The role of excess capacity in reaching and holding on to success: evidence from Swedish industrial development

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Abstract: During the second half of the 19th century, Sweden was transformed from a poor agricultural economy into an industrial economy with a relatively high level of technology. This development was spearheaded by raw material intensive industries: wood products, pulp and paper, and iron ore. Today, the same industries are still highly competitive and make up a substantial share of the Swedish industrial sector. This article asks how Sweden was able to industrialise so rapidly, and how raw material intensive industries have maintained their competitiveness for over 100 years. We argue that *excess capacity* in learning, human capital, and institutions account for part of the answers to both questions. We also argue that benchmarking – drawing on the experiences and lessons from competitors and role models – may provide a tool for deciding what kind of excess capacity may be needed to prepare for various challenges in economic and industrial development.

Keywords: economic growth; excess capacity; forest industry; institutional development; learning; Sweden.

Reference to this paper should be made as follows: Kokko, A. (2005) 'The role of excess capacity in reaching and holding on to success: evidence from Swedish industrial development', *Int. J. Learning and Change*, Vol. 1, No. 1, pp.122–140.

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1 Introduction

Sweden is among the world's richest and most highly developed economies today, but it is often forgotten that it was still one of the poorest parts of Western Europe 150 years ago. The transformation that gradually changed the country from a weakly developed agricultural economy to an advanced industrial welfare state did not begin until the 1850s, but subsequent developments were remarkably fast. After a slow start, industrialisation took off in the 1870s and by the early 20th century, manufacturing industry was driving

the economy. By that time, Swedish innovators had already established several companies that had become multinational and carved out significant shares of the international market. This rapid development is notable even in the light of the impressive performance of today's newly industrialised countries, and raises questions about how Sweden managed to move to the international technology frontier so quickly.

One of the distinguishing features of the Swedish industrial breakthrough is that growth was fuelled by the expansion of industries based on domestic raw materials, such as timber and iron ore. From a position as a supplier of simple intermediate products to more advanced economies in Western Europe, Swedish industry gradually upgraded its production processes and established a foundation for a more advanced economic structure. Over time, the economy was also able to diversify from raw material extraction into related activities, such as machinery, engineering products, transport equipment and various types of services. However, raw material based industries like pulp and paper and wood products have remained important and still account for 13–14% of manufacturing employment and value added, and the bulk of the country's net exports. The continuing prominence of these industries is significant, and raises questions about how the forest sector is still able to maintain its importance, in spite of rising labour costs and increasing international competition.

This article aims to describe and analyse the evolution of industrial competitiveness in Sweden from a long-term perspective. It makes two main points. Firstly, reinterpreting Swedish economic history in the light of recent findings concerning innovations and knowledge management, we argue that the rapid development after the initial industrial breakthrough in the mid-19th century owed much to the existence of an innovation system with strong institutions and favourable conditions for learning, and human capital development. The conditions prior to the industrial breakthrough were arguably more sophisticated than what was required to maintain the income level and living standards of the pre-industrial economy. The *excess capacity* in terms of institutions and human capital was essential for the economy's ability to exploit the opportunities that emerged as a result of favourable exogenous shocks, e.g. increasing export demand from other parts of Europe and technological advances in paper and pulp and steel production. Secondly, we assert that the sustainability of raw material based industries, like pulp and paper, is also related to the existence of a strong sectoral innovation system. Public policies and company strategies have jointly contributed to an environment where it has been possible to develop the knowledge and skills that are needed to remain competitive in a rapidly changing world: this has not only been essential for innovations in product and process technology, but has also contributed to the sustainability of raw material supplies.

The present article consists of three sections in addition to this introduction. Section 2 looks at the industrial take-off in Sweden, with focus on the preconditions in terms of institutional development and human capital: the role of excess capacity is emphasised as a major success factor. Section 3 turns to the Swedish forest industry and aims to identify the factors underlying its continuing competitiveness. Institutions, human capital and excess capacity are the key elements here as well, although excess capacity plays a smaller role than in the case of the industrial breakthrough. Section 4 summarises the development lessons from the Swedish experience, and attempts to draw some conclusions for the management of success.

2 The industrial take-off in Sweden

Most studies of Swedish economic history suggest that industrialisation commenced around the middle of the 19th century, and that the real take-off occurred some decades later, during the 1870s and 1880s. Two exogenous events are often highlighted as the main triggers of this process. One was the rapid growth of export demand from England, the main industrial power at the time. The export market provided an outlet for Swedish raw materials – during the 1850s, mainly grains and timber, and increasingly also pulp and paper and iron ore from the 1870s – and motivated substantial investment in production capacity and trade infrastructure. In addition, export incomes created domestic demand for a variety of other manufactured products, contributing to a broadening of the industrial base. The other event was technical progress in pulp and paper and steel production. The development of chemical pulp technology after the 1870s created new opportunities for exploiting the vast forest resources in northern Sweden, and created another export boom. Similarly, the conditions for mining and steel production improved dramatically from the late 1870s thanks to new production technologies. Northern Sweden had abundant supplies of iron ore, but the high phosphorus content of the ore had made it unsuitable for steel production until the so-called Thomas smelting process was introduced in 1876. This new technology raised the value of the northern iron ore supplies and led to a very substantial export expansion during the following decades.

However, the Swedish economy had already begun to change from the beginning of the 19th century, and the transformation that started at this time laid the necessary foundations for the subsequent industrialisation process. In particular, it can be argued that the changes made it possible for Sweden to seize the development opportunities that opened up through changes in international demand and technology. This foundation was, to some extent, created through conscious policies in agriculture and education, but exogenous technical changes also played an important role. Policy played a particularly important role for the subsequent industrial success by establishing an innovation system that facilitated the development and diffusion of new technology. Following Bengt-Åke Lundvall's broad interpretation of the concept of an innovation system, we refer here to the institutions and actors directly involved in the creation and diffusion of knowledge and technology as well as to other parts of the institutional set-up that affects learning and development.[1] A specific feature of this system at the time of the industrial breakthrough was that it exhibited substantial *excess capacity*. This concept refers to the fact that Sweden had more human capital and a more sophisticated institutional structure for knowledge management than was needed, given the requirements of the pre-industrial economy. The surplus capacity proved to be an essential competitive advantage once the exogenous events that facilitated the industrial take-off fell in place.

