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Published in:
Science and Public Policy

DOI:
10.1093/scipol/scu064

2015

Science and Public Policy **42** (2015) pp. 415–426
Advance Access published on 10 October 2014
doi:10.1093/scipol/scu064

Unpreparedness and risk in Big Science policy: Sweden and the European Spallation Source

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The politics of European collaborative Big Science are inherently uncertain. The European Spallation Source (ESS) for materials science, planned to be built in Sweden with a collaborative European funding solution that was recently finalized is the most recent example. Sweden has so far invested around one billion SEK (≈€110 million), taking a significant risk given these uncertainties and given Sweden's complete lack of experience in hosting such big labs. Tracing the Swedish government's investments in the ESS project, this article shows that so far, the Swedish ESS bid seems to be generally well funded, but that a long-term plan for the funding and a contingency plan for increased costs seem to be absent. This adds to the seeming unpreparedness of Sweden and elevates the already quite high level of risk for Swedish science and science policy of investing in the ESS.

Keywords: Big Science; European research policy; Sweden; European Spallation Source; research funding.

1. Introduction

European collaboration in Big Science has traditionally not been a policy area of the European Community/European Union (EC/EU) intergovernmental collaboration, and has therefore never become a coherent policy field. Most collaborative European Big Science projects such as CERN (the European Nuclear Research Laboratory in Geneva), the European Southern Observatory (ESO), and the European Synchrotron Radiation Facility (ESRF) have eventually become scientific and political successes, but in the processes towards their realization they have had to rely on improvisation, *ad hoc* negotiation and political compromises, with limited transparency and significant built-in uncertainty (Krige 2003; Papon 2004; Hallonsten 2012b, 2014). This has created a muddled and opaque policy field and a heterogeneous collection of labs and institutes, and few institutionalized pathways exist that can provide a precedent and serve as assistance for those who seek to establish a collaboration and want to avoid previous typical pitfalls.

One of the most recent Big Science projects in Europe is the European Spallation Source (ESS), to be used for a wide range of studies of materials with the aid of neutron beams. It has been under planning for over two decades and is currently set to be located in Lund in Southern Sweden. According to the latest estimations, its construction costs will be €1.84 billion, of which Sweden has offered to cover roughly one-third. Since 2007, the Swedish government has been engaged in a lobbying and negotiating effort to encourage other European countries to participate and fund the other two-thirds of the costs, and on 4 July 2014, it was announced that a funding solution had been reached that allowed the start of construction. Already before this, and hence with the future of the project still in doubt, the Swedish government had invested around SEK1 billion (≈€110 million)[1] in the ESS.

Looking at history, both the European and Swedish science policy systems show worrying unpreparedness for the ESS project, though in essentially different ways. Scholarly documentation and analysis of past cases show that the lack of precedent and structure on the European stage makes the politics of collaborative Big Science projects highly unpredictable (Krige 2002, 2003; Papon 2004; Hallonsten 2012b, 2014). Sweden's experiences of

similar campaigns are virtually non-existent, and its research policy system is essentially consensus-oriented and decentralized (Benner and Sandström 2000; Benner 2012; Granberg and Jacobsson 2006; Hallonsten 2011). The aim of this article is to analyze Big Science policy in action, namely the efforts of a small country to host a major collaborative European facility, and to highlight the risks involved in Big Science projects, with specific attention paid to the seeming unpreparedness on the European as well as national Swedish level, and what appears to be an elevated risk level in the case of the ESS, given the circumstances.

The article begins with a historical contextualization of the Swedish ESS bid, based on secondary sources. Thereafter, the government's strategy to fund the several-billion-SEK investment is analyzed on the basis of policy language (qualitative analysis) of the government's annual budget bills and quadrennial research bills, and the detailed funding allocations in the same bills (quantitative analysis). The data is complemented with that from annual reports of the Swedish Research Council and the ESS company (founded in 2010). The analysis shows that although the ESS is a project of unprecedented size for the comparably small Swedish public science system, there are so far no provable displacement effects, and hence the ESS seems (so far) well-financed from the Swedish side. Importantly, however, some prospective European partner countries' apparent hesitation to participate did delay the reaching of a funding solution by several years, and Sweden's complete lack of previous experience in hosting collaborative Big Science projects places some doubt on its capability to take the lead in the realization of the ESS. The analysis of the funding model for the Swedish share of the investment also suggests that the Swedish government lacks a thoroughly devised long-term plan for its commitment to the ESS, and shows unpreparedness for unforeseen cost increases. These results suggest that several risks still pose threats to a successful future ESS facility in Lund, Sweden, some of which have clear connections with the (apparent) unpreparedness on European and Swedish policy levels. Thus, Section 5 discusses these risks and their implications on various levels, including the prospects of success for the future facility and general lessons for research policy.

