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The Swedish Paradox

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Keywords: Sweden; paradox; R&D; growth; entrepreneurship.

The Swedish paradox[1]

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This paper sums up the debate about the Swedish 'paradox' and provides new evidence. The paradox thought has emerged in different versions, which share the common basics that Swedish R&D expenditures are high, but do not produce sufficient economic results. This empirical paradox is part of a more general debate concerning relations between R&D and growth. We show that the theoretical underpinnings of the paradox are rather weak. There is a long chain of different gears between R&D, high-tech and growth, which should lead to expectations of high variation among countries. Previous evidence suggests that Sweden appears to have problems in two of these gears, the entrepreneurial climate and innovation to high-tech production. We support this conclusion on new empirical results. First, we show that the high persistence in concentration of R&D to a few multinationals

[1] This paper has benefited from the many useful suggestions we got from a seminar held in Lund in October 2005, and an earlier version presented at the Uddevalla symposium in September 2005. In particular we thank our commentators in Lund, Merle Jacob and Annika Rickne.

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remains, which in itself is an indication of weak entrepreneurship. Second, Sweden is still behind the OECD in high-tech and medium-high-tech exports, given her R&D intensity, although she is catching up. Moreover, employment figures in the high-tech sectors point to a more favorable development. Academia has been suggested to be another weak component for interaction with business, but the empirical evidence is here scant and less transparent.

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1 Introduction

This paper sums up the debate about the Swedish ‘paradox’ and provides new evidence. Although this topic may appear specifically Swedish, we believe that elements of this discussion may be of relevance to a wider European audience, since the debate concerns the expected outcome from R&D on growth, and deals with issues such as the benefits from academia to business, lacking entrepreneurship and high dependence on large firms.

The idea of a Swedish paradox has appeared in three different versions, sharing the common stance that Swedish R&D expenditures do not produce sufficient economic results.

The first formulation of the Swedish paradox is that there was surprisingly low production of *high-tech products* in Sweden in relation to her high R&D expenditures (Edquist and McKelvey, 1998).[3] The second formulation of the paradox states that high-tech exports are

[3] Apparently this ‘paradox’ was noted already in 1991 although not labeled as a Swedish one. The notion about a Swedish paradox originally appeared in a working paper in 1996 (Edquist, 2002).

low given the high R&D investments (Braunerhjelm, 1998). The third formulation of the paradox is more general and states that Sweden is inefficient in transforming its high R&D expenditures into productivity and growth (Andersson et al., 2002) or more generally that economic performance is poor (Klofsten, 2002). This, if it holds true, is of course interesting but not very illuminating, it just informs us that there may be some problems on the long road winding from inventive input to GDP. One fact that has been used to demonstrate the existence of a Swedish paradox in this version is that Swedish growth has been relatively sluggish since the early 1970s. Sweden's GDP per capita dropped from fourth to fifteenth place among OECD countries between 1970 and 2003 (Marklund et al., 2004). Also, Sweden invests more R&D in relation to GDP than any other country.

We aim here at scrutinizing the Swedish paradox and start in Section 2 with a discussion about the relationships between R&D and growth. We argue that in a strict meaning there is no paradox, since there are more reasons to expect high variation among countries, than there is to expect a simple and strong relationship where R&D efforts automatically are transformed into growth. We focus the discussion on four gears on the long way between R&D and growth: A) R&D to inventions, B) inventions to innovations, C) innovations to high-tech production, and D) high-tech production to growth.

In Section 3 the different previous formulations of the Swedish paradox are treated at some length. Section 4 gives up to date evidence of R&D and growth. Section 5 explores the gear between inventions and innovations, by looking at empirical facts of Swedish entrepreneurship. Section 6 discusses the role of Swedish academia for entrepreneurship. Section 7 discusses another gear: the one between innovations and high-tech production.

Section 8 concludes by a summary of our results, policy implications, and suggestions for further research.

2 A proportional relation between R&D and growth?

Growth theory provides a natural starting point for discussing the relationship between R&D and growth. Endogenous growth models ultimately make a growing stock of knowledge contributing to growth, where the most well-known models (Romer 1986, 1990, 1994, Grossman and Helpman 1991a, b, 1994, and Aghion and Howitt (1992) all imply a proportional relationship between R&D and GDP growth in the steady state. Jones (1995) questions this proportional implication by pointing out that the number of scientists engaged in R&D in advanced countries has grown dramatically over the last 40 years, while growth rates either have exhibited a constant mean or have even declined on average. This empirical critique of the idea of a simple proportional relationship between R&D and growth led Aghion and Howitt in one of their model variants (1998, 404 pp.) to modify their original (1992) model so that rising R&D in a steady state does not cause an increased growth rate. This is because of increasing complexity of technology, which makes it necessary to raise R&D over time just to keep the innovation rate constant and since R&D at a higher level gives rise to relatively smaller spillover effects. Easterly and Levine (2001) contest the claim by Jones (1995) that growth rates have not been increasing. They also claim that no growth model to date can adequately fit the growth experience of all countries and periods. Thus, there is no automatic reason to expect a very high return from R&D investments on growth.

Going beyond the somewhat mechanistic view of formal growth theory, we propose an analytical scheme, see Figure 1, to illuminate why there is no proportional relationship between R&D and growth. We argue that variations in R&D to growth ratios among countries should be large. The distinction between *return* and *variation* is important. The return aspect can be addressed by the concepts *low versus high- geared relationships* that form intermediate steps in the chain ranging from R&D to GDP. The variation in R&D to GDP is addressed by the concepts *weak or strong linear relationships*. Generally every reason put forward for low-geared relations has the potential also to affect variations among countries, since the gear can be different.

In the following we discuss some of the gears that lead to different R&D-growth relationships for different countries – and hence is a way of systematizing why Sweden may have lower geared relationships than many other countries. Our arguments are summarized in Figure 1, with arrows labeled A, B, C and D for the different gears. Even though the linear model of innovation has been condemned by innovation scholars (e.g. Kline and Rosenberg, 1986), for reasons of dynamic feedback loops, we think it would be a mistake not to have an idea of the *main direction* of relationships. This means in terms of our Figure 1 that we believe that R&D mainly contributes in the direction of *invention*; inventive activity normally contributes to *innovation* which affects high-tech production, which in turn makes up part of GDP. We have in our figure added academia to the left in this chain of events; its main effects are on the R&D capabilities of firms, the entrepreneurial climate and inventions, i.e. not yet commercialized efforts. This assumption reflects the Swedish institutional feature that academia only plays a limited role in direct commercial activities, a feature also shared with other European countries.[4] Some of the relationships between the boxes in Figure 1, marked by dashed lines, are only briefly touched upon in the present paper. The reason why we do not put much emphasis on these links is that they may not constitute the core of the ‘gear-relationships’, but also because research may be lacking in these areas.

Gear A: *R&D to inventions*

The first gear deals with the link from R&D to invention. Not only has the innovation literature questioned the automatic link going from inventive inputs to invention; it also stresses that other inputs of less formal, yet inventive, character, may also lead to inventive outcome[5] and are crucial to the innovation process. Moreover, the empirical construct of R&D statistics is somewhat problematic. R&D here denotes resources specifically set aside for the purpose of inventing. This means that staff also engaged in production does not count. This tends to bias data towards showing larger firms to conduct more R&D by virtue of their larger resource endowments. This means that R&D data should ideally be complemented by other invention data, and economies one with a high proportion of large firms may report higher R&D figures.

Gear B: *Inventions to innovations*

A second reason not to expect too strong linear relations between R&D and growth is that it is not sufficient for R&D efforts to translate into inventions. In order for them to become

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[4] Sweden may be moving in the direction of more commercialization activities in academia, following an official report to the Swedish government (SOU, 2005).

[5] These include lead time, learning curve advantages, marketing and customer service, as stressed by Levin et al. (1987).

actual innovations, i.e. to diffuse on the market, there is a need for *entrepreneurial activities* (Gear B_1) to be effective. The entrepreneurial link has been the latest amendment to endogenous models of economic growth (Acs et al., 2004). In addition, academic life may be more or less beneficial for gear B. *Academia* (Gear B_2) can have a direct positive effect on entrepreneurship, which is the case when there are spin-offs (new enterprises created by people employed in academia). A well-functioning higher education system in addition has more important effects on R&D and growth than this direct one. It provides the skill and knowledge basis for inventions in general and may affect the efficiency in transforming R&D into inventions.

Gear C: *Innovations to high-tech production*

There is a gear between innovations and domestic production. This gear depends on the exchange with the global economy, because knowledge is partly a public good and therefore diffuses internationally. Generally the growth rates of countries are more similar than the R&D investment ratios among countries. This partly common process of world-wide economic growth implies less reason to expect linear relations between own R&D and production for small, open countries, and more reason to expect this for larger integrated economies like the US. Countries more talented in absorbing knowledge from this common pool by imitation than others may perform better than their own R&D investments would allow. In addition, not only are there spillovers due to imitation, but it may also be the case that inventions or innovations generated in one country will not result in any related production there at all. They may instead directly lead to production in other countries.