2.1 Improvements in agricultural efficiency

The most significant pre-industrial changes took place in the agricultural sector. Up to the end of the 18th century, Swedish agriculture had relied on archaic production techniques, and harvests were barely sufficient to feed the population. Famines were not uncommon: the last widespread famines occurred in the early 19th century. Three main changes contributed to a transformation of agriculture that began around 1800, and continued throughout the 19th century.

Firstly, the structure of land ownership was reformed. Traditionally, the land holdings of rural families had been divided into several separate strips of land, dispersed around the village. The purpose was to make sure that farmland of different quality was distributed fairly among all families belonging to the village. However, the fragmented ownership pattern also contributed to inefficiency and slow diffusion of innovations, since all production decisions – including the adoption of new technologies – had to be coordinated among the village members. To overcome these obstacles, land reforms were introduced in most parts of the country during the first decades of the 19th century. The traditional ownership pattern was broken up, and land was redistributed so that each farm got one larger plot instead of the many separate pieces (Carlsson, 1980). In some parts of the country (especially in the more fertile southern regions), this also meant that the villages were broken up: the peasant families moved their houses from the village to the centre of their own plot of farmland.

Secondly, new production techniques were adopted, and agricultural productivity increased. This was partly a result of the land reforms – diffusion of new techniques became faster when it was not necessary to convince the village majority about the adoption of new practices – but it was also related to technical progress in the machinery industry. The most important innovations during the early part of the century were better ploughs, and after the 1850s, machinery for sowing, harvesting and threshing also became widely used. Furthermore, the increasing use of fertilisers made more intensive cultivation possible.

Thirdly, the potato became the new staple crop. It had been introduced to Sweden several centuries earlier, but its breakthrough did not come until the end of the 18th century – before that time, potatoes had mainly been used as animal feed. The potato was well suited to Swedish conditions, and it yielded larger harvests than the traditional staple foods, beets and turnips.

One result of the changes in the agricultural sector was a marked improvement in food supply. Together with improvements in healthcare and medicine (and a long period of peace beginning in 1809), this led to rapid population growth. During the first 60 years of the 19th century, the Swedish population increased from 2.3 million to about 4 million. The area of farmland grew from 1.5 million hectares in 1800 to 2.6 million hectares in 1850 and 3.6 million hectares in 1900 (Larsson, 1991, p.28). Agricultural productivity grew continuously, and output sufficed to feed both the farmers and a growing urban population. In fact, Sweden became a significant exporter of cereals in the 1850s, after having been a steady net importer of grains until the 1830s. Hence, the increase in agricultural productivity facilitated the transfer of labour to urban occupations, and generated export earnings that could be used for investments in forestry and manufacturing. The increasing rural incomes also translated into demand for the goods produced in the emerging manufacturing industries.

The domestic manufacturing industry was quick to respond to this demand increase from the very beginning. It is possible to identify at least two strong explanations for the rapid supply response. One reason was that some primitive manufacturing activities – a kind of *protoindustrialisation* – had begun several centuries earlier and created various kinds of skills and expertise that were highly useful for the industrial era. This included, for instance, the framework for the Swedish army's procurement of supplies and equipment. Cloth, uniforms, weapons, utensils, tobacco and alcohol were produced by so called *manufaktur* companies, some of which were relatively large, although their production

methods were primarily based on handicrafts. Yet, they provided important elements of industrial culture, and the towns where the *manufaktur* firms were located had an advantage over other locations after the advent of the industrial revolution.

Due to the highly seasonal nature of Nordic agriculture, the rural households had traditionally produced significant amounts of handicrafts during the winter months: leather goods, textiles, shoes and simple tools were made by most families. After 1800, this production increased and became more specialised, both because of population growth and because demand was growing due to the higher incomes. In some parts of the country, merchants purchased a large share of the output, and they sometimes commissioned the production of entire villages. The main significance of this type of activity may have been the development of commercial skills. As modern technologies for production of textiles became available after the middle of the 19th century, the Swedish textile factories were often established by the same merchant groups that had been involved in the trade with handicrafts.

A related development was apparent in mining and forestry. Swedish producers already had strong positions in the European markets for copper, iron, and tar from the 17th century, and it has been argued that one of the most important skills learned during the early years was international marketing (Hallvarsson, 1980, p.13). Merchants and traders were involved in the establishment of many of the ironworks and sawmills that emerged because of good export opportunities during the 19th century. Hence, some important elements of industrial culture were in place already before industry itself.

2.2 Education and technical skills

An even more important determinant of industrial success was the increase in the level of education and human capital that had started well before Sweden entered the industrial revolution. Like the institutional changes in agriculture, this was also a result of conscious policies. Both formal and informal types of education and training were supported by the state and various private interests. Perhaps the most important step was the introduction of a mandatory school system in 1842, which proved crucial for the creation of a skilled human capital base and for the dissemination of new technology. The official ambition was to guarantee basic skills in reading, writing and arithmethic to all citizens, and literacy rates reached nearly 100% within one generation. This was essential for the ability of individuals and firms to learn and adopt new knowledge: much elementary learning and technology transfer was based on written instructions, such as blue-prints and handbooks.