2. Background

Neutron scattering originally emerged as an experimental technique for condensed matter physics in the 1950s, using the neutron beams unavoidably produced by research reactors (built for uranium enrichment and nuclear energy production) as a probe into materials comparable with X-rays. In the 1970s, significant efforts to increase the efficiency of reactors as neutron sources led to a steady growth in use in materials sciences worldwide (Westfall 2010: 361–4), and in the mid-1980s, some 15 neutron-producing reactor facilities were available in Western Europe. Among them was the European flagship facility, the Institute Laue–Langevin (ILL) in Grenoble, a European collaborative lab that became the main reason for Europe's claimed world leadership in neutron scattering (Kaiserfeld 2013: 28; Hallonsten 2014: 38). In the late 1980s it became clear that the reactors would not suffice to meet the scientific demand for high-intensity neutron beams, and in the early 1990s a number of European research institutes joined forces to explore the prospects of a collaborative next-generation neutron source, under the name European Spallation Source (ESS). Spallation sources had already been built in the 1980s, using linear accelerators to shoot protons into a target material (typically mercury or tungsten), thus releasing intense bursts of neutrons (through spallation, which literally means fragmentation) (Berggren and Matic 2012: 31).

In 1993, the ESS Council was formed among the collaborating European research institutes to develop a conceptual design for the envisaged facility (Berggren and Hallonsten 2012: 22–3). Soon enough, the ESS Council had convinced the OECD Megascience Forum that Europe (and the world) was facing a looming 'neutron gap' (i.e. a shortage of high-quality neutron beams relative to the demand), and while the forum had no formal decision-making powers, it had a certain weight as an informal discussion club among OECD countries in the area of Big Science (Papon 2004: 63). In 1999, the Megascience Forum issued a report on neutron sources recommending that three new, high-intensity spallation neutron sources be built in North America, the Asia-Pacific area, and in Europe. In the USA and Japan, the plans for new spallation sources were already at an advanced stage, and in the first years of the 2000s such facilities were constructed at Oak Ridge National Laboratory in Tennessee and at the Japan Proton Accelerator Research Complex (J-Parc) in the greater Tokyo area, opening in 2007 and 2009, respectively. The design of these facilities largely followed the general ESS concept published in 1996, and the ESS Council responded by devising a new, ambitious conceptual design for the ESS which outlined a facility which was significantly more powerful than its competitors in the USA and Japan, and set the ambitious aim that a multilateral European political agreement regarding construction of the ESS would be reached in 2003 or 2004, so that the facility could eventually start operating in 2010 (Kaiserfeld 2013: 30, 37–8). In May 2002, the project proposal for the ESS was presented at the users' meeting of the European Neutron Scattering Association, with an updated scientific case, and a cost estimate of €1.5 billion. At the meeting, five candidates also presented their Expressions of Interest for hosting the future ESS; two in Germany and two in the UK (reflecting these two

countries' leading roles in European neutron-based research), and the ESS Scandinavia (see Section 3) (Berggren and Hallonsten 2012: 24–5).

But the Bonn meeting brought an unexpected setback. Although the ESS was envisaged as the future of neutron scattering in Europe, the project met resistance among leading European neutron researchers, who feared that their governments' commitment to the ESS would come at the expense of a much-needed upgrade of the ILL (Hallonsten 2012a: 103). The ESS project was effectively put on hold, and the British and German ESS candidatures withdrew their bids, apparently prioritizing other projects (such as the European X-ray Free Electron Laser (XFEL) in Hamburg and an upgrade of the British neutron source, Isis). Within a few years, however, new site contenders emerged: Debrecen in Hungary and Bilbao in Spain (Berggren and Hallonsten 2012: 25–6). These two, plus ESS Scandinavia, continued their campaigns.