Thus the gear for individual countries between innovations and production is affected by the exchange-flow of innovations with the 'world pool' of ideas.

Whether a country is capable of reaping the fruits of its own R&D or not have been measured by production indicators like high-tech production, high-tech exports and employment in high-tech industries (Edquist and McKelvey, 1998, Braunerhjelm, 1998). The construct "high-tech" is built on R&D-intensity, so focusing on its production is a natural consequence of studying the effects of business R&D.

Gear D: *High-tech production to GDP*

High-tech indicators only partly reflect total production in a country, which also consist of low- and medium-tech industries, service production etc. Moreover, even though high-tech industries are the most R&D-intensive ones, R&D is conducted elsewhere, also in the low-tech and medium-tech industries. One rationale for focusing on high-tech industries rests in their spillover-generating capability, e. g. they influence growth in other sectors. However, market structures (e.g. monopolistic or competitive) and other factors may limit spillover characteristics or generate spillovers outside the high-tech industry.

{Figure 1 about here}

To sum up, the many gears between R&D and GDP growth make it quite natural that countries may differ and so we should perhaps not be so surprised to find that Sweden (or any other country) may differ from the average with respect to the R&D-GDP relationship.

In the remainder of the paper we will focus on the empirical evidence for there being any spectacular results, or a paradox, for Sweden and to what degree such results may be due to malfunctioning gears.

3 The Swedish paradox: three formulations

Edquist and McKelvey (1998) had a rather precise definition of a Swedish paradox. It referred to the finding that the production of R&D-intensive products in Sweden was relatively lower than in other countries, despite a high R&D-intensity. OECD uses R&D-intensity to divide industries into low, medium and high-tech. A reason why high-tech, and hence R&D-intensive, production may be considered particularly beneficial, rests in its potential for generating externalities or spillovers.[6] This may for instance contribute to the emergence of firms in the formation of geographical clusters based on so-called Marshallian localization externalities (Marshall, 1920). These encompass the emergence of "subsidiary trades" around an industry, labor pooling and increased flows of knowledge about inventions and machinery ('knowledge spillovers').[7]

Edquist and McKelvey (1998) prefer to examine production rather than export data, since they argue that it is "production and development of technologies which lead to significant long term positive externalities such as cumulative development of knowledge. Export data only imperfectly reflects this." Edquist (2002) maintains that a notion of paradoxical R&D-investments should at least partially be related to the (in)ability to generate commercially viable innovations. In a preliminary investigation, Bitard et al. (2005) maintain that a paradox still exists when Sweden is compared to other small countries.

[6] The latter term is often used to denote positive side-effects on actors beyond those intended by the producer of an good.
[7] See e.g. Ejermo (2005a) for further discussion.

A second and slightly different version of the Swedish paradox is proposed by Braunerhjelm (1998) who argues that due to the theory of comparative advantage, a country that invests heavily in R&D should also be exporting high-tech products. Exports may in contrast to production reflect innovative advantage that extends beyond the borders of the own nation. Braunerhjelm (1998) finds that this is not the case for Sweden, since the Swedish technology balance of payment had a higher surplus (in relative terms) than any other OECD-country, suggesting that Swedish technology may be commercialized elsewhere.[8] Braunerhjelm (1998) also reports a high concentration, about 75-80 percent in 1994, of Swedish R&D to multinationals. Four multinationals in turn stood for slightly more than 70 percent of this, or roughly half of all Swedish business R&D. It also seems from Braunerhjelm's material that the concentration of R&D in the four most R&D-intensive multinationals has increased over the time-span 1965-1994. This is potentially important since a high concentration of R&D, may imply slow diffusion of new results that can be applied to other sectors and firms, since application of R&D generally requires own investments in R&D to generate absorptive capacity (Cohen and Levinthal, 1989, 1990). Studies confirm that there may indeed be limited spillovers due to R&D where Swedish firms are involved, whether internationally (Braconier et al., 2001) or domestically (Ejermo, 2004).

A third formulation of the paradox is more general and concerns the link between R&D and growth. Andersson T. et al. (2002) state that the Swedish paradox comes from large

[8] The technology balance of payment consists of sales of licenses and acquisition of R&D. With this definition, Swedish technology exports was roughly 350 million USD in 1997 – imports only 45 million USD.

investments that lead to doubtful results in terms of output, although they do not give a precise definition. Klofsten (2002) states that a basic problem of the Swedish innovation system is its inability to generate output related to inputs (research money vs. commercial results). He claims that Swedish firms both bring few new products to the market, and that there are few growing enterprises. The above stories are all related to the industry structure, and internationalization of Swedish firms. Highly related to this is the possibility that Swedish firms outsource or disintegrate their production chains so that while still being competitive in the product development phases (R&D) which is kept within domestic borders, production activities are increasingly undertaken abroad. Since it seems probable that the latter may be more labor-intensive, this means a net-emigration of job opportunities.

4 Swedish R&D and growth: the facts

Sweden is a small open economy; a large share of its industrial production is exported, which means that it is highly influenced by international markets and conditions. The industrial structure has become dominated by big multinationals many of which originated in one major innovation that was successfully sold abroad (Ejermo, 2004). Subsequent expansion was based on the ability of these firms to innovate incrementally and sometimes radically. This made these big firms conduct a lot of R&D domestically, while also generating substantial employment in Sweden, as well as in other countries. In addition, some large companies enjoyed (indirect) support, or were directly owned by the national government.[9] The governmental influence in these firms, however, has declined from the 1980s and onwards, influenced by the European integration process.

At first, we should update and possibly reconfirm the ‘established notion’ that: 1. Business R&D-expenditures are high, and 2. Recent growth has been sluggish.

The first point can easily be confirmed. Official statistics on R&D-expenditures, i.e. the sum of current costs and R&D investments, should be related to some size-measure, customarily GDP. Table 1 shows Gross R&D Expenditures (GERD), which covers both public and business R&D, and Table 2 gives Business R&D Expenditures (BERD) separately. Both measures are given as a share of GDP, and the countries are ranked. These figures reveal that Sweden had the highest GERD and BERD as a share of GDP in 2001 and also the highest BERD/GDP ratio in 2003. Moreover, Sweden has climbed compared with the 1991 ranking. Sweden ranked second in GERD/GDP and third in BERD/GDP in 1991. Furthermore the relative gap increased over this decade. Sweden invested 1.9 % in 1991, compared to the OECD average of 1.5 %. In 2001 her BERD/GDP ratio was 3.3 %, compared to an unchanged mean for OECD (1.5%). Among other business R&D-intensive countries we find Finland, Japan, Korea and the United States.

{Table 1 about here}

{Table 2 about here}

[9] Former state-owned Televerket is now partially private-owned under the name Telia-Sonera. This company formed a powerful and semi-public partnership together with Ericsson. Another important partnership was in defense between SAAB, Bofors and others with Technology for Sweden’s Security – a government agency (FMV, Försvarets Materielverk).

However, some researchers distrust the reliability or at least comparability, of R&D-figures, and claim that the high Swedish figures originate from specific Swedish features. One reason could be her high dependence on few large firms. For academia, Jacobsson (2002) and Jacobsson and Rickne (2004) argue that to compare R&D-expenditures of the higher education sector in different countries is misleading. Many countries allocate a lot of R&D resources to specific research institutes, while this type of research is allocated to the higher education sector in Sweden.

It has been customary in the Swedish debate to choose 1970 as a starting point for GDP/capita comparisons. Material from Groningen Growth and Development Centre and The Conference Board (GGDC) which covers a longer time-period spanning 1950-2004 (see Figure 2) reveals that Swedish growth has in fact been relatively high over the last 10-year period. Figure 2 shows real GDP per capita 1950-2004. As seen from Figure 2, Sweden was actually ahead of OECD (excluding Sweden) for the whole period up to 1970. But already by 1980 most of this difference was erased, and by 1990 OECD overtook Sweden. Following the wake of a Swedish crisis in the early 1990s, Sweden lagged substantially behind, but beginning in 1994 Swedish growth has on average been higher than that of other OECD-countries, so that by 2004 the gap was again miniscule. All in all, this seems to indicate close convergence of the GDP time-series in the long-run between Sweden and the rest of the OECD. Sweden is (presently) not underperforming compared to other OECD countries. A different issue is of course if she is underperforming in relation to her R&D.

{Figure 2 about here}

These results then reject the second ‘established fact’ we wanted to examine, that the recent growth experience has been sluggish. In recent years, overall economic performance in Sweden has been clearly better than the OECD average.

5 Entrepreneurial-innovation explanations (Gear B_1)

Entrepreneurs play a key role in introducing competitive pressure, which leads to transformation of economies. Much of this pressure seems to be absent in the Swedish economy (Jakobsson and Henrekson, 2001). However, some authors have stressed that industrial transformation and innovation sometimes take place in industries characterized by ‘swarms of innovation’ and sometimes in industries dominated by big corporations (Schumpeter, 1934, 1950, Breschi, et al., 2000). But there may be lock-in risks for an economy which for a long time has been path-dependent on the cumulative inventive capabilities of big corporations. Even though these firms may be highly successful, they may prevent restructuring and renewal that is essential for growth. There may be two ways these firms hinder such renewal: i) the institutional framework becomes adapted to the dominant business model and ii) crowding out of nascent businesses. We here examine to what degree Sweden is characterized by dynamic pressure or has too high concentration of R&D to big firms.