Concurrently, there were important changes in higher education. At the summit of the formal education system were the old universities in Uppsala and Lund, already established in the 15th and 17th centuries. These expanded throughout the 19th century, with a greater emphasis on the natural sciences than formerly (when law and theology had been the dominant subjects). The great increase in the number of professorial chairs during the period when industry started developing rapidly, in particular between 1870 and 1914, was arguably of ‘immense importance’ for the industrial breakthrough (Ahlström, 1992, p.35). Several institutions for advanced technical education were also founded outside the traditional universities during first half of the 19th century. The Technological Institute in Stockholm was established in 1826, and it became the Royal Institute of Technology in 1877. In Gothenburg, the Chalmers Technical School was set up in 1829, and it provided scientific and technical education at a university level from

its inception, although it was not formally named a Technical University until 1937 (Ahlström, 1992, p.4). Technical colleges were established in several Swedish cities – Malmö, Borås, Örebro, and Norrköping – during the 1850s. Numerous vocational training schools were also set up in various parts of the country from the same time, numbering about 35 at the end of the 19th century and 66 in 1908–1909 (Ahlström, 1992, p.7). The guild system was abolished in 1846, and the training schools quickly began to replace apprenticeships as the main form of vocational education. Most of the vocational schools depended on private initiatives, although some were financed by the state. Among the latter were nautical training schools (from 1842), forestry secondary schools (from 1860), and agricultural colleges (from 1887) (Nilsson and Svärd, 1991, p.5). The state's engagement in this area increased further from the early 20th century, and vocational schools have been important tools for the upgrading of labour skills ever since that time.

Parallel to the development of formal education, there also appeared other institutions that were involved in the development of technology and industry. The Royal Swedish Academy of Science dates back to 1739, and the Swedish Ironmasters' Association was established in 1747. The Ironmasters' Association, which was partly state-financed, was particularly important for the transfer of foreign technology to Sweden. The Association started the publication of the mining science journal *Annalerna* in 1817, and financed a very large number of foreign study trips made by Swedish engineers and scientists, requiring detailed written reports that were made available to the rest of Swedish industry. Several new organisations emerged during the 1860s, e.g. the Swedish Association of Engineers and Architects and the Stockholm Engineering Association. The Swedish Academy of Engineering Sciences, the Wood Pulp Association, and the Swedish Institute of Metal Research were added in the early 20th century. These institutions were closely in touch with scientific research and technical education, and they played – and continue to play – a significant role for the diffusion and dissemination of technical skills. New engineering workshops, like Motala Verkstad, established for the construction of lock-gates and iron bridges for the Göta canal network in the early 19th century, were also indispensable as training centres. In addition, it is necessary to note the importance of labour migration. Swedish engineers were often trained and educated in Great Britain and Germany, and important contributions were made by several British engineers that immigrated to Sweden (Schön, 1982).

It is difficult to find accurate measures of the importance of these different types of investment in skills and human capital. However, it is clear that the supply of skilled workers increased steadily from the 1850s. The number of engineers educated at the higher technical institutes amounted to about 700–800 in 1850, and some 2000 in the late 1890s. The number of engineers with secondary education also reached about 2000 at the end of the 19th century (Ahlström, 1992, p.9). Before the industrial breakthrough, these resources could not be fully exploited in Sweden – consequently, many engineers emigrated to the USA in search of qualified jobs – but they provided a strong competitive edge for the development of industry once the other conditions for industrialisation were in place. Moreover, the technical skills often translated into entrepreneurial success. The founders and leaders of several of the most successful Swedish companies were educated at the technical institutes and had received foreign training that was paid by the state or some of the institutions mentioned above. For instance, Hans Tore Cedergren, who played a central role in the emergence of the Swedish telephone industry, and Gustav de Laval, founder of the AB Separator in 1883 (known as Alfa-Laval from 1963) were educated at

the Technological Institute of Stockholm. Gustav Dalén, manager and chief engineer of AGA, was a graduate of Chalmers, and Sven Winquist, founder of SKF, had been educated at the technical college of Örebro. Lars Magnus Ericsson, the founder of the telephone company still carrying his name, had received state grants for studying the electrical engineering industry in Germany and Switzerland, as had most other leading industrialists in the country. Göran Ahlström argues that the successful innovators and entrepreneurs illustrate that a network already existed between the technical institutions, industry and the government from the middle of the 19th century, and that this contributed significantly to the success of Swedish industrialisation (Ahlström, 1992, 1993). It was of central importance for the development of industry, especially after the 1880s, when products became more differentiated and goods such as pulp, paper and engineering products became more important (Gustavsson and Kokko, 2003; Nilsson and Svärd, 1991).[2]

In addition to the development in education and research, it is appropriate to note that there were other institutional changes that preceded industrialisation but turned out to be of the utmost importance for developments once the industrial take-off commenced. One of the most significant was a restructuring of the state's forest holdings in the mid-19th century. Large amounts of forest land were distributed to private owners, especially in southern Sweden, and the structure of forest ownership was registered. This meant that property rights were well defined, and the private owners were in a position to respond rapidly to the increasing export demand that emerged some years later. Another notable event was the introduction of Limited Company laws in 1848. This made it possible to raise more capital and take risks, which was necessary as the rate of technical change increased during the second half of the century. Earlier, most firms had been owned or at least dominated by one single family, and the owners were personally responsible for the firm's debt (Larsson, 1991). Limited companies – where the owners' stake was limited to their share of the firm's initial capital – employed 45% of the industrial labour force in 1872, and 80% of the labour force in 1912 (Hallvarsson, 1980, p.19). Moreover, the financial system started developing from the 1830s, with commercial banks, savings banks, mortgage institutes and other actors taking over large shares of lending from *Riksbanken*, the state bank. While Riksbanken had accounted for over 80% of total lending in 1835, its share had fallen to 20% by 1855 (Myhrman, 1994, p.74). As long as the agricultural sector dominated the economy, it would arguably have been possible to maintain a steady (but slow) rate of output growth even without these institutional innovations. In combination with the advances in education and technical skills, however, they defined a system that proved very efficient in exploiting the opportunities opened up some years later as a result of foreign innovations and demand.