Thus in 2009, after almost two decades of planning and politicking, a decision of sorts could be taken in favor of locating the ESS in Lund. By this time no detailed technical design existed, and there was no plan for how to finance it, but the intense political campaign on behalf of the Swedish government had succeeded in mustering political support from other European countries for the location of the ESS in Lund. The Swedish ESS Secretariat (see Section 3) thus obtained the lead role in planning and designing the future facility and negotiating a funding solution with other European countries. On 4 July 2014, Germany became the last major partner country to join the collaboration with a pledge to cover 11% of the construction costs, which effectively meant that the project had enough of its funding secured to allow the start of construction. At the time of writing, 2.5% of the total construction costs are still missing and subject to 'ongoing discussion' with additional prospective partner countries (Latvia, Lithuania, and the Netherlands) as well as the European Commission (see Table 1) (Swedish Government 2014).

Interestingly, while the USA and Japan went ahead and rather swiftly funded and constructed their spallation sources, even using the conceptual design of the ESS from 1996, the European project took over 20 years of planning, and also as much as five years of negotiation once a site had been chosen, before a funding solution could be reached. The current rather optimistic estimations that the ESS will start operation in 2019 thus mean that when operational, the ESS will have taken 30 years from idea to reality.

The reason for this delay lies ultimately with the shortcomings of European intergovernmental collaboration in the area of Big Science as compared with, for instance, the USA and Japan. When the first steps towards the current EU were taken, through the early treaties of Paris (1951) and Rome (1957), the collaboration was given no mandate in the realm of science (outside EURATOM's coordination of nuclear energy R&D), and it took until the late 1970s before the EC initiated some collaborative programs in technology development and thus began its involvement in research policy (Grande and Peschke 1999: 45; Papon 2004: 69–70). Way before that, however, the need for (Western) European countries to collaborate in order to remain internationally competitive in Big Science (particle physics, ground-based astronomy and eventually synchrotron radiation and neutron scattering) had led to several intergovernmental collaborative efforts (for a list, see Krige 2003: 899). But the lack of a coherent policy framework, due partly to the absence of EC/EU authority in science policy, meant that all of these collaborations had to rely on *ad hoc* solutions and the reinvention of legal arrangements and organizational structures for each new project (Hallonsten 2014; Krige 2003). CERN, ESO, ILL, ESRF, as well as the more recent XFEL, have come about through muddled and opaque political processes, and have been characterized by great uncertainty at several stages of their realization. Though this lack of structure has forced negotiating parties to burdensome reinvention of legal and organizational arrangements, it has also spared projects from the typical EC/EU bureaucracy and enabled organizational optimization to meet current scientific demands (Hoerber 2009: 410), but it has also meant that current peculiarities of intergovernmental relations in Europe at the time of negotiations have been allowed to significantly influence their outcome (Hallonsten 2012b, 2014). The comparison with the federal US science policy system and its highly efficient procedures for priority and investment in Big Science institutionalized in the Department of Energy's system of national laboratories (Hallonsten and Heinze 2012; Westfall 2012) is therefore somewhat unfair, but nonetheless striking. There is a generally high risk involved in all Big Science projects, that has to do with extremely long time frames and high costs, which

Table 1. Funding solution for ESS finalized in July 2014

Country	Share (%)	Amount (SEK million)	Amount (€ million)
Czech Republic	0.3	50	5.6
Denmark	12.5	2,070	230.0
Estonia	0.25	41	4.6
France	8	1,330	147.8
Germany	11	1,820	202.2
Hungary	1.5	249	27.7
Italy	6	995	110.6
Norway	2.5	415	46.1
Poland	2	332	36.9
Spain	5	829	92.1
Sweden	35	5,810	645.6
Switzerland	3.5	581	64.6
UK	10	1,660	184.4
'Ongoing discussions'	2.5	415	46.1
Sum	*100*	*16,600*	*1844.4*

Source: Swedish Government (2014).

accentuate the uncertainties built into all scientific work (Whitley 1984: 119–30), and in European collaborative Big Science projects, this risk seems further elevated by severe political uncertainty.

