 5).

5.5 The 1990s: Telecom boom and bust

Innovation activity during the period 1990-2007 can be described as primarily driven by a positive transformation pressure and the opportunities stemming from computerization and the expansion of telecommunications and Internet. Breakthroughs had been made in the 1980s. Mobile telephone networks were pioneered in Sweden with NMT (Nordic Mobile Telephone system), invented by Östen Mäkitalo and launched in 1981. Early innovations were launched in the 1980s, but it was not until the abolishment of Televerket's monopoly with Telecommunications Act of 1993 that the expansion took off. Similarly, the first Swedish network was connected to the Internet in 1984. Internet did not however become publicly available in Sweden until 1994, when Algonet connected Internet with the Swedish telephone network. These both events signaled the burgeoning opportunities ahead, and a wave of new firms acting on the new opportunities in the fields of mobile telephone equipment and networks. New firms were often developing innovations that aimed to solve critical problems in the deployment of Internet and Telecommunication networks. Transmission systems, network switches and electronic components for data and telecommunications were often responding to obstacles to the introduction of e.g. broadband access technologies such as DSL, transmission standards such as ATM or Voice-over-IP. Ericsson naturally accounted for a large part of these innovations. Ericsson for instance developed the first wap phone (2000), the first Bluetooth product and the first mobile telephone supporting both Bluetooth and MMS (Multimedia Messaging Service).

5.6. Summary

The qualitative evidence discussed above can be summarized in the observation of sets of innovations that have been centered on industry specific opportunities and problems. The main traits in Swedish innovation activity are tentatively summarized in Table 3. We have observed two episodes in which innovation activity has responded to economy wide problems and obstacles to the introduction of new technologies. Both the time around the Second World War and the period after the structural crisis of the 1970s meant an establishment and consolidation of domestic industries and the appearance of problem-solving innovations that laid the basis of further advancement in new development blocks. This may be said to be true of the Swedish airplane and automotive industry for which WWII was a formative period.

Table 3. Summary of Swedish innovation activity in key engineering industries on the basis of innovation data, 1930-2007 (very preliminary)

Industry	1930-1949	1950-1969	1970-1989	1990-2007
Tele-communication		Jacobaeus' crossbar selector (1950), First wholly electronic and digital automatic switches, e.g ”AKE” system.	“AXE” (1973) Nordic Mobile Telephone Network (1981)	Telecom deregulation. Expansion based on broadband and data communication. “Skype” (2003)
Automotive vehicles	Establishment of domestic industry. ”SAAB 92” (1949), ”PV 444” (1947)	Exuberant transformation. Three point security belt (1959)	Environmental challenges. Introduction of catalytic converters.	Emission control-technologies, “Haldex break” (1998), WHIPS Whiplash protection system (1999), Airbag (1998)

Computers and factory automation		Initial computer research (BARK project), burgeoning automation (numeric control)	Computerized numeric control, "IRB 6" (1973) First personal computer "ABC 80/800" (1978)	Personal computers. Software based automation technologies.
Energy, electricity and electrical apparatus	Overcoming of obstacles to HVDC. Energy crisis during WWII. Experimentation with generator gas and electric cars.	Infrastructural projects (e.g. Gotland cable, 1954). Nuclear power plants.	Innovation activity solving problems in e.g. district heating. Experimentatio n with renewable energy technologies.	HVDC Light (1997). Powerformer (1998). Resurgence of innovation activity in solar and wind power.

Sources: Schön (1990), Carlsson (1995), Elsässer (1995), Taalbi (2014)

The breakthroughs made in electrification during the 1930s were critical to the development of HVDC during the post-war era. Similarly, after initial steps taken in the 1950s, a consolidation of a domestic Swedish development block around factory automation occurred in the 1960s and 1970s laying a basis for the capability to adopt and develop ICT. The postwar era is also similar in content to the 1990s, as eras largely describable as driven by the infrastructural diffusion of new development blocks. It is hardly controversial to say that innovation activity in the postwar era was fundamentally connected to the wider development of combustion engines and motor driven vehicles, not only in the automotive industry, but also encompassing the shipbuilding industry (not discussed in the present version of the paper), and the transportation sector.