An obvious question is what motivated the institutional changes. Johan Myhrman argues that an important reason was the spread of liberal ideas in Swedish politics from the late 18th century (Myhrman, 1994). The period 1772–1809 was characterised by absolute monarchy, restrictions on public debate, and two major wars with Russia. The wars were not only unsuccessful from a military and political perspective – for instance, Finland was lost to Russia in 1808–1809 – but the large public expenditure for the wars also led to high inflation and economic chaos. The dissatisfaction with the monarch led to a *coup d'état*, the appointment of a new king, and a new constitution. This new constitution was characterised by a division of power between the monarch and the *Riksdag*, the Swedish parliament, and drew on ideas from the American and French revolutions

(Myhrman, 1994, p.61). It also gave more political influence to interest groups promoting liberal ideas and commercial ambitions. Many of the institutional reforms introduced during the following decades seem to have been driven by comparisons with the leading industrial nations in Western Europe: if it could be done in England, then why not in Sweden? While some developments were based on the existing domestic institutional framework, there were also cases where foreign solutions were imported. One example is the expansion of science and technical education, where the French and German models, already introduced at the end of the 18th century, provided much of the inspiration. Interpreting these events in light of the current debate on innovations and knowledge management, this may be characterised as an early example of benchmarking.

2.3 The industrial breakthrough

While the productivity increases in agriculture and the advances in education and human capital development were essential prerequisites for industrialisation, there is no doubt that the immediate trigger for industrialisation was a boom in foreign demand for Swedish products. This occurred in several steps, starting in the 1850s with grain and sawn wood as the main export commodities, and continuing during the 1870s and 1880s with pulp and paper, iron ore and steel as the dominant products.

Exports of grain were of tremendous importance for the industrialisation process, although their origin was in the agricultural sector rather than in manufacturing, and although the era of grain exports lasted only from the 1850s to the 1880s. One reason was that the expansion of agriculture during these three decades provided employment for the increasing population at a time when industry was not sufficiently developed to absorb enough employment. Another reason, already mentioned above, was that export incomes created demand for a variety of domestic manufacturing products in the early stages of the industrialisation process. In addition, export incomes were also used to finance important parts of the early industrial expansion.

Sweden had been a net importer of cereals until the 1830s, as noted above, and exports were still limited during the late 1840s, reaching some 40,000 barrels annually. At the peak, 30 years later, exports had grown to four million barrels per year (Carlsson, 1980, p.212). The reasons for the grain boom were largely to be found outside of Sweden. Demand was high, especially from England, where the industrialisation process had taken off, and domestic cereal production was not sufficient to feed the growing urban population. Bad harvests in England and elsewhere on the European continent during the early 1850s increased demand further. At the same time, Swedish harvests were unusually plentiful. Moreover, the leading European grain exporter, Russia, was hit by the Crimean War in 1853–1856, and Russian exports ceased almost completely.

The successful Swedish response to this new export opportunity was a combination of the flexibility of the agricultural sector (that had been created by the institutional changes in the structure of land ownership) and the appearance of various technical innovations that increased productivity, e.g. machinery for sowing, harvesting and threshing (which could be quickly diffused across the country as a result of the advances in education and technical skills). Sweden managed to hold on to large shares of the English grain imports until the 1880s, but the trade disappeared as suddenly as it had emerged after that. The reasons were that Russian exports resumed on a large scale, and the USA emerged as the new leader when the Great Plains had been taken into production.

From the 1850s, there was also an increase in the demand for forest products – mainly pit props and sawn wood – that was fed by English urbanisation. Swedish exports of sawn wood products had been insignificant before the 1840s, for several reasons. Norway was a stronger exporter, both because of lower transport costs and because the technical level of Norwegian sawmills was higher. In addition, the English *Navigation Acts* gave preferential treatment to Canadian producers (Carlsson, 1980, p.218). However, the situation changed very rapidly in the early 1850s. English import protection was abolished, and the Norwegian forest resources were over-exploited, which gave ample opportunities for Swedish wood exporters to step in. The increase in demand motivated investments and technical improvements – for instance, steam-powered saws were introduced – and sawmills became more efficient. Norwegian entrepreneurs actually played an important role in this process, as several companies moved to Sweden because of the dwindling forest supplies in Norway. As a consequence, exports of sawn wood increased from less than 200,000 m^3 in the 1830s to 4,800,000 m^3 at the end of the century. In the 1870s, wood products had grown to make up 43% of Swedish exports (Hallvarsson, 1980, p.14).

Some decades later, there were new export booms, for pulp and paper and iron ore. Exports of pulp and paper started growing from the 1870s, and Sweden had become the world's largest pulp exporter by 1913. However, this expansion differed from the sawn wood boom in several ways. Sawmilling had been an easy start, since the capital requirements were low and the technology was simple. Pulp and paper production was significantly more capital intensive and technology intensive, and posed much tougher requirements on domestic institutions and technological competence than sawmilling had done. Domestic policies were also much more important for the success of the industry. Thanks to the development of a relatively efficient banking system, profits from sawmills could be channelled to finance the expansion of pulp and paper mills (Hallvarsson, 1980, p.26; Sandberg, 1979).[3] At the end of the 1870s, the Swedish financial system comprised 35 commercial banks with offices in 160 cities, which was comparable to the most highly developed nations in the world (Larsson and Olsson, 1992). The development of domestic technological capability had also proceeded far enough to allow production and exports of more advanced goods. In fact, Swedish inventors had taken the lead in the development of pulp technologies, and the world's first chemical pulp factory was established in Bergvik, on the coast of Norrland, in 1872. While the success of the first export booms – grains and wood products – might have been possible in a less sophisticated institutional environment, it seems clear that the existence of an innovation system, including institutions for learning and research as well as for the commercialisation of new knowledge, was a necessary precondition for the pulp and paper boom.

The mining industry that started expanding during the last decades of the century was also heavily dependent on the existence of an efficient innovation system. Sweden had held a strong position in the international market for metals for several centuries. The main export product until the middle of the 19th century was bar iron. The production of iron was strictly controlled by the state, in order to avoid deforestation and degradation of forest resources: the industry used massive amount of timber in the form of charcoal. It has been estimated that the mining industry's use of wood was four to five times larger than wood exports as late as 1854. Hence, exports of iron ore and pig iron (which were low value added products) were restricted. These strict rules were liberalised in the 1850s, when technological innovations – the Bessemer and Martin processes – made it possible to use coal and coke instead. However, the Swedish production and exports of iron and

iron ore stagnated during the decades after 1850, because the comparative advantage of the Swedish iron industry had been the abundant supply of charcoal. Instead, coke and coal based steel production in continental Europe increased rapidly. It was not until the so-called Thomas process was introduced in the late 1870s that the industry started recovering. It was known for centuries that there were rich iron ore deposits in northern Sweden (Lapland). These had not been exploited earlier because of their high content of phosphor, which made the steel weaker. Now it became economically viable to develop the industry, and new ironworks were established. Production of steel for domestic use increased rapidly, but exports of steel remained low. Instead, iron ore was exported directly to the main iron and steel plants in Germany and Great Britain.