Sweden has historically been a reliable but minor partner in European Big Science, typically taking an active part in early planning phases and eventually entering collaborations with a budget contribution of a few percent of the total. In domestic (research) policy, Swedish participation in European Big Science is typically viewed as uncontroversial, but the decision to join a particular collaboration has always been delegated by the government to the scientific community (as represented for instance by research councils) who have had to find the funds for membership fees within existing budgetary frameworks (Widmalm 1993; Granberg 2012; Edqvist 2009). Most memberships come at a relatively low cost, but there are exceptions. The Swedish CERN membership is a huge financial commitment (over SEK200 million $\approx$€22 million annually), and its worth relative to other expenses has occasionally been questioned, not least since the CERN membership has evidently been financed at the expense of domestic physics research (Widmalm 1993: 123–6). This unforgiving resource reprioritization is a function of a structural deficit in Swedish science policy, which stems from its decentralized governance structure and the lack of central coordination (Benner and Sandström 2000; Benner 2012; Granberg and Jacobsson 2006; Hallonsten 2011; Hallonsten and Hugander 2014). Strategic prioritization and mobilization in Swedish public R&D has historically been a bottom-up process, whereby initiatives in the scientific communities have grown organically. This has created a certain default efficiency of priorities but also contributed to institutionalizing an inability to take discontinuous decisions at the top political level (Benner 2012; Hallonsten 2011). The only example of domestic Big Science in Sweden is the MAX-lab synchrotron radiation facility in Lund, which has grown stepwise from a small-scale university project in the late 1970s to an international research facility with some 1,000 annual users today. But national science policy has just as often hindered and delayed MAX-lab's growth to international preeminence as facilitated it—the history of MAX-lab is mostly a history of strong personal scientific and technical creativity, council-level executive ingenuity, and generous investment by private foundations in lieu of high-level political backing (Hallonsten 2011).

The Swedish bid to host the ESS and cover 35% of its construction costs is a venture of unprecedented size and scope in Swedish science and science policy, and clearly a break with the tradition of participating as minor partner in European collaborative Big Science. It is a highly unusual top-down science policy initiative by the Swedish government, certainly underpinned by local/regional efforts in Lund, but clearly deviating from tradition, having not been anchored in the concerned scientific communities, not exhaustively and comprehensively evaluated and investigated, and not brought about by gradual legitimization and stepwise coalition building among universities, interest groups and governmental agencies (Benner 2012: 167–9).

3. A chronicle of the Swedish ESS bid

The ESS Scandinavia Initiative was founded in October 2000 among members of the scientific communities in Sweden, Denmark and Norway, to propose that the future ESS be located in Lund in Southern Sweden, close to Denmark. Within a couple of years the initiative had gathered the support of local and regional government authorities, as well as most of the larger universities in Scandinavia, a number of research institutes, and the neutron scattering user organizations in Sweden, Denmark, and Norway. In 2002, these organizations formed the ESS Scandinavia Consortium and prepared a formal expression of interest to host the ESS (Berggren and Hallonsten 2012: 23–4).

The aforementioned setback at the Bonn meeting, where ESS Scandinavia put forward its expression of interest, did not halt the work of the consortium, which continued to work through a small-scale project secretariat (comprising only two to three people) to strengthen its proposal. The efforts had no official support from the Swedish government but had some seed money from Lund University, the Swedish Research Council, and local and regional government and authorities. The scientific communities both locally and nationally remained cautiously positive but few spoke out clearly in favor of the project. In 2004, increased attention at national level led the government to appoint Allan Larsson, a former finance minister, to investigate the prospects for locating the ESS facility in Lund. In June 2005, Larsson delivered a report that recommended the Swedish government to endorse the ESS Scandinavia Initiative and to begin to work actively to locate the ESS to Lund (Berggren and Hallonsten 2012: 26–7).

This recommendation was, however, conditional. Importantly, Larsson advised the government to seek a funding solution for the Swedish part of the investment that reflected his assessment that the expectable positive effects for Sweden of hosting the ESS would primarily be socio-economic. The benefits for Swedish research are not as evident, writes Larsson, and therefore it will:

> ... be hard to get the necessary support for a Swedish hosting bid for the ESS purely on research policy grounds. (Larsson 2005: 29)

As noted by Granberg (2012: 130), Larsson was:

> ... clearly at pains to remove, or at least substantially reduce, the risk (and fears) that the ESS would encroach on the national research budget.