6 Concluding remarks

The research questions of this paper are dependent on the long-term series of significant innovations which is not completed. However, some provisional remarks and conjectures may be provided.

First, the LBIO method could be used for historical periods. The historian must however be careful and notice the changes in the journal's interest and eagerness to publish edited material about innovations. One basic idea with LBIO is that journals with the aim to report about the development of an industry have the expertise to make the selection of significant innovations. A great advantage with the LBIO is that it provides the actual output of innovation, which is all the more important as it seems the relation between human capital (and R&D) has shifted after 1980.

Second, the number of significant innovations increased over the postwar period but shows otherwise no simple linear relation to economic activity. A large share of innovations are incentivized by, or have their origin in, transformation pressure. Transformation pressure, in turn, can be of both positive and negative kind, which variates over time and between industries. The qualitative analysis shows the different circumstances in which innovation activity finds incentives and opportunities.

Third, it is possible to interpret our data as indications that innovation activity appears to cluster, that is, fluctuate in numbers in a way that is not at random. Over the past half century this is obvious and clearly related to economic factors. What the pattern looks like for earlier periods should not simply be seen as a matter of absolute numbers but a reasonable interpretation must rest on a yardstick, for example by a comparison with output or human capital.

References

Bäckström B, Flyckt U, Lindqvist G, Löndahl G, Olsson H, Persson P, Engblom C (1992) Den svenska kylteknikens historia : *Kyltekniska föreningens jubileumsbok 1992*. Svenska Kyltekniska Föreningen, Järfälla

Beckeman M, Olsson A (2005) Driving forces for food packaging development in Sweden-a historical perspective. https://lup.lub.lu.se/search/publication/167896

Clark J, Freeman C, Soete L (1981) Long waves, inventions, and innovations. *Futures* 13(4): 308-322

Dahmén E (1950) *Svensk industriell företagarverksamhet: kausalanalys av den industriella utvecklingen 1919-1939.*, vol 1. Industriens utrednings-institut

Dahmén, E. (1991 [1942]). Economic-structural analysis. reflections on the problem of economic development and business cycle fluctuation. In B. Carlsson, R. G. H. Henriksson, & E. Dahmén (Eds.), *Development blocks and industrial transformation : the dahménian approach to economic development* (pp. 25--41). Stockholm: Industrial Institute for Economic and Social Research (IUI).

Elsässer, B (1995) *Svensk bilindustri: en framgångshistoria*. Stockholm: SNS

Fogelberg H (2000) Electrifying visions. *Mimeo*. Gothenburg University, Section for Science and Technology Studies, Gothenburg

Freeman C, Louça F (2001) *As time goes by: the information revolution and the industrial revolutions in historical perspective*. Oxford University Press, New York

Freeman C, Perez C (1988) Structural crises of adjustment: business cycles and investment behavior. In: Dosi G (ed) *Technical Change and Economic Theory*, London: Pinter.

Freeman C, Clark J, Soete L (1982) *Unemployment and Technical Innovation. A Study of Long Waves and Economic Development*. Frances Printer

Fridlund M (1997) *Shaping the tools of competitive power : government technology procurement in the making of the HVDC technology*. Tema, Univ., Linköping

Glete, J. (1987) *Ägande och industriell omvandling,* Stockholm: SNS.

Gårdlund, T (1942) *Industrialismens samhälle,* Stockholm: Tiden.

Granstrand, O. (2005), "Innovation and Intellectual Property Rights", ch. 10 in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds) *The Oxford Handbook of Innovation.* New York: Oxford University Press.

de Groot B, Franses PH (2009) Cycles in basic innovations. *Technological Forecasting and Social Change* 76(8):pp. 1021-1025

Kleinknecht A (1981) Observations on the schumpeterian swarming of innovations. *Futures* 13(4):pp. 293-307

Kleinknecht A (1987) *Innovation Patterns in Crisis and Prosperity: Schumpeter's Long Cycle Reconsidered.* London: Macmillan.