The development of mechanical and engineering industries, which started during the latter part of the 19th century, was also driven by technological innovations, but these were more directly connected to domestic capabilities and skills. The 1880s in particular proved to be a golden decade for Swedish industry, when several path-breaking innovations were presented, and when industrialisation really took off: the number of industrial workers increased by 66% between 1880 and 1889 (Hallvarsson, 1980, p.9).[4] Examples of long-lived Swedish firms that were established during the late 19th century or the early 1900s are Ericsson, Alfa Laval, ASEA, AGA, Nobel and SKF. Table 1 illustrates the changes in the structure of Swedish exports between 1881–1885 and 1911–1913. The relative importance of sawn wood and cereals fell, whereas more advanced products, like pulp and paper, engineering products and iron ore became more important. While export demand was the driving force behind the early stages of industrial development until the late 1860s, the domestic market gradually became more important after that, partly as a result of explicit policy intervention. One example was the development of domestic infrastructure. Heavy investments in railways (especially during the 1870s) and the introduction of electric energy (from the 1880s) made it possible to specialise production and transport raw materials and finished goods across the country. The earliest industrial developments, in e.g. sawmills, had relied on waterways, but now a more general industrialisation, based on the domestic markets, was possible. The demand for metal and wood generated by the construction of infrastructure facilities, mainly railways, also stimulated domestic demand.

Table 1 The structure of Swedish exports 1881–1885 and 1911–1913

	1881–1885 (percent)	*1911–1913 (percent)*
Sawn wood	40	26
Iron and steel	16	9
Cereals	12	1
Butter	6	6
Pulp and paper	5	18
Engineering products	3	11
Iron ore	–	8
Other	18	21
Total	100	100

Source: M. Larsson and U. Olsson (1992), 'Industrialiseringens sekel', in *Sveriges Industri*, Industriförbundet, Stockholm, Table 3.

Another reason for the heavier emphasis on the home market was even more directly related to policy. The export booms during the early stages of the industrialisation process took place at a time when economic liberalism and free trade ideologies reached their first peak. This meant not only that Sweden could freely sell primary products to the rest of Europe, but also that Sweden imported many advanced consumer and investment goods from the industrially more developed countries in Europe. These policies changed from the late 1880s, when a wave of protectionism swept over Europe. Both agricultural and industrial imports were restricted, and the average tariff level in Sweden before the First World War reached about 15% of value added. A further sign of the changing policy climate was the introduction of policies to limit foreign ownership of Swedish resources. Earlier, foreign participation and investment had been welcomed. Similar developments also occurred in the rest of Europe, resulting in an increasingly important role for the domestic market.

One can only speculate about the significance of the timing of policy regimes. It appears that Sweden was fortunate, in that the inward-looking policies were not introduced until there was a firm base for domestic development in the form of a national system for innovation and technical progress. Agriculture had expanded and the increased productivity created incomes and demand for various types of consumer goods. Technological skills had been developed, which facilitated the creation of a variety of import substituting industries. The export success had brought in foreign capital, and a foundation for a more comprehensive industrialisation was in place. These elements have not been in place in most of the developing countries where inward-looking policies have failed during the 20th century.[5]

3 Sustaining success in the Swedish forest sector

The rapid expansion of Swedish industry after the 1870s depended crucially on favourable initial conditions in the form of an institutional structure that was more sophisticated than required to maintain the country's income level. The resulting excess capacity in the innovation system facilitated learning, knowledge development, and commercialisation of innovations, and made it possible to quickly grasp the opportunities that emerged as a result of unforeseen technical breakthroughs during the second half of the 19th century. The importance of most of the elements making up the Swedish institutional environment at this time – property rights, education, rules and regulations, incentives and outward orientation – is commonly recognised. However, excess capacity is not commonly proposed as a characteristic of successful innovation systems. Instead, it is often seen as an indication of inefficient investment decisions and wasteful use of resources. This raises the question to what extent the experiences from the Swedish industrialisation process can be generalised. When is it motivated to invest in excess capacity and is excess capacity needed to sustain success or competitiveness?

A look at the innovation system contributing to the sustainability of the Swedish forest industry may provide some tentative answers. The industrial breakthrough for the industry came in the 1850s, as discussed above, with an export boom for wood products. From the 1880s, after the introduction of chemical pulp technology, pulp and paper emerged as another core export sector. Today, some 125 years later, the forest sector remains a prominent part of the Swedish economy. Sweden is the world's third largest exporter of paper and the second largest exporter of sawn wood products. The net exports

of forest products (gross exports minus the sector's import value) are larger than the aggregate net exports of automobiles, electronics, telecom and pharmaceuticals. Altogether, the forest industry also accounts for some 13–14% of value added and employment in the Swedish manufacturing sector. The industry's production technologies have grown steadily more sophisticated, enterprises have specialised in processes with strong economies of scale, and shifted their focus towards new products with higher value added. As a result, labour productivity has grown fast enough to match the continuous increases in labour costs: this has allowed the industry to maintain its competitiveness in an environment where technologies, competition and demand conditions have been changing continuously.