The resulting recommendation was a dual track funding solution, with one 'basic funding' share on par with

Swedish participation in other international scientific collaborations, i.e. 'approximately 3%', and one 'extra allocation', motivated by the positive socio-economic effects that would be to the benefit of any hosting country, of approximately 20–5% of the total ESS construction costs. The 'basic funding' part should be covered by ordinary governmental R&D appropriations, whereas the 'extra allocation' should 'in its entirety be funded by industrial support funding, from the government and the private sector'. This public–private partnership (PPP) solution was stated to be a fundamental prerequisite for a Swedish ESS bid (Larsson 2005: 10, 30, 33–4), and it is also taken as such by the 37 organizations representing the research community (universities, funding bodies, academies) in the referral round that followed.[2] The generally positive assessments and endorsements of the Swedish ESS plans in these review responses were for the most part conditional upon such a PPP funding solution and that the financing of the facility was not to interfere with the ordinary governmental R&D appropriations (Granberg 2012: 136–8). Several respondents also stressed the need for a (very costly) national mobilization in neutron scattering technology and in related scientific fields in order to manage the leadership role in design, construction and operation of the facility, and to ensure that the domestic scientific community can reap the benefits of having the ESS in their back yard, in all making the real Swedish financial commitment far greater than Larsson's report estimated (Granberg 2012: 139–42).

A few respondents were outright negative to a Swedish ESS hosting bid, among them Uppsala University and the Royal Academy of Sciences, who questioned that ESS and neutron scattering is really the right priority for Sweden. Comparing with the simultaneously proposed major MAX IV upgrade of MAX-lab in Lund, which was judged to be a better priority by most commentators, due to its solid anchoring in Swedish science (proven through decades of operation of MAX-lab), especially the Royal Academy of Sciences voiced fears that the ESS would be realized at the expense of MAX IV (see further below). Other respondents recommend collocating the ESS with MAX IV to achieve synergies that would further strengthen both projects (Granberg 2012: 140).

On 26 February 2007, when the Swedish government made the announcement that it endorsed the ESS Scandinavia Initiative and would start working actively to have the ESS located at Lund, it came as a surprise to many. Prior to the 2006 elections and its shift of government, the ESS project had received no official governmental support, but by the February 2007 announcement, the project became a national science policy priority (Berggren and Hallonsten 2012: 27). In March the same year, Allan Larsson was appointed to be the Swedish government's chief negotiator for the ESS, and in June, the government installed an ESS Secretariat at Lund University, replacing the ESS Scandinavia Consortium and receiving government funding channeled through the Swedish Research Council (Berggren and Hallonsten 2012: 28).

The government pledged to cover 30% of the construction costs of the ESS, if it were to be located to Lund, and invited other countries to participate. Neither the announcement nor any subsequent governmental policy document or statement bore any trace of the Larsson funding model or a PPP solution, instead 'financing will be made within existing frameworks', that is, as part of the ordinary governmental R&D appropriations, as stated in the 2008 research bill (Swedish Government 2008b: 2). The government has not given any reasons for departing from the Larsson funding model, which has simply sunk into oblivion.

Issued quadrennially, the Swedish governmental research bill conveys the aims of the government's R&D policy and details the framework for governmental R&D appropriations for the coming years. Containing all significant priorities for several years and outlining medium-range R&D policy development, the bills are important policy documents but do not include formally binding funding allocations. Instead, the annual governmental appropriations for R&D are found in the governmental budget bills issued in October each year (and covering the next calendar year) and while there is seldom any great discrepancy between what a research bill promises and the budget bills deliver, the former can launch initiatives and priorities with only sketchy funding estimations attached—detailed figures need only be released year-by-year, in the annual budget bills.