Kleinknecht A (1990) Are there Schumpeterian Waves of Innovations? *Cambridge Journal of Economics* 14(1):pp. 81-92

Kleinknecht A, van der Panne G (2006) Who was right? Kuznets in 1930 or Schumpeter in 1939? In: Devezas T (ed) *Kondratieff Waves, warfare and world security,* IOS Press, Amsterdam, pp 118-125

Kondratiev N (1935) The Long Waves in Economic Life. *Review of Economics and Statistics* 17(6):pp. 1105-1115, translated by Stolper, W.F.

Ljungberg J (1990) *Priser och marknadskrafter i Sverige 1885-1969: En prishistorisk studie.* Ekonomisk-historiska fören.[distributör], Lund, diss. Lund Univ.

Ljungberg, J (1999) A revision of the Swedish Producer Price Index, *Lund Papers in Economic History,* 68.

Ljungberg, J and Nilsson, A (2009) "Human capital an economic growth: Sweden 1870-2000", *Cliometrica*, 3: 71-95.

Ljungberg, J and Schön, L (2013) "Domestic markets and international integration: paths to industrialization in the Nordic countries", *Scandinavian Economic History Review,* 61: 101-21.

Mensch G (1979) *Stalemate in technology: innovations overcome the depression*. Cambridge, Mass.: Ballinger.

Perez C (1983) Structural change and assimilation of new technologies in the economic and social systems. *Futures* 15(5):pp. 357-375

Perez C (2002) *Technological revolutions and financial capital: The dynamics of bubbles and golden ages*. Edward Elgar Publishing, Cheltenham.

Roubert, C J (2009) *Småländsk världsindustri. En studie om entreprenörer och cluster 1950-2002*, Lund Studies in Economic History, 50 (diss).

Schön L (1990) *Elektricitetens betydelse för svensk industriell utveckling*. Vattenfall, Vällingby

Schön L (1994) Omvandling och obalans : mönster i svensk ekonomisk utveckling. *Långtidsutredningen 1995*. Bil. 3. Stockholm: Fritze.

Schön L (1998) Industrial crises in a model of long cycles: Sweden in an international perspective. In: Myllyntaus T (ed) *Economic Crises and Restructuring in History*, Scripta Mercaturae Verlag, Katharinen, pp 396-413

Schön L (2006) *Tankar om cykler*. *Perspektiv på ekonomin, historien och framtiden*. Stockholm: SNS

Schön L (2012) *An Economic History of Modern Sweden,* Oxon: Routledge.

Schön, L and Krantz, O (2012) "The Swedish economy in the early modern period: constructing historical national accounts", *European Review of Economic History,* 16:529-49.

Schumpeter JA (1939) *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process.* Volume 1. McGraw-Hill Book Company Inc, New York

Silverberg G (2002) The discrete charm of the bourgeoisie: quantum and continuous perspectives on innovation and growth. *Research Policy* 31(8):pp. 1275-1289

Silverberg G, Lehnert D (1993) Long waves and "evolutionary chaos" in a simple Schumpeterian model of embodied technical change. *Structural Change and Economic Dynamics* 4(1):pp. 9-37

Sjöö K (2014) *Innovation and transformation in the Swedish manufacturing sector, 1970-2007.* Department of Economic History, Lund University, Lund, diss. Lund Univ.

Sjöö K, Taalbi J, Kander A, Ljungberg J (2014) SWINNO - A Database of Swedish Innovations, 1970-2007. *Lund Papers in Economic History* (133)

Solomou S (1986) Innovation clusters and Kondratieff long waves in economic growth. *Cambridge Journal of Economics* 10(2):pp. 101-112

Taalbi J (2014) *Innovation as creative response: A study of the determinants of innovation in the Swedish manufacturing industry, 1970-2007.* School of Economics and Management, Department of Economic History, Diss. Lund : Lund University, 2014

Tylecote A (1992) *The Long Wave and the World Economy: The Current Crisis in Historical Perspective*. Routledge, London

Wallmark JT, McQueen D (1988) *100 Important Swedish Technical Innovations from 1945 to 1980*. Studentlitteratur, Lund

Wallmark JT, McQueen DH (1991) One hundred major Swedish technical innovations, from 1945 to 1980. *Research policy* 20(4):pp. 325-344