The ability to adjust and restructure successfully has depended crucially on the institutions and human capital created by the forest industry's innovation system, just as the success of Swedish industrialisation depended on the national innovation system built up prior to the industrial take-off. However, there are some notable differences between the two cases. While the specific technological innovations leading up to the industrial breakthrough were in principle impossible to foresee, it has over time been possible to identify the main challenges for the forest industry. These are related to the protection of the raw material base and the development and dissemination of the new technologies and skills needed to survive in a changing world. Identifying the key challenges has allowed a concentration of institutional resources to handle these issues and reduced the need to maintain excess capacity in areas that are not of central importance. One example is forest management. It was recognised early on that a depletion of the raw material supply was a serious threat to the sustainability of the industry: the demise of the Norwegian wood industry in the mid-19th century illustrated the dangers. The first modern forestry laws were, therefore, introduced as early as in 1903 and mandated replanting after each harvest. Over time, the forestry laws have come to cover additional objectives, such as environmental considerations. Today, all forest owners are required to prepare a forestry plan, outlining expected thinning, felling, replanting and other operations. The regulations and requirements are combined with fiscal incentives and training and extension services provided by the public sector as well as cooperative forest owners' organisations. The cooperatives are especially important for the diffusion of new technologies among forest owners: in addition to education and training, they also provide forest management services to the growing group of owners that have moved to the cities and lack both the time and skills to actively work on their lands. The results of these targeted institutional investments have been highly successful. The growing stock of timber in Sweden is estimated to be at least twice as large as a century ago, when the first laws requiring replanting were introduced, and stock is still growing. Similar institutional investments have been made in knowledge creation and management, as will be discussed below.

Another distinguishing feature of the forest industry's innovation system is that it has not been able to draw heavily on experiences from other countries, since Sweden has been one of the industry's technological leaders since the late 19th century. To maintain its leading position, Sweden has, therefore, been forced to invest more in R&D with uncertain returns than countries that have been able to benefit from technological benchmarking and convergence. Moreover, to stay in the lead, it has been necessary to maintain a readiness to respond faster than others to changing market conditions. Taken together, these requirements have translated into a need for excess capacity in skills and knowledge.

A sophisticated network or cluster of organisations involved in the development of new technology, knowledge and skills has, therefore, emerged over time, and has become the main competitive advantage of the Swedish forest sector. This network – which corresponds roughly to Bengt-Åke Lundvall's narrow definition of an innovation system[6] (Lundvall, 1992, p.12) – includes well over 100 highly specialised research and training institutes in a wide array of fields covering the entire value chain from the forest to the final consumer. Taking the pulp and paper sector as an example, Table 2 illustrates some of the core institutions in the innovation system. The table distinguishes between two dimensions of the system (Ds, 1991). One dimension focuses on the outputs of the innovation system, which can be skills or knowledge. Skills are embodied in people and generated through various types of education and training. Knowledge is a public good that is generated by research and development activities, and can be transferred from person to person through various means of communication – lectures, scientific articles, handbooks, manuals, and so forth. The other dimension distinguishes between institutes and organisations that create skills and knowledge and those that disseminate skills and knowledge: while there is some overlap, these are distinctly different tasks that are typically undertaken by different actors.

The main characteristic of the pulp and paper industry's innovation system is that all of the four functions of the innovation system illustrated in Table 2 are strongly represented. This is one of the great strengths of the industry, and contributes not only to technical progress and innovations, but also to the efficient dissemination of innovations. Another feature is that the investments in this knowledge cluster are increasingly concentrated and coordinated. The high fixed costs in the pulp and paper industry have acted as entry barriers and contributed to the emergence of an oligopolistic market structure, where mark-ups are high enough to allow large corporate investments in R&D (Konkurrensverket, 2002). Much of the research and training taking place in universities and the industry's research institutes is conducted in various networks and other collaborative arrangements, often including participation from the industry.

Regarding the creation of education and skills, most of the leading Swedish universities provide university training for engineers specialising in pulp and paper processing and related fields. Since the mid-1990s, the universities have also had a network for postgraduate education in collaboration with the main industrial research institutes, the Pulp and Paper Research Institute (PPRI) and the Institute for Surface Chemistry. This network is known as the Forest Products Industry Research College (FPIRC) and includes all Swedish universities with specialised PhD level education in pulp and paper technology. As a result, there is a sufficient supply of highly educated manpower for the pulp and paper industry. About half of the engineers recruited by the industry have formal training focusing on pulp and paper technology, but the increasingly sophisticated production technology also requires an increasing number of specialists from other fields. Partly for that reason, the PPRI itself manages shorter specialised training courses for industry professionals. In addition, the Institute is actively involved in the various academic programmes by financing student research projects, arranging guest lectures, and providing lecture rooms and equipment.

Table 2 Participants in the knowledge cluster of the Swedish paper and pulp industry

	Generation	*Dissemination*
Skills (education)	FPIRC Swedish Pulp and Paper Research Institute (PPRI) Institute of Surface Chemistry (ISC) Individual companies	PPRI
Knowledge (research)	FPIRC PPRI Institute of Surface Chemistry Graphical Research Laboratory Swedish Packaging Research Institute Swedish Newsprint Mills' Research Laboratory Individual companies	PPRI Institute of Surface Chemistry Graphical Research Laboratory Swedish Packaging Research Institute Swedish Newspaper Mills' Research Laboratory

Notes: FPIRC (Forest Products Industry Research College) is a network of all Swedish universities providing higher education in pulp and paper technology. The members include the Royal Institute of Technology, Chalmers University of Technology, Lund Institute of Technology, Linköping Institute of Technology, Umeå University, Luleå University of Technology, Mid-Sweden University and Karlstad University.

The universities participating in the FPIRC also account for a sizeable share of the non-corporate research activities in the pulp and paper sector. Most of the basic research originates in the university system, in the form of master's and PhD projects as well as research by regular academic staff. PPRI is the other major research producer in this part of the knowledge cluster. With 250 employees, more than half of whom are qualified researchers, it is one of the largest research institutions of any kind in Sweden, and recognised as one of the internationally leading centres in its field. The character of PPRI's operations has changed somewhat during recent decades because of the growing level of competence in the industry's larger companies. Product development has gradually shifted to corporate research laboratories, while PPRI itself has become increasingly focused on basic and applied research of common interest to the entire industry, often in collaboration with the university system. This collaboration has obviously been facilitated by the shift from product development to basic and applied research. Research is also conducted at several of the industry's smaller collective research institutes, such as the Institute of Surface Chemistry, the Graphical Research Laboratory, the Swedish Packaging Research Institute and the Swedish Newsprint Mills' Research Laboratory, to mention a few of the dozens of research organisations in this area.