5.1 Concentration of R&D

As discussed above, high concentration of R&D in business has been a distinguishing feature of the Swedish National Innovation System for a long time. We now examine whether this pattern prevails using the latest available data. Given data on R&D on the firm level, concentration of R&D may be examined from two perspectives, both which can be used to examine R&D-expenditures and R&D man-years. The *first perspective* is to construct R&D concentration measures, see Table 3. There are two measures used in Table 3. First, the Hirschmann-Herfindahl index (HHI) [10] which is a standard measure for concentration. Second, we report on C5 and C20, which show the 5 and 20 most man-year-intensive, and R&D-expenditure-intensive firms, respectively. Statistics Sweden has improved their sampling so that now more firms are covered by the micro-data that they provide. This in itself would contribute to more dispersion other things equal. C5 and C20 have the benefit that they are less dependent on samples over time. Table 3 demonstrates that it is obvious that the Swedish structure is marked by a continued high concentration of R&D. Concentration as measured by HHI has gone up over time. The share of man-years among the top 5 has been ever increasing, only among the top 20 is the trend less clear, and if anything there is a slight downward trend. We conclude that concentration of R&D remains a distinctive feature of Swedish business R&D. This means that the findings of concentration in Braunerhjelm (1998) remain unchallenged.

[10] The HHI measure is:

$$HHI = \sum s_i^2$$

, where s_i is the share of man-years/R&D-expenditures in firm *i*. Total dispersion would imply that an infinite number of firms have equal shares, a figure that approaches zero, and hence the measure becomes zero. On the other end of the scale, just one firm has all the activity and the measure becomes 1.

{Table 3 about here}

The measures reported there do not consider changes in the composition of firms, such as if one company stops doing R&D, while another enters. The second perspective examines the stability of firms. Although R&D is concentrated to a small number of firms, these firms may change over time. The stability of R&D performers is illustrated in
Table 4.

{Table 4 about here}

Concentration may be a problem since R&D does not only contribute to inventions but is also often related to capabilities to access new knowledge (absorptive capacity). The big concentration of Swedish R&D may thus be a problem for a wide diffusion of knowledge and productivity gains. However, a lot of innovative activity is going on that is not adequately captured by R&D. That is, if new firms enter the material they probably add a new kind of R&D that in a sense could be more ’radical’. Clearly, the innovation process entails also an element of bringing new knowledge to the market through its embodiment in new firms. We can actually trace the percentage of firms that are the same from one survey to the next in the C5 and C20 measures discussed above.
Table 4 shows this and it is clear that we find a large stability in terms of what firms belong to the top R&D performers. Roughly half of the firms are the same throughout the period 1991-1999, whether we use C5 or C20 as our stability indicator.

5.2 Employment effects in R&D-intensive companies

A widely felt concern in Swedish society to date is that multinationals, which used to be successful in creating and maintaining jobs in Sweden, nowadays generate most of their employment abroad.

This seems to be true, but is still somewhat misleading. Recent evidence from ITPS (2004) shows that many employment changes are related to internationalization in ownership structure, as was the case when ASEA merged with Swiss Brown Boveri to form ABB in 1987. Hence, registered data cannot always be used to assess if employment is transferred abroad. But the material shows that more people are employed in other countries by companies that have Swedish origin and by the same token more personnel than ever are now in Sweden employed by a company which is foreign-owned. Hence, cross-border ownership has become increasingly important over the period 1996-2001. Since 1998, Swedish multinational groups have more people employed in other countries than domestically.

5.3 Start-ups and business formation

One indication of business renewal is given by the frequency of start-ups. Despite having low barriers to trade, investment and entrepreneurship, according to the Global Entrepreneurship Monitor (2005), Sweden consistently scores among the countries with the lowest start-up rates out of 40 countries (Ejermo, 2005b). In the U.S. the share of entrepreneurs in the population is 11.3 percent, while in Sweden only 3.7 percent take on this role. This rate is lower than for instance in Denmark (5.3 percent) and Norway (7 percent), (Global Entrepreneurship Monitor, 2005). The Confederation of Swedish Enterprise reports that only one of the 50 largest Swedish companies were formed after 1970, Tele2 in 1993 (Wallen and Fölster, 2005). This can be contrasted with the situation in the U.S. where the largest companies are frequently exchanged, and those with highest stock value are commonly quite young. This gloomy view of Swedish entrepreneurship does not accord with evaluations of her general competitiveness. Sweden ranks very high (3rd in 2004 and 2003) on the World Economic Forum's list of competitiveness. This ranking is based on sub-indices comprising technology, public institutions and the macroeconomic environment. Entrepreneurship and business renewal do not play more than indirect roles, but are especially important indicators for domestic employment generation.

6 Academia (Gear B_2)

This section mainly treats the empirical results regarding *interaction* between academia and entrepreneurship which contribute to innovation (Gear B_2 in Section 2). In this context we cannot completely avoid the debate about a so-called academic paradox. This debate has been somewhat confusing, and clarifying the issues at stake may therefore be to the benefit of the reader..

There are three tasks of universities and university colleges[11] in Sweden: 1. *Teaching*, which should be connected to research, 2. *Research*, whose direction is to be decided mainly by independent researchers, and 3. *Interaction with society* ("the third task"). The confusion referred to above emerges when some discussants have mixed up tasks 2 and 3. Certain facts cannot be disputed: Sweden has a lot of higher education R&D, see

Table 5, and she is doing well in terms of academic output. The expenditures on higher education R&D in relation to GDP are about double as high in Sweden compared to the mean of OECD countries (see

Table 5). A series of arguments put forward by Jacobsson (2002), Jacobsson and Rickne (2004) and Granberg and Jacobsson (2005) suggest that official figures on higher education R&D in Sweden may be overstated compared to other countries.[12] Jacobsson and Rickne (2004) in addition show that Sweden ranks as the second country (after Israel) in terms of publications in all sciences, in relation to GDP, and also ranks second if we restrict the results to natural science, engineering, and medicine.[13,14]

A cautious conclusion would be that Swedish academia is not unproductive (and may in fact be highly productive), judging from pure *academic criteria*. The confusion arises when these pure academic criteria are mixed with 'interaction goals' Andersson and Henrekson (2003) for instance claim that Jacobsson (2002) tries to explain away the "academic

[11] Focusing on higher education sector R&D is motivated by the fact that the bulk of academic and public research takes place in the higher education sector. The institute sector is in Sweden very small by international comparison. We restrict our discussion here to non-defense related public research, although defense R&D also has a role to play in Sweden.

[12] Two of the arguments: i) Costs for training a PhD student be higher because of stronger social networks, ii) block funding of academic R&D may be used for other things than actual research such as administration, development of graduate course, applications for fundings, internal inquiries, etc.

[13] The data are originally from NSF (2002).

[14] There are some signs though that Swedish publications in medicine are becoming less cited as compared to other European countries (Swedish Research Council, 2003).

paradox", in their definition apparently encompassing also effects on entrepreneurship (gear B_2). However, Jacobsson never discussed these matters, but focused on the scientific productivity of Swedish academics. Jacobsson (2002, p. 347) naturally agrees that universities play a role for technical change in society, where a central function is to make accumulated knowledge available; the university could be seen as a reservoir of knowledge. This reservoir is, of course, transferred primarily through teaching, at both the undergraduate and the graduate levels, but transfer also takes place in various fora where industry meets academia. The question then becomes if this transfer is efficient enough. We now turn to the evidence of these latter effects.

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Table 5 about here}

There are many ways in which academia may affect the innovation climate. The goal of research output in relation to research input is the main focus of the academic paradox discussion and the interaction goal can only be imperfectly addressed. Although *interaction* has been a part of the goals for the sector since the law changed in 1977, such contribution is not as easily assessed as more classically research-oriented activities, which to some extent may be assessed by quantity and quality of publications and by external evaluators. First, interaction is a very wide concept. For instance this interaction may consist of:[15] a) direct production of inventions/innovations, b) provision of meeting places where business and academia can meet, c) creation of networks, d) interaction with businesses – e.g. responding to their needs in terms of direction of research and adapting education to

[15] This listing is inspired by Jacobsson (2002).

economic needs and e) contribute/encourage the creation of spin-offs. These effects are almost by definition difficult to quantify. Secondly, a reason for difficulties in tracing the direct production of inventions/innovations by university staff rests in the Swedish institutional construct that ownership of inventions from university researchers/teachers is awarded to the individual who comes up with it, and not to the university. This is referred to as the teacher's exemption (*lärarundantaget*). A change in this law in the direction of more rights falling in the hands of universities may be under way following a report to the government (SOU, 2005). These proposed changes are to be accompanied by more transparency in terms of how many inventions are produced by university staff, regardless of whether these are eventually commercialized by the university itself or otherwise.