The 2008 research bill focused strongly on the expansion of the overall annual governmental R&D appropriations that meant 'by far the largest resource increase for Swedish research presented at once' (Swedish Government 2008b: 22) and that was part of a general level rise of governmental R&D appropriations (that both preceded this bill and continued in its 2012 sequel) that made the annual budget for research in the universities and the research funding of the Swedish Research Council[3] no less than 45% higher (or SEK6.6 billion $\approx$€733 million, adjusted for inflation) in 2014 compared to 2007, the year when the government announced its ESS bid. The expression 'within existing frameworks' used in connection with the funding of the Swedish 30% share of the ESS construction costs (estimated to a total of SEK13 billion $\approx$€1.4 billion in the bill) would perhaps otherwise have been quite alarming, given that it essentially signals the intention to fund the ESS at the expense of other investments/allocations. But the unprecedented overall increases announced lessened the drama, and the research bill furthermore announced specific increases of the annual research infrastructure budget of the Swedish Research Council, to be used for the ESS investment (Swedish Government 2008b: 190). This increase was made effective in the 2010 budget bill (see Section 4).

The supporters of the MAX IV project, however, found reasons to worry, as the bill delegated responsibility to fund this project entirely to the Swedish Research Council and Swedish universities, refusing to invest directly in it (Swedish Government 2008b: 194). The MAX IV technical design and scientific case had received praise from international evaluation panels in 2005 and 2006, which had led the Swedish Research Council to urge the government to swiftly proceed towards the realization of the facility (Benner 2012: 165). Not least the Royal Academy of Sciences considered the ESS a scientifically ill-fitting project for Sweden compared to MAX IV (Granberg 2012: 147; Hallonsten 2013: 51), and interpreted a statement by the Minister of Education, that 'there won't be two accelerator facilities in Lund' as a flat-out rejection of MAX IV in favor of the ESS (quoted in Hallonsten 2013: 52). The thread was picked up in early 2009 by Anders Flodström, a former university chancellor and professor of materials science, who was charged by the government to investigate possible funding models for MAX IV and asked the rhetorical question:

> Why does ESS have 'political' funding and not MAX IV? (quoted in Benner 2012: 166)

In official governmental policy documents and in the advertising material for the ESS, MAX IV was always presented as a complementary lab that would contribute to make Lund and Sweden a hothouse for materials science and produce all kinds of synergy effects with the ESS. In 2009, as the competition for hosting the ESS neared a decision, MAX IV became a pawn in the game. The 27 April 2009 announcement by the Swedish Research Council, the Swedish National Agency for Innovation Systems, Lund University and the Skåne Regional Council (a regional government authority) that they had found a solution among themselves to fund MAX IV in part and thus set the course for a realization of the facility, became a major factor for the ESS decision made in favor of Lund later the same year (Berggren and Hallonsten 2012: 28).

This decision was made at a closed meeting with the European Union Competitiveness Council in Brussels, on 28 May 2009. The meeting came to no binding agreement for the funding and organization of the ESS, which instead had to be worked out in bilateral and multilateral negotiations. The 4 July 2014 announcement that a funding solution had been reached means that 11 of the 15 partner countries (not counting the co-hosts Denmark and Sweden) who had made previous 'declarations of intent' to participate have now made binding pledges of financial support to the construction of the ESS in Lund (see Table 1). It still remains to be seen, however, how the future operations costs will be covered (they are currently estimated at €140 million per year (Swedish Government 2013: 97)), as well as how the facility's organization (including representation by the countries, and their voting rights etc.) will be structured.

4. Following the money

As noted, the Swedish experience with Big Science has been restricted to steadfast participation in nearly all the European collaborative projects and the operation of the synchrotron radiation laboratory MAX-lab which has grown organically from a small-scale university project to international user facility in small steps, over 30 years (Hallonsten 2011). The Swedish ESS bid therefore constitutes a major break with tradition in Sweden, but as mentioned in Section 3, it is also discontinuous in terms of the way in which it has been handled. Although originally a bottom-up initiative by some Swedish physicists, the ESS project has been almost entirely a political affair since the government announced its hosting bid in February 2007 (Benner 2012). As noted by Hallonsten (2013: 45–6), as a scientific and technological project the ESS is by all available measures very sound and solid, as it 'stands on the shoulders of giants' in the shape of a world-leading European neutron scattering user community whose 'core elite' took the original initiative for the ESS and developed its basic conceptual design and scientific case. However, neither its appropriateness for Sweden (in comparison with other possible investments), nor the prospects for fulfilling its potential if built in Sweden, has been evaluated (Edqvist 2009: 135; Benner 2012: 167–8; Hallonsten 2013: 53). The aforementioned 2005 Larsson evaluation focused almost entirely on socio-economic effects, commenting that it was doubtful whether the benefits of the ESS for Swedish science would motivate the investment. Furthermore, its key recommendation that a PPP funding solution be sought was ignored, in spite of the fact that the fairly positive responses by representatives of the scientific community were generally conditional upon this PPP idea. Thus, there appears to be a disconnect between the essentially political campaign to locate the ESS to Lund and the internal priorities of the Swedish scientific community, and there are also signs that for instance MAX IV would have been a better priority, but there are no evaluations that could bring clarity and confirm or refute these suspicions.