In addition to the activities that take place in each of the research institutes, recent years have also witnessed the establishment of collaborative research projects undertaken in various networks involving several of the industry institutes. For instance, a notable share of the industry's present research is concentrated to three networks focusing on printing technology, paper surfacing, and material sciences.[7] Each of these include academic institutes as well as industry research institutes and individual firms, each has a long-term perspective on research, and is jointly funded by the state and the pulp and

paper industry. Swedish research is a world leader in many of these fields, and it is safe to conclude that the generation of knowledge in the pulp and paper industry is highly efficient in comparison with that undertaken in other countries. To the extent that industry voices objections to this argument, the most typical complaint is that much of the knowledge created today is not yet relevant for the industry's needs, and that it may take five to ten years before it will have any practical impact on operations (Ronne, 1996). This is one indication of the excess capacity that is created in the short run – in the long run, some of this capacity is, of course, expected to contribute to the industry's competitive advantages.

Almost all of the industry's research institutions are involved in the dissemination of research results, and it is generally assumed that technology transfer is highly efficient because the industry's general level of education and skills is high. One reason is that the PPRI has, for at least two decades, taken the lead in transferring skills from the academic institutions to the industry. To this end, the PPRI has acted on two fronts. On the one hand, it has attempted to stabilise the demand for engineers and researchers by recruiting skilled labour during slumps in the business cycle. These recruitment activities have largely been financed by the pulp and paper industry. On the other hand, PPRI has encouraged the industry to employ skilled labour, both by providing information about various types of education to the industry, and by influencing the content of higher education in the direction of the industry's demand. The result has not only been efficient diffusion of skills and knowledge from academia and research institutes to the industry, but also increased demand for higher education from students: with good job opportunities, it has appeared safe to invest in long university programmes focusing on pulp and paper.

In this regard, it can be argued that the innovation system in the pulp and paper industry also makes up a model for other sectors. For instance, one commonly identified complaint in the wood products industry concerns a shortage of academically educated staff in sawmills and other firms (Ds, 1991). Without the necessary skills, companies are not able to keep pace with technological developments and changes in the competitive environment. Even if the research organisations manage to generate product and process innovations, there is a risk that few individual firms will recognise the opportunities and adopt the innovations. This problem is caused by the weak dissemination of skills from the universities to the industry: in the wood products industry, there is no institute playing the role of PPRI to promote the career prospects for advanced wood technology graduates. This notwithstanding, the existing knowledge cluster in the Swedish wood products sector is still more advanced than that found in other countries (with the possible exception of Finland) and it has played an essential role in allowing that industry to adjust to the continuous changes of its competitive environment.

One conclusion from this brief look at the forest industry's innovation system is that excess capacity is a relevant concept here as well, but that it appears to be of a different kind than in the case of Swedish industrialisation. The forest industry has been able to foresee its own major challenges, and it has, therefore, been able to concentrate its investments in the relevant areas. By focusing on its two main challenges – to secure the long-term supply of raw materials and to generate the knowledge and skills needed to adjust product and process technologies to changing market conditions – the industry has been able to reach and hold on to a leading position in the international market. The amount of skills and knowledge required to stay in the lead is very substantial: the leader has to respond faster than its competitors to the changes in the market environment. In the

long run, this may be impossible unless there is more capacity than is required to handle the current challenges. In this sense, excess capacity may also be necessary for long-term success in a mature sector, such as the forest industry.

4 Summary and concluding comments

This paper has explored two questions relating to the long-term development of Swedish industry. Firstly, we asked what explained the rapid early industrialisation process in Sweden. In a few decades during the second half of the 19th century, Sweden was transformed from a weakly developed and largely agricultural economy into an industrial economy that was leading in several areas of technological development. Secondly, we asked how some of the raw material intensive industries spearheading the industrialisation process – in particular, pulp and paper – were able to maintain their leading position until the present day, in spite of very substantial changes in technologies, markets and competitive conditions.

The answers to both questions focused on the same key words: institutions, learning and human capital. In the first case, the development challenge amounted to a fundamental shift in the Swedish production structure, from an agricultural to an industrial economy. This shift was handled successfully because the conditions prior to the industrial breakthrough were characterised by excess capacity regarding the quality and sophistication of institutions and human capital. Swedish society had already begun to modernise on several fronts before the arrival of the industrial revolution, and changes in agriculture, science, education and institutions formed a strong foundation for subsequent development. These improvements were not necessary for maintaining living standards in the circumstances where they were initiated. However, when the industrialisation process was triggered by foreign technical innovations and a strong demand for Swedish raw materials from other parts of Europe, Sweden was well positioned to take advantage of the new opportunities. Excess capacity was arguably a necessary precondition for success, because the specific events that eventually triggered the industrial take-off could not be predicted. Sweden could use the experiences of more advanced countries as a guide for the modernisation of institutions, laws and technical skills. This early example of benchmarking was important, because it provided a tool for deciding where the scarce resources available for capacity development should be invested.

The continuing prominence of the forest industry, by contrast, has depended on institutional reforms and knowledge investments of a different kind. Here, the challenge has not been any fundamental shift in the production paradigm, but rather continuous and incremental changes in competitive conditions. It has been possible to identify the industry's main challenges and to develop institutional solutions tailored to these specific challenges. In this more predictable environment, industry has been able to concentrate investments in those areas which are most critical for competitiveness: in particular, this has amounted to education and research and development. Yet, some degree of excess capacity (in terms of technical competence) has been necessary. To maintain its leading position, Swedish industry has needed more knowledge than others in order to react faster than others to changing market conditions.