6.1 Evidence on gear B_2

Businesses created with the help of university and/or academic inventors provide a potential venue for dissemination of knowledge from the scientific sphere. Lindholm Dahlstrand (1997a) examines the origins of 60 small Swedish technology-based firms. Of these, 30 represent entrepreneurial spin-offs. Two-thirds of these 30 spin-offs have originated in private firms and only one-sixth in universities. The spin-offs grew faster than the 30 non-spin-offs, but there was a difference in the level of inventiveness. In Lindholm Dahlstrand (1997b), employment growth and technological development in terms of patenting of university spin-offs from Chalmers University of Technology in Gothenburg are compared with the development of other new technology-based firms. A general result is that corporate spin-offs have higher employment growth, while university spin-offs are more engaged in patenting activities.

Delmar et al. (2003) investigate the total Swedish population of academics with at least three year’s university education in natural sciences, technology and medicine. They find that such persons run their own businesses slightly more frequently than Swedes in general, but this result is entirely attributed to medicine academics; otherwise the number of businesses per capita is the same. Moreover, data shows that this business involvement by medicine academics is mainly comprised of consultancy as side-activities to their ordinary employment. They conclude that academic entrepreneurship is probably not going to be a major factor behind economic development in the future. Similarly Wiklund (2005) reports on the poor ambitions with regard to starting a new business among last-year engineers’ future career plans. These new engineers think that starting a business ranks as less likely, in decreasing order, than being employed, continued studies, and unemployment. The conclusion is that the incentives to start businesses are too poor, which is related to the reliance of the welfare-system on the status of being an employee. Incentives to be an entrepreneur should be more balanced relative to the incentives of being employed.

Inventions do not necessarily have to be transferred via new businesses, but may instead come through established companies. Goldfarb and Henrekson (2003) discuss whether Swedish large firms are able to fill this role. In their opinion, the Swedish business climate is not conducive to small businesses. They further argue that innovations may thrive in different milieus, i.e. small and large businesses may work better for different types of innovations. Hence, if one type of businesses (i.e. small) is lacking, this may reduce innovation. Goldfarb and Henrekson (2003) point to large differences between how the

American university system and the Swedish university system are run.[16] The American system is based on a "bottom-up" perspective; the universities have a considerably larger degree of freedom in deciding their own 'rules of the game', i.e. how teaching should respond to market signals, how universities should best make use of the commercialization abilities of innovations, etc. In contrast to Sweden, universities in the U.S. own the right to patented inventions ever since the implementation of the so-called Bayh-Dole act of 1983. It is stressed that the Swedish organizational setup may not be conducive to innovations, since universities have nothing to gain from allowing their researchers to engage in commercialization activities. Instead, it is argued that if the incentives between university and the inventor are aligned they may better work towards the goal of commercialization. This argument in favor of transferring the ownership right seems to us somewhat fuzzy, since Swedish inventors do in fact have the right to transfer ownership *a priori* to the engagement in inventive activities. For example, inventors may negotiate a deal that part of the invention falls to the university, and part to the researcher, prior to their engagement in a research project. The only difference to the U.S. system is then where the ownership rests by default.

An investigation by Sellenthin (2004) compares Sweden with Germany, where Germany recently transferred ownership from the inventor to the university. Sellenthin does not clearly favor abolishment of the Swedish university inventors' rights to patents, but his main conclusion is that abolishment would require a better support structure for commercialization of inventions with universities. In this endeavor he favors a centralized

[16] They claim that their findings have bearing to the larger group of the continental European university system as well.

organization that can pool the inherent risks, since only a fraction of patents generate commercial value. Such an institutional set-up would be especially important for a small country like Sweden. Today the most prestigious higher education institutions have their own technology transfer offices. In our interpretation, it seems likely that the resources available to these organizations are too small for them to be efficient and able to pool risks, especially since today's system allows some inventions to be commercialized outside the control of university. Sellenthin argues that there may be a selection mechanism at hand, so that excellent inventions are commercialized outside and mediocre ones within the university. Goldfarb and Henrekson (2003) also consider the risk that resources may be too scanty so that university's assistance may become less professional. So what are the effects of this system? Ideally one would like to know how many inventions are produced by academia and how valuable they are. Knowledge about this is almost entirely lacking in Sweden.[17] The value of patenting is uneven; few patents generate substantial income. In the U.S. this income is also highly unevenly distributed between universities, where mainly the most well-known institutions are able to capitalize on their commercialization strategies.

[17] We know of only two researchers that are dealing with this. Ingrid Schild at Umeå university has worked to find out patenting among inventors active at Linköping university and Devrim Göktepe at Lund university has a similar project going on to find inventors at Lund university. However, we do not know the value of the inventions created, and these are only two out of several universities.

7 A high-tech paradox? (Gear C)

A lot of attention in the discussion of the Swedish paradox has been given to the gear C, linking innovations to production, employment and production in high-tech sectors. Edquist and McKelvey (1998) and Braunerhjelm (1998) concluded that in the early 1990s Sweden was not efficient in transforming her research in high-tech into high-tech production or high-tech exports. We widen the analysis from a pure high-tech focus to a view where we also take in lower technology levels. This analysis is carried out by comparing R&D intensities on industries classified by OECD:s recent division into four different technology levels: 1. low-tech, 2. medium-low-tech, 3. high-medium-tech, and 4. high-tech.[18] We relate these R&D-intensities to exports and employment performance on the different technology levels and set this in comparison to the performance of OECD countries.

Table 8 and Table 9 of Appendix B show the R&D-intensity, here defined as R&D as share of value added in HT and MHT industries for available countries from OECD:s STAN databases. We have previously shown that Sweden has the world's highest business R&D-intensity. The additional information given by these tables is whether this R&D is evenly distributed across technology levels, and whether Sweden's R&D-intensity follows the same distribution as that of the whole OECD. One could, for example, imagine that a lot of R&D would fall in categories thought of as low-tech due to Sweden's traditional export-dependence on raw-materials such as wood products and steel.

Table 8-Table 9 show that Sweden ranks as the country with the highest R&D-intensity in high-tech industries in 1990, 1995 and 2000 out of 13-18 countries. The gap is large to

[18] The list of branches of these four technology levels is given in Appendix A.

Canada (the second highest), which had an R&D-intensity of roughly half that of Sweden. In MHT, Sweden ranked as 1-3 in 1990, 1995 and 2000 out of 12-17 countries, and the gap is equally large as in HT. In medium-low-tech and low-tech Sweden does not have quite the same leading role in R&D intensities. The data shows that Sweden ranked as the country with 4^{th}-6^{th} highest R&D-intensity in medium-low-tech industries and 1^{st} -4th in low-tech.[19] Sweden's R&D-intensity compared to other countries is relatively higher in HT industries, than in industries with lower tech-level.

Turning to the performance measures of these sectors, Table 6 compares the export performance of the four technology levels *relative* to R&D intensity.[20] The following expression is evaluated:

$$E_i = D_i / C_i,$$

where D_i is exports in Sweden in technology level i relative to OECD-countries, and C_i is Sweden's R&D-intensity relative to that of the G7-countries.[21] It is clear that Sweden underperforms in HT and MHT exports compared to R&D-intensities. Only 50% of the average value of other developed countries is reached. In medium-low- and low-tech, on the other hand, she is nearly at the average level. Relative employment performance is given in Table 7 together with a comparison of the results from the previous studies by Edquist and McKelvey (1998) and Braunerhjelm (1998). In order to make our results

[19] Data available on request.
[20] For employment, the available data forced us to choose between employment as a share of all employed or as a share of all employed in manufacturing. The former measure would capture changes in the distribution between services and manufacturing and relative changes in employment shares between high-tech and medium-high-tech. The latter measure only captures relative changes within manufacturing employment. For Sweden both measures revealed very similar patterns, so we chose the practical approach of using shares of manufacturing employment since there were data for more countries available.
[21] Unfortunately R&D-intensities and exports data were not available for all years for both the G7- and the OECD-group, but the data indicates that this approximation does not alter the results.

comparable with the mentioned studies, these measures are not adjusted for R&D-intensities as we did in Table 6.

Table 7 shows that while Swedish employment in HT has increased more than in other countries, the share of Swedish HT exports has not risen to the same degree. Actually Swedish HT exports is fluctuating around the OECD average. There is a significant drop in 2003 which can be attributed to the poor performance of one single actor in high-tech: Ericsson, which was hit by the crises in the telecommunications sector in the early 2000's. Annual growth in telecommunications exports (current prices), according to data from Statistics Sweden (2005), are shown in Figure 3. Of the 50 largest Swedish export performers, Ericsson alone was responsible for 27 percent in 1999 (Sönne, 2000); exports which for the most part falls under the heading of the telecommunications sector. The late 1990s and the year 2000 saw two-digit increases in export-growth of this sector, which was replaced by a negative development 2001-2003. In 2004 and 2005, Ericsson has managed to turn this problematic situation around, and growth is again very impressive. This means that Swedish high-tech development is very dependent on one single company. This is an unfortunate situation for Sweden as a nation, since it implies high vulnerability, and it also reveals that the choice of reference year is crucial for outcome of comparisons.