It can be argued that decision-making and priority-setting regarding Big Science must be political and cannot build on consensus, since by nature the effects are so asymmetrical, especially in a small country like Sweden. It is a clearly stated aim of the current Swedish government's research policy to take a more active role in priority-setting and to make strategic investments (Hallonsten and Silander 2012; Hallonsten and Hugander 2014) and in the context of such a research policy doctrine, the ESS can rightly be declared a success. Furthermore, as noted in Section 3, a compilation of the numbers presented

in the annual budget bills of the past six years yields the conclusion that the government has followed through on its rhetoric and substantially increased its annual R&D appropriations (by 45% between 2007 and 2014). Sizable portions of this additional money are line-item funding, such as the excellence funding programs and investments in 'strategic research areas' (Hallonsten and Silander 2012), but there has doubtlessly also been a general increase in the unfettered first-stream funding to the universities and the budget of the Swedish Research Council. Thus the claim in the 2005 Larsson report, that the Swedish ESS investment cannot be realistically expected to be funded by a major expansion of the governmental R&D budget, can be declared erroneous. By itself, the SEK6.6 billion difference between the annual governmental R&D appropriations in 2014 and 2007 could fund the Swedish share of 35% of the ESS construction costs. But this is beside the point, as it says nothing about whether the Swedish ESS bid is well funded and well planned from the government's part. Such an assessment requires another level of analysis.

In the budget bill for 2008, presented in October 2007, the Swedish ESS bid was mentioned as one of many policy actions to strengthen Swedish competitiveness (Swedish Government 2007b: 204–6), but no funding for the ESS was introduced. The next year's budget bill, issued in October 2008, introduced extra line-item funding to Lund University of SEK120 million (≈€13.3 million) in 2009 to fund the ESS, to be included in the general block allocation research funding to the university, which was increased with SEK145 million (≈€16.1 million) in 2009 (Swedish Government 2008a: 143). Deducting the SEK120 million for the ESS from this increase leaves Lund University with a general unguided resource increase in 2009 of SEK25 million (≈€2.7 million), which is on par with what the other large universities in Sweden received (the average for the five largest universities in Sweden, among which Lund University is one, was SEK23.94 million ≈€2.6 million). Hence the 2009 governmental funding of the ESS, though small in comparison with what would have to come, was made on top of, and not at the expense of, other allocations (and their increases), although somewhat strangely it was 'hidden' in the allocation to Lund University.

Simultaneously, in 2007–9 the Swedish Research Council allocated a total of SEK52 million (≈€5.77 million) to the ESS (Swedish Research Council 2008, 2009, 2010). There is no mention of this money in the governmental budget bills for the years in question and no specific motivation for the expenses in the council's annual reports, but both the overall Swedish Research Council budget and the council's total allocation to infrastructure and international research facilities were increased by significantly more in these years which suggests, once again, that funding for the ESS was 'hidden' in other appropriations.

The governmental budget bill for 2010, issued in October 2009, was the first bill after the May 2009 decision at European level in favor of Lund as location for the ESS. By this decision, the Swedish ESS commitment was scaled up from campaign and negotiating effort to leadership of an ample effort to plan the ESS technically, scientifically, organizationally and financially. But Sweden was still alone in funding these efforts (until in 2012 when Denmark made a shareholder's contribution, see below), and so the 2010 budget bill had to launch major investments in the ESS project. Interestingly, the bill increased the pledged Swedish share of the construction costs from 30% to 35%, with no particular reasons given, but most importantly, it introduced the line-item funding for the ESS previewed in the 2008 research bill (see Section 3), in the shape of a SEK150 million (≈€16.6 million) increase in the annual allocations to the Swedish Research Council, to be used for financing the ESS (Swedish Government 2009: 70). The bill