Assuming that these findings can be generalised, it is possible to suggest some cautious policy conclusions. Some lessons are related to the differences between the two cases

discussed in this article. The first case involved a fundamental paradigm shift where Sweden took a decisive step in the development from an agricultural to an industrial economy. It was not possible to predict what specific industry or activity would provide the main impetus for change, but the transition was successful because excess capacity had been created in several areas. Perhaps the most difficult question emerging from this case is how other countries (or individual firms) may be able to prepare for a similar event. A trivial answer is to call for a high degree of excess capacity regarding human and social capital, but it should be noted that this capacity has an obvious cost in terms of static efficiency. Hence, richer countries will typically be better prepared for unexpected situations. On a more practical note, there may be a reason to focus more systematically on the benchmarking of technologies and institutional solutions, to identify efficient alternative approaches to common challenges. While none of the existing strategies is likely to be a perfect match to the new situation created by a radical innovation, it is clear that those countries or firms that are familiar with several alternative strategies will have clear advantages in adjusting to the new conditions.

The second case focused on the determinants of sustainable growth in the Swedish forest sector. Some excess capacity was required to maintain the competitive advantages of the sector, but it was known in advance where this capacity was needed. Hence, knowledge investments could be concentrated and coordinated to exploit economies of scale and maximise investment efficiency. The R&D strategies of many mature industries are likely to follow a similar pattern. However, whether concentration is desirable in the long run depends on how predictable the development of technologies and markets are. This relates closely to the Schumpeterian Dilemma regarding static versus dynamic efficiency (Rosenberg, 1994, ch. 3; Schumpeter, 1943). In much of the policy discussions regarding the choice between competition and static efficiency on the one hand or market concentration and dynamic efficiency on the other hand, attention has focused on the cost reductions that are possible through increased R&D investments. The larger the cost reduction, the smaller the loss in terms of consumer welfare from allowing (or even encouraging) monopolistic market structures. The examples discussed in this article suggest that there is another factor that should be taken into account in policy making: the extent to which technological developments can be foreseen. When the future competitive conditions appear difficult to predict – e.g. when technologies are relatively young or subject to frequent change – it appears more risky to allow concentration of economic decision-making power and R&D efforts. In these cases, it is, instead, valuable to encourage a variety of research strategies, to raise the likelihood that some of them will be successful.[8]

A comment about the need for further study is also appropriate. In the Swedish case, the impetus for upgrading the innovation system came from political changes: a new constitution in the early 19th century paved the way for new liberal ideas and institutional reforms. It is not clear whether such changes in political objectives are necessary to motivate accumulation of excess capacity at the macro level: analysis of other success cases would be instructive. It would also be useful to explore cases where excess capacity did not lead to the kind of success experienced in connection with Swedish industrialisation. Given the role of chance and uncertainty in the development process, it likely that there are examples of countries and industries that failed to utilise their excess capacity: what were the factors inhibiting stronger performance? Studies of transition economies might be particularly interesting from this perspective. The command

economies promoted different institutions – both formal and informal – than market economies typically do. In the transition process, many countries are struggling to strengthen those market institutions that are weak or missing. However, in some areas, transition economies probably have more capacity than is needed, given the current challenges. What distinguishes useful excess capacity from entirely redundant capacity? Finally, firm and industry level studies of changes in technical paradigms – or nonlinearities in technical development – would be highly interesting to explore what strategies and firm characteristics are connected to success. The findings from the Swedish cases discussed in this article suggests an important role for excess capacity.

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Notes

[1] The broad definition of the innovation system includes 'all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as sub-systems in which learning takes place.' See B.-Å. Lundvall (1992) 'Introduction', in B.-Å. Lundvall (Ed.) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter, p.12.

[2] The importance of education and labour skills for industrial success has not diminished since the early era of Swedish industrialisation. On the contrary, the increasing supply of skilled labour has generally been considered one of Sweden's main comparative advantages over recent decades. Apart from a well-developed educational system of the classical type, attention has also been called to the existence of large scale vocational education programmes. As a result, it has often been argued that Sweden's particular comparative advantages are found in medium-level skills rather than the highest skill levels.

[3] The banking sector began to develop in the 1830s, and the expansion accelerated some decades later when liquidity increased as a result of rapidly increasing export incomes. Sandberg (1979) characterised the Swedish banking system in the mid-19th century as an 'impoverished sophisticate', meaning that it was much more developed than what could be expected looking only at the country's income level. The construction of the Swedish railway network from the 1870s was also important for the development of the banking system. The railways were largely financed with foreign capital, and several of the larger commercial banks were employed by the state to sell Swedish government bonds abroad. It is interesting to note that the foreign debt built up to finance the domestic infrastructure investments was comparable to the present debt burden of many developing countries. For instance, the interest payments to foreigners amounted to 10% of export value in 1908 according to Hallvarsson (1980). The ultimate repayment of the debt also illustrates the importance of chance and luck for long-term development. Most of the debt stock was denominated in German marks and French francs, and the heavy depreciation of these currencies during and after the first World War reduced the value of the outstanding liabilities to very modest amounts.

[4] Yet, agriculture was still the dominant activity. It was not until about 1900 that the GDP share of manufacturing equalled and eventually surpassed that of agriculture, and agricultural employment remained larger than manufacturing employment until the 1930s.

[5] The importance of chance is also reflected by the sizeable Swedish migration to America during the second half of the 19th century. This made it possible to urbanise at a rate that was consistent with industrial development. It is estimated that a quarter of the Swedish population (1.2 million people) emigrated between 1850 and 1910. As a result, Sweden avoided the worst problems related to rural poverty and mass unemployment: it is also likely that this helped avoid political problems caused by polarisation between left and right (Haavisto and Kokko, 1991).

[6] The narrow definition of an innovation system refers to the 'organisations and institutions involved in searching and exploring – such as R&D departments, technological institutes and universities.'

[7] These programmes are known under the acronyms T2F (Tryckteknisk forskning – printing technology), S2P2 (Surface Science Printing Programme), and FSCN (Fibre Sciences Communications Programme). A fourth programme, BiMaC (BioFibre Materials Centre) includes both pulp and paper technology and wood technology.

[8] In the business literature, there are some discussions about the need for excess capacity in conditions with substantial uncertainty (Campbell, 2004).