{Figure 3 about here}

How does Sweden compare to other OECD-countries in medium-high-tech industries? In terms of employment, Sweden had the second largest share of jobs in the MHT sectors throughout the period, second only to Germany. In MHT exports, Sweden ranks as an average country consistently over time.

In conclusion, Sweden seems to be doing well in employment in both HT and MHT, whereas exports from these sectors are around the same as for other OECD-countries. The main reason for the discrepancy between employment and export figures for HT and MHT is due to path dependence, where Swedish production is heavily natural-resource- based. These industries are capital intensive rather than labor intensive. In addition, the favorable employment figures have more important direct effects on jobs and welfare than exports as such.

The very large depreciation of the Swedish currency that occurred in 1992 stimulated export-led growth. In real terms, exports have grown 7% per year 1995-2004 (Statistics Sweden 2005). Natural- resource intensive exports (e.g. iron, steel and forest-based industries) only grew by 3% per year in this period and HT and MHT exports increased even faster than the average 7%.

{Table 6 about here}

{Table 7 about here}

It seems that Sweden's specialization is only slowly moving in a more high-tech direction. This is still more spectacular in view of the increasing R&D-specialization of the economy. We would like to suggest a possible explanation to the R&D-intensive mode of production chosen by Swedish industry: low costs for engineers and academic staff in general. These relatively low costs contributed to high R&D-intensity in all sectors, but particularly in high-tech-industries. This would explain why Sweden has an R&D-intensity relatively higher than the G7-countries in high-tech industries. Such an argument on relative costs would also imply a comparative advantage in the sense that R&D is conducted in Sweden, while the high-tech products are produced elsewhere, where R&D is more expensive.

8 Concluding discussion

In this final section we will sum up our main arguments and results and in addition make some suggestions for further studies in the field.

The Swedish paradox has been formulated in three versions, with the common feature of stressing high R&D efforts in relation to meagre results:

1) Edquist and McKelvey (1998) original formulation of the paradox was that the manufacturing of R&D-intensive products in Sweden was surprisingly low given her large R&D-expenditures.
2) Braunerhjelm (1998) found that the technology balance of payment was on higher surplus in relative terms than for any other country. In addition, Swedish high-tech exports was found to be lacking and was hence formulated as a Swedish export paradox.
3) Andersson et al. (2002) talks of output in a more abstract sense, referring to growth and productivity at the national level. Klofsten (2002) claims that Sweden brings few new goods to the market and that there are few new enterprises.

Is there anything paradoxical in high R&D and more modest high-tech production, exports and growth? We argue that in a strict sense there is no reason to talk of a Swedish paradox, once we look at the theoretical underpinnings of such an idea. There is no sound reason to expect a strong proportional relationship between the level of R&D in a country and its growth performance. This is because of several gears on the road from R&D to growth. The larger the possible variation in these gears, the larger possible variation could result in the R&D to GDP ratios of different countries, and the weaker thus the proportional relationship. The four reasons (gears) we proposed for this lack of a simple proportional relationship are:

A) R&D does not necessarily result in a proportional amount of inventions,

B) Inventions do not always become innovations, due to lacking entrepreneurial functions or because of lacking demand.

C) Innovations do not always result in domestic high-tech production, because of exchange with the world pool of innovations

D) There are other sources for growth than the direct contribution from growth of high-tech sectors, or spill-over effects from high-tech to other sectors.

.That the relationship between R&D and growth is not a simple proportional one may seem obvious, but apparently is not so for many policy makers or even academic researchers, something which is presently expressed in the Lisbon-strategy of increasing the R&D/GDP ratio of EU member states to 3% to make their growth rates increase and possibly make the European economy surpass that of the US. This strategy determines R&D investments of billions of Euros at the moment. We therefore think that there are reasons for a wider audience to contemplate a bit on the actual relations. Sweden is already at a level above 3%. She presently invests more than 4% of her GDP in R&D. If this does not produce expected results in terms of growth, why will there be such results on the EU level?

Although there is no reason to talk of a paradox in a strict meaning, we still think it is worthwhile to look into the somewhat surprising results for Sweden that drew our predecessors' attention to these issues in the first place. We use the gears A-D to organise our discussion on possible explanations for the Swedish paradox and examine some recent evidence on indicators used by our predecessors and add some new indicators.

Our empirical examination focuses strongly on gears B and C. This is symptomatic for the way the discussions have been carried out so far and shows that the gears A and D have been pretty much neglected. We recommend that future research devote more attention to these two gears, as they are also important for explaining returns and variations in the R&D to growth relation.

There seems to be a problem with the transformation of inventions to innovations (Gear B). One problem that seems to prevail in the Swedish innovation system is the low willingness of people to take on entrepreneurial roles (Gear B_1). There is a uniform picture given by different investigations that Swedes are not keen on becoming entrepreneurs (e.g. Delmar et al.2003, Wiklund 2005). This suggest that the incentive structure may need to be changed.

One weakness of the Swedish innovation system that prevails according to our examination here is the high concentration of R&D in a few large enterprises. We showed that this pattern has not weakened during the last years. It seems possible that this industrial structure is detrimental for spill-over effects within Sweden (Ejermo 2004), and prevents innovative behaviour and start-ups of small businesses (Jakobsson and Henrekson, 2001; Goldfarb and Henrekson, 2003). Especially the possible hindrance to innovative behaviour needs further empirical support.

Some researchers like Henrekson and Rosenberg (2001), Andersson and Henrekson (2002) and Goldfarb and Henrekson (2003) claim that an important component of the Swedish paradox is rooted in a sub-paradox: high expenditures of university R&D and poor output from this. In terms of output from academic research Sweden ranks second both in terms of publications in all sciences and in natural sciences, medicine and engineering (Jacobsson and Rickne 2004). A more important issue than sheer academic output is the wider influence from academia on entrepreneurship (Gear B_2). The few studies available on this issue do not show that Swedes with academic exams are more likely to start up new enterprises than the average population, especially not ones that generate employment. This is another field of study that deserves more attention.

There seems to be some leakage of innovative ideas (gear C). Sweden does not seem to reap all the benefits from her innovations in terms of high-tech production. Our results show that exports and employment in high-tech are much better than previous authors have claimed. Exports have improved relatively since 1990. Braunerhjelm (1998) did not acknowledge that there was in fact a positive trend for high-tech exports between 1970 and 1993 in his data. We show that this trend has continued. The export shares for HT are sensitive to the year picked for comparison, since Sweden fluctuates around the OECD average between 1990 and 2003. Employment in high-tech and medium-high tech has improved. The HT employment ranking was 7 in 1990 and 3 in 2003. In medium-high-tech Sweden maintained the second largest share of employment throughout the period 1990-2003.

There is more warrant for focusing on the more optimistic figures of employment in HT and MHT than to look at export shares for HT and MHT. Relatively low export shares for HT and MHT depends on Swedish comparative advantage in natural-resource intensive exports. This advantage has its root in the fact that Sweden is richly endowed with iron and forests and has over time built up specialist competence in the refinement of these goods. The forest and iron industries are capital intensive, thus not providing many job opportunities. The HT and MHT industries provide many job opportunities in Sweden, because highly qualified people such as engineers and researchers can be hired at low cost in Sweden. The Swedish wage structure is very compressed in an international perspective. This is the result of many years of directed policy towards decreasing wage differences, where strong unions have played an important role.[22] It could be argued that employment is more directly connected to welfare than exports.

We find it likely that Sweden, a small open economy with lots of international trade and good skills in English, has unusually large exchange with other countries in terms of

[22] Sweden has the lowest Gini-coefficient together with Denmark among the OECD-countries (Ejermo, 2005b).

innovative ideas. Our absorptive capacity, imitative skills, are high according to the Community Innovation Surveys (as shown by Bitard et al. 2005) and we are likely to give lots of spill-overs to other countries. As long as there is a balance in the in- and outflows of knowledge this should hardly be thought of as a problem, but as a strength. The net-balance of this international exchange is however not easy to measure, but there is no a priori reason to assume that it is negative for Sweden. From a Swedish policy perspective, the exchange of ideas is a neglected dimension and something that should be studied more.

With respect to gear D (high-tech to growth) we have demonstrated that Swedish R&D is particularly pronounced in high-tech and medium-high-tech, but also above average in low-tech and medium-low tech industries. Sweden has managed to get high export in low-tech and medium-low-tech industries and hence the return in Sweden from R&D efforts in these sectors has been good. This is a perspective that has not been lifted forward before in the R&D and growth debate and in doing so we would also like to stress that more of a coherent growth theory that takes all the dynamic interactions between domestic sectors and the global economy into account is needed. R&D is not the sole driving force for growth in any sector. To investigate R&D and production in high-tech industries and talk of a paradox is a too simplistic perspective.

9 Main text figures

Figure 1. The interrelations between R&D and growth.

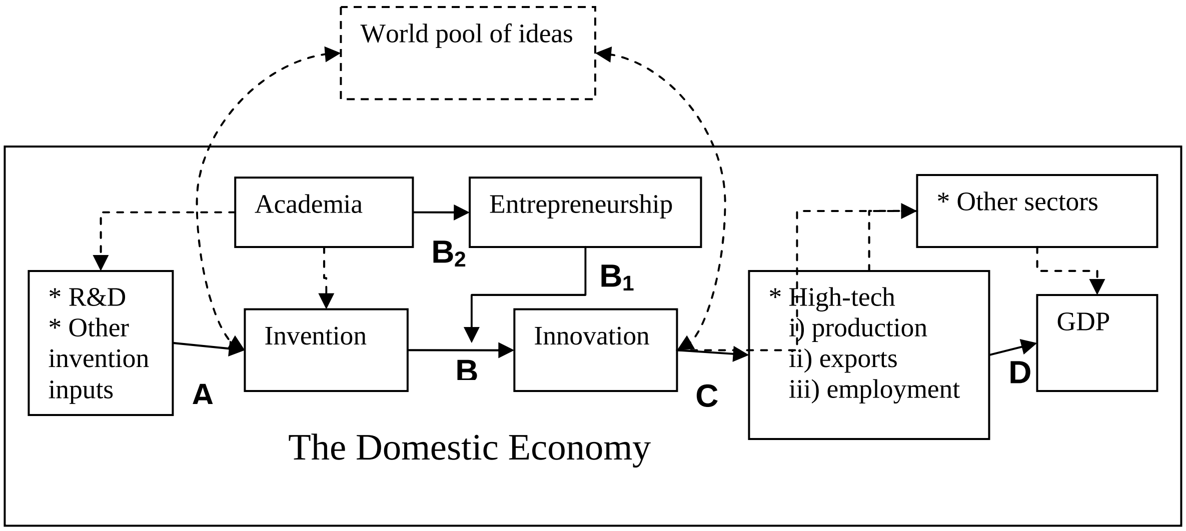
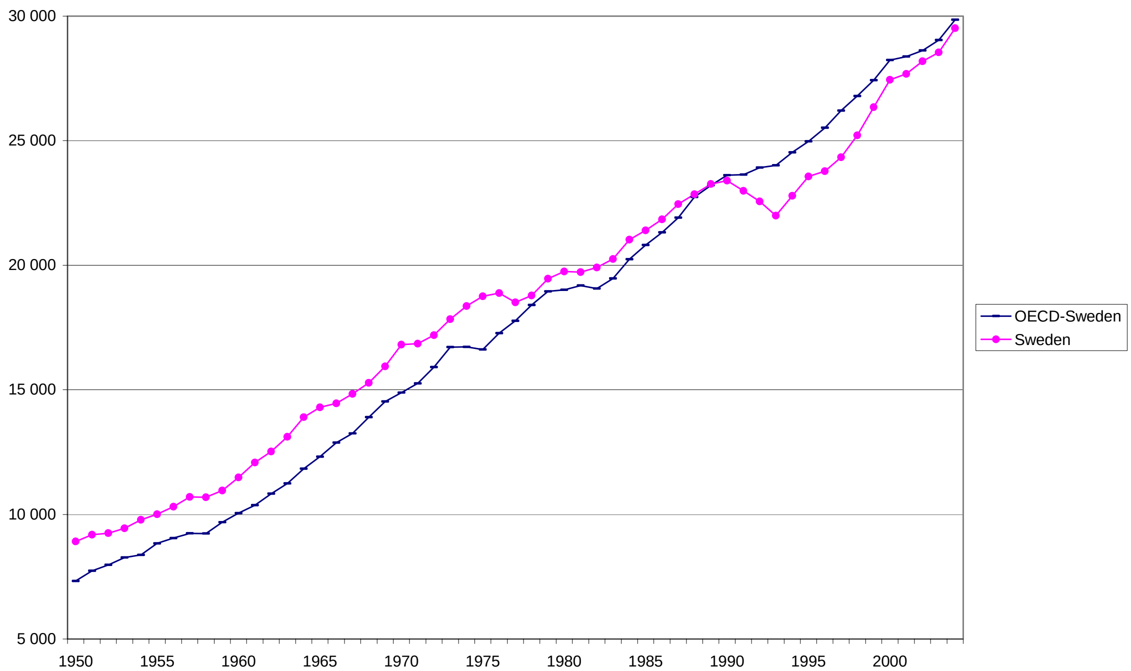


Figure 2. GDP per capita 1950-2004, in constant 2002 year's prices, using OECD:s EKS[23] PPP method. The OECD group is defined based on pre 1994 OECD membership.



Source: Groningen Growth and Development Centre and The Conference Board, Total Economy Database, August 2005, http://www.ggdc.net. Data includes West Germany before 1988 and Germany from 1989 onwards.

[23] The EKS method adjusts for the effect that lower prices generally induce higher demand, and hence the comparison basket of goods differs between countries.

Figure 3. Export development in the Swedish telecommunications sector 1999-2004; annual percentage growth, current prices. Source: Statistics Sweden (2005).

10 Main text tables

Table 1. Gross Domestic Expenditure on R&D (GERD) as a percentage of GDP. Source: OECD (2005).

Country	1991	2000	2001	2002	2003	Rank 1991	Rank 2001
Australia		1.56		1.62			
Austria	1.44	1.91	2.04	2.12	2.2	16	12
Belgium	1.62	2.04	2.17	2.23	2.31	14	10
Canada	1.6	1.93	2.08	1.96	1.94	15	11
Czech Republic	1.9	1.23	1.22	1.22	1.26	10	16
Denmark	1.64		2.41	2.53		12	8
Finland	2.04	3.4	3.41	3.44	3.49	8	2
France	2.37	2.18	2.23	2.26	2.19	5	9
Germany	2.52	2.49	2.51	2.53	2.55	4	7
Greece	0.36		0.65			26	24
Hungary	1.06	0.8	0.95	1.02	0.95	19	20
Iceland	1.17	2.75	3.06	3.09	3.04	18	4
Ireland	0.93	1.14	1.11	1.12		21	18
Italy	1.23	1.07	1.11	1.16		17	18
Japan	2.94	2.99	3.07	3.12	3.15	1	3
Korea	1.82	2.39	2.59	2.53	2.64	11	6
Luxembourg		1.71					
Mexico		0.37	0.39				27
Netherlands	1.97	1.9	1.88	1.8		9	13
New Zealand	0.98		1.14		1.16	20	17
Norway	1.64		1.6	1.67	1.75	12	15
Poland	0.76	0.66	0.64	0.58	0.56	23	25
Portugal	0.57	0.8	0.85	0.94		24	22
Slovak Republic	2.13	0.65	0.64	0.58	0.58	6	25
Spain	0.84	0.94	0.95	1.03	1.1	22	20
Sweden	**2.72**		**4.27**			**2**	**1**
Switzerland		2.57					
Turkey	0.53	0.64	0.72	0.66		25	23
United Kingdom	2.07	1.86	1.87	1.9	1.89	7	14
United States	2.71	2.72	2.73	2.66	2.6	3	5
EU-25		1.8	1.83	1.85	1.85		
Total OECD	**2.21**	2.23	**2.27**	2.25	2.24		

Source: OECD (2005).

Table 2. Business Enterprise Expenditure on R&D (BERD) as a percentage of GDP.

Country	1991	2001	2002	2003	Rank 1991	Rank 2001	Rank 2003
Australia	0.58	0.81	0.79		17	15	
Austria			1.42				
Belgium	1.08	1.60	1.63	1.71	10	9	7
Canada	0.79	1.27	1.09	1.03	14	12	11
Czech Republic	1.32	0.74	0.75	0.77	8	19	15
Denmark	0.96	1.65	1.75		12	8	
Finland	1.16	2.42	2.41	2.46	9	2	2
France	1.46	1.41	1.43	1.36	6	11	9
Germany	1.75	1.75	1.75	1.78	4	7	6
Greece	0.09	0.21	0.20	0.20	24	28	21
Hungary	0.44	0.38	0.36	0.35	19	24	19
Iceland	0.26	1.80	1.77	1.67	20	6	8
Ireland	0.59	0.78	0.77	0.80	16	18	14
Italy	0.68	0.55	0.56	0.55	15	20	17
Japan	2.08	2.26	2.32	2.36	1	3	3
Korea		1.97	1.90	2.01		5	4
Luxembourg							
Mexico	0.09	0.12			24	29	
Netherlands	0.98	1.10	1.02	0.99	11	15	13
New Zealand	0.26	0.42		0.47	20	23	18
Norway	0.89	0.96	0.96	1.00	13	16	12
Poland		0.23	0.12	0.15		27	22
Portugal	0.13	0.27	0.30		22	25	
Slovak Republic	1.59	0.43	0.37	0.32	5	22	20
Spain	0.47	0.50	0.56	0.60	18	21	16
Sweden	**1.87**	**3.31**		**2.95**	**3**	**1**	**1**
Turkey	0.11	0.24	0.19		23	26	
United Kingdom	1.39	1.24	1.26	1.24	7	13	10
United States	1.97	1.99	1.87	1.79	2	4	5
EU-25		1.17	1.17	1.17			
Total OECD	**1.52**	**1.57**	1.53	**1.51**			

Source: OECD (2005).

Table 3. Concentration of R&D in Swedish companies.

	HHI Man-years	HHI R&D-exp	C5 man-years	C5 R&D-exp	C20 man-years	C20 R&D-exp
1991	0.026	0.034	27.8%	34.0%	60.1%	65.9%
1993	0.026	0.031	29.4%	31.8%	58.2%	64.9%
1995	0.024	0.031	27.9%	33.2%	56.1%	62.5%
1997	0.026	0.032	30.0%	32.7%	56.9%	62.3%
1999	0.028	0.040	30.1%	36.8%	57.0%	65.4%
Trend	+	+	+	+	-	~ 0

Table 4. Share of firms that are the same from one survey to the next in R&D concentration measures.

	C5 man-years	C5 R&D-exp.	C20 man-years	C20 R&D-exp.
1991 to 1993	80%	70%	100%	70%
1993 to 1995	80%	85%	60%	80%
1995 to 1997	100%	80%	80%	85%
1997 to 1999	60%	90%	80%	90%
1991 to 1999	60%	55%	40%	65%

Table 5. Higher education R&D expenditures as a percentage of GDP.

	1991	**1999**	**2001**
Belgium	0.43 c	0.41	0.42
Canada	0.49	0.53	0.59
Czech Republic	0.03 *g*	0.14	0.19
Denmark	0.37	0.43	0.45
Finland	0.45 a	0.64	0.62
France	0.36	0.37	0.42
Germany	0.41 *a*	0.40	0.41
Greece	0.12	0.33	0.29
Hungary	0.22	0.15	0.24
Iceland	0.34	0.50	0.58
Ireland	0.22 *c*	0.25 *c*	0.24 *c*
Italy	0.26	0.33	0.36
Japan	0.51 f	0.44	0.44
Korea	..	0.27 d	0.27 d
Luxembourg	..	..	0.01
Mexico	..	0.11	0.12
Netherlands	0.58	0.53	0.51
New Zealand	0.28	0.34	0.35
Norway	0.44	0.47	0.41
Poland	..	0.20	0.21
Portugal	0.23 *c*	0.29	0.31
Slovak Republic	0.08 g	0.07	0.06
Spain	0.19	0.27	0.29 c
Sweden	**0.75**	**0.78**	**0.83**
Switzerland	..	..	..
Turkey	0.38	0.35	0.43

United Kingdom	0.34	0.37	0.41
United States	0.39 e	0.37 e	0.39 e
EU-25	..	0.37 *b*	0.39 *b*
Total OECD	0.36 a,b	0.37 b	0.40 b

Source: OECD (2005). a) Break in series with previous year for which data is available. b) Secretariat estimate or projection based on national sources. c) National estimate or projection. d) Excluding R&D in the social sciences and humanities. e) Excludes most or all capital expenditure. f) Overestimated or based on overestimated data. g) Do not correspond exactly to the OECD recommendations. p) Provisional.

Table 6. R&D-intensity and export performance in low-, medium-, medium-high-tech and high-tech industries.

	High-tech		**Medium-high-tech**		**Medium-low-tech**		**Low-tech**	
	1995	2000	1995	2000	1995	2000	1995	2000
A. Sweden – R&D-	41	48.9	12.5	12.8	2.6	2.5	1.7	1.4
B. G7 – R&D-intensity	23	22.3	8.6	9.7	2.2	2.2	-	1.1
C = A/B	1.8	2.2	1.5	1.3	1.2	1.1	-	1.3
D. Sweden exports index, OECD = 100	100.0	106.5	84.6	84.6	112.0	111.5	120.8	114.9
E = D/C	56.1	48.6	58.2	64.1	94.8	98.1	-	90.3

Table 7. Summary of 'high-tech' performance and corresponding results from Braunerhjelm (1998) and Edquist and McKelvey (1998).

Paper	Method	Production index	Employment ranking	Employment index	Exports ranking	Exports index
Ejermo & Kander Employment: 21 countries Exports: 30 countries	Ranking for available countries/Average comparison. 4 technology categories.		HT: 7th in 1990 3rd in 2000 MHT: 2nd in 1990 2nd in 2000		HT: 8th in 1990 12th in 2003 MHT: 12th in 1990 14th in 2003	HT: 82.3 in 1990 88.6 in 2003 MHT: 88.4 in 1990 91.8 in 2003
Braunerhjelm[24] Employment: 12 countries Exports: 12 or 14 (?) countries	Average comparison. 3 technology categories.			HT: 75 in 1970 79 in 1993 MT: 96.3 in 1970 117.2 in 1993		HT: 74 in 1970 85 in 1993 MT: 84 in 1970 88 in 1993
Edquist & McKelvey[25] Production and employment: 14 countries	Average comparison. 3 technology categories.	HT: 72 in 1970 72 in 1980 71 in 1990		HT: 75 in 1970 80 in 1980 79 in 1990		

Index 100 = OECD average. MT refers to medium-tech. OECD:s employment data for different technology levels is expressed as employment shares of the manufacturing sector, not as shares of total employment in the economy. However, data of employment shares is not provided for the OECD as a whole, and the necessary information for computing such an average is not provided. Hence, an index where Sweden is compared to OECD could not be calculated.

[24] Index data for Braunerhjelm's employment figures has been calculated from his information given in Table 3.
[25] The data have been taken from visual inspection of Figure 1 in their paper, and may as such differ somewhat from the actual numbers the Figure is based on.

11 Appendix A: Classification of manufacturing industries based on technology

High-technology industries	
Aircraft and spacecraft	353
Pharmaceuticals	2423
Office, accounting and computing machinery	30
Radio, TV and communications equipment	32
Medical, precision and optical instruments	33
Medium-high-technology industries	
Electrical machinery and apparatus, n.e.c.	31
Motor vehicles, trailers and semi-trailers	34
Chemicals excluding pharmaceuticals	24 excl. 2423
Railroad equipment and transport equipment, n.e.c.	352 + 359
Machinery and equipment, n.e.c.	29
Medium-low-technology industries	
Building and repairing of ships and boats	351
Rubber and plastics products	25
Coke, refined petroleum products and nuclear fuel	23
Other non-metallic mineral products	26
Basic metals and fabricated metal products	27-28
Low-technology industries	
Manufacturing, n.e.c.; Recycling	36-37
Wood, pulp, paper, paper products, printing and publishing	20-22
Food products, beverages and tobacco	15-16
Textiles, textile products, leather and footwear	17-19
Total manufacturing	15-37

Source: OECD ANBERD and STAN databases, May 2003

12 Appendix B: R&D-intensities, share of employment and exports in high-tech and medium-high-tech among OECD-countries.

Table 8. R&D intensity (R&D/value added) in high-tech industries. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000
Australia	16.8 (10)	18.4 (13)	-
Belgium	-	23 (8)	26.1 (3)
Canada	23.1 (5)	26.5 (4)	29.3 (2)
Czech Republic	-	7.2 (18)	5.2 (14)
Denmark	21.1 (6)	21.1 (9)	-
Finland	19.5 (8)	24.7 (6)	25 (6)
France	34.1 (2)	30.7 (2)	25.9 (5)
Germany	-	26.3 (5)	22.9 (7)
Ireland	6 (13)	7.4 (17)	-
Italy	-	14.1 (14)	12.7 (12)
Japan	17.3 (9)	19.3 (11)	21.7 (9)
Korea	-	12.5 (15)	14.6 (11)
Netherlands	14.9 (11)	19.8 (10)	26.1 (3)
Norway	32.9 (3)	27.1 (3)	-
Poland	-	-	3.5 (15)
Spain	11.8 (12)	10.9 (16)	10.7 (13)
Sweden	**39.6 (1)**	**41 (1)**	**48.9 (1)**
United Kingdom	20.7 (7)	18.6 (12)	21.5 (10)
United States	25.1 (4)	24.4 (7)	22.5 (8)
G7	-	23	22.3
Number of countries	13	18	15

Table 9. R&D intensity (R&D/value added) in medium-high-tech industries. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000
Australia	4.4 (8)	6 (11)	-
Belgium	-	6.5 (10)	7.4 (9)
Canada	1.4 (12)	1.7 (17)	2 (15)
Czech Republic	-	4.7 (13)	4.8 (11)
Denmark	4.4 (8)	5.9 (12)	-
Finland	6.8 (7)	7.7 (8)	8.2 (6)
France	8.1 (5)	8.7 (5)	8.6 (5)
Germany	-	9 (3)	10.8 (3)
Ireland	1.8 (11)	2 (16)	-
Italy	-	3.2 (14)	3.1 (12)
Japan	11.1 (2)	11.6 (2)	13.3 (1)
Korea	-	8.3 (6)	6.5 (10)
Netherlands	12.3 (1)	8.2 (7)	7.7 (7)
Norway	-	-	-
Poland	-	-	2.3 (14)
Spain	2.6 (10)	2.2 (15)	2.4 (13)
Sweden	**10.7 (3)**	**12.5 (1)**	**12.8 (2)**
United Kingdom	7.5 (6)	7 (9)	7.6 (8)
United States	9.1 (4)	8.8 (4)	9.8 (4)
G7	-	8.6	9.7
Number of countries	12	17	15

Table 10. Exports in high-tech industries – indices, OECD = 100 and ranking in parenthesis. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000	2003
Australia	44.9 (14)	55.5 (14)	48.2 (19)	47.7 (22)
Austria	- (-)	45.2 (18)	55.7 (16)	59.3 (17)
Belgium	36.1 (17)	43.1 (20)	49.5 (18)	76.5 (15)
Canada	57.7 (11)	50.7 (15)	59.3 (15)	49.2 (20)
Czech Republic	- (-)	18.9 (25)	35 (25)	59.6 (16)
Denmark	76 (9)	71.3 (12)	79.4 (13)	84.8 (13)
Finland	45.3 (13)	69.9 (13)	101 (11)	97.1 (10)
France	83.3 (6)	90.5 (10)	94.9 (12)	91.1 (11)
Germany	72.1 (10)	71.5 (11)	74.7 (14)	77.7 (14)
Greece	10.7 (21)	20.1 (23)	35.4 (24)	50.4 (18)
Hungary	- (-)	47.2 (16)	113.2 (8)	130.2 (6)
Iceland	5 (23)	12.2 (26)	9.9 (30)	20.8 (30)
Ireland	182 (1)	189.5 (1)	185.1 (1)	217.1 (1)
Italy	52 (12)	45.6 (17)	43 (20)	44.7 (23)
Japan	155.9 (3)	148.4 (3)	121.8 (6)	117.2 (8)
Korea	- (-)	136 (4)	137 (4)	146.1 (3)
Luxembourg	- (-)	- (-)	51.9 (17)	39.7 (25)
Mexico	36.1 (18)	107.7 (7)	106 (10)	115.1 (9)
Netherlands	82.6 (7)	99.1 (9)	120.3 (7)	125.3 (7)
New Zealand	7.5 (22)	12 (27)	11.2 (29)	21.7 (29)
Norway	44.9 (15)	45 (19)	42.8 (21)	50.3 (19)
Poland	- (-)	19.5 (24)	23.7 (27)	26.5 (26)
Portugal	31.2 (19)	37.7 (22)	38 (22)	47.7 (21)
Slovak Republic	- (-)	- (-)	19.2 (28)	23.2 (28)
Spain	42.3 (16)	40.1 (21)	37.3 (23)	43.6 (24)
Sweden	**82.3 (8)**	**100 (8)**	**106.5 (9)**	**88.6 (12)**
Switzerland	134.6 (5)	133.2 (6)	124.7 (5)	155.5 (2)
Turkey	17.8 (20)	9.6 (28)	28.9 (26)	26.3 (27)
United Kingdom	134.9 (4)	134.4 (5)	138.2 (3)	139.8 (5)
United States	167.4 (2)	151.7 (2)	141.5 (2)	144.8 (4)

Table 11. Exports in medium-high-tech industries – indices, OECD = 100 and ranking in parenthesis. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000	2003
Australia	34 (19)	44.2 (24)	47 (27)	45 (27)
Austria	- (-)	93.5 (10)	97.9 (11)	96.2 (11)
Belgium	94.7 (8)	107.6 (5)	107.2 (8)	103.1 (8)
Canada	102.7 (6)	105.1 (7)	107.4 (7)	105.1 (7)
Czech Republic	- (-)	89.8 (13)	113.5 (5)	107.2 (6)
Denmark	62.9 (15)	64.4 (18)	67 (21)	69.6 (21)
Finland	65 (14)	61.1 (20)	59.3 (23)	58.9 (25)
France	97.5 (7)	97.3 (8)	98.4 (10)	100.9 (9)
Germany	125.3 (2)	127.1 (1)	126.6 (2)	125.2 (2)
Greece	20.2 (21)	29.7 (27)	35.5 (28)	39.4 (28)
Hungary	- (-)	79.4 (15)	98.8 (9)	97.1 (10)
Iceland	1.9 (23)	4.4 (28)	8.4 (30)	8.4 (30)
Ireland	49.7 (16)	51.7 (22)	77.3 (19)	72.6 (20)
Italy	90.1 (11)	93.4 (11)	96.6 (13)	95.5 (12)
Japan	123.4 (3)	122.4 (2)	127 (1)	129.9 (1)
Korea	- (-)	69 (17)	66.5 (22)	77.2 (18)
Luxembourg	- (-)	- (-)	54.9 (24)	66.4 (23)
Mexico	127.1 (1)	118.1 (3)	117.7 (3)	112.5 (4)
Netherlands	75.5 (13)	74.7 (16)	68.2 (20)	69.5 (22)
New Zealand	19.2 (22)	30.2 (26)	34.5 (29)	32.1 (29)
Norway	38 (18)	45 (23)	47.4 (26)	51.5 (26)
Poland	- (-)	59.5 (21)	85.4 (16)	85.7 (17)
Portugal	49.7 (17)	62.6 (19)	78.6 (18)	74.4 (19)
Slovak Republic	- (-)	- (-)	111.6 (6)	117.9 (3)
Spain	103.5 (5)	115 (4)	116.4 (4)	112 (5)
Sweden	**88.4 (12)**	**84.6 (14)**	**84.6 (17)**	**91.8 (14)**
Switzerland	105.6 (4)	106.1 (6)	97 (12)	89.8 (15)
Turkey	32.1 (20)	40 (25)	51 (25)	61 (24)
United Kingdom	92.3 (10)	91.8 (12)	88.2 (15)	88.4 (16)
United States	94.1 (9)	96.2 (9)	92.3 (14)	93.1 (13)

Table 12. Employment in high-tech industries – shares of manufacturing employment and ranking in parenthesis. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000	2001
Australia	6.5 (13)	6.1 (17)	- (-)	- (-)
Austria	8.5 (9)	8.2 (12)	8.9 (11)	8.9 (9)
Belgium	- (-)	7.2 (15)	8.4 (12)	- (-)
Canada	8.2 (10)	8.1 (13)	8.4 (12)	8.1 (10)
Denmark	8.1 (11)	8.4 (11)	9.4 (9)	9.7 (7)
Finland	6.2 (15)	10.1 (9)	13 (4)	12.9 (3)
France	10.4 (6)	10.3 (7)	10.6 (6)	10.8 (5)
Germany	9.7 (8)	9.2 (10)	9.4 (9)	9.4 (8)
Greece	- (-)	3.3 (20)	- (-)	- (-)
Ireland	12.8 (4)	17.8 (1)	- (-)	- (-)
Italy	7 (12)	6.9 (16)	7 (14)	7.2 (11)
Japan	13 (3)	12.9 (4)	13.4 (2)	13.3 (1)
Korea	13.3 (2)	13.2 (3)	- (-)	- (-)
Mexico	6.5 (13)	7.5 (14)	10.1 (8)	- (-)
Netherlands	- (-)	10.2 (8)	10.2 (7)	10.4 (6)
Norway	6.2 (15)	6.1 (17)	6.9 (15)	7.1 (12)
Portugal	3.2 (18)	3.3 (20)	- (-)	- (-)
Spain	5.2 (17)	5.2 (19)	4.9 (16)	5 (13)
Sweden	**10 (7)**	**12.4 (5)**	**13.1 (3)**	**13.2 (2)**
United Kingdom	12.6 (5)	11.7 (6)	12.5 (5)	12.6 (4)
United States	17.5 (1)	15.2 (2)	15.8 (1)	- (-)

Table 13. Employment in medium-high-tech industries – shares of manufacturing employment and ranking in parenthesis. Source: OECD STAN database and own calculations.

Country / Time	1990	1995	2000	2001
Australia	19.6 (16)	18.7 (18)	- (-)	- (-)
Austria	22.6 (9)	22.5 (12)	24.7 (6)	25.3 (4)
Belgium	- (-)	27.3 (3)	27.3 (3)	- (-)
Canada	20.2 (14)	21.3 (15)	19.8 (14)	19.6 (12)
Denmark	24 (5)	23.9 (7)	24.2 (7)	24.8 (5)
Finland	22.7 (8)	23.2 (10)	22.4 (12)	22.8 (8)
France	23.5 (6)	23.4 (8)	23.5 (10)	23.6 (6)
Germany	39.2 (1)	36.2 (1)	37.9 (1)	38.5 (1)
Greece	- (-)	9.8 (20)	- (-)	- (-)
Ireland	20 (15)	21.8 (14)	- (-)	- (-)
Italy	22.5 (10)	21.9 (13)	22.9 (11)	22.8 (8)
Japan	25.6 (3)	25.7 (5)	27 (4)	27.8 (3)
Korea	22 (11)	26.8 (4)	- (-)	- (-)
Mexico	23.5 (6)	23.4 (8)	25.3 (5)	- (-)
Netherlands	- (-)	18.9 (17)	19.8 (14)	19.9 (11)
Portugal	10.7 (17)	10.6 (19)	- (-)	- (-)
Spain	21 (13)	20.6 (16)	21.4 (13)	21.6 (10)
Sweden	**28.9 (2)**	**29.1 (2)**	**30.1 (2)**	**30.5 (2)**
United Kingdom	24.1 (4)	24 (6)	23.7 (8)	23.4 (7)
United States	22 (11)	23 (11)	23.6 (9)	- (-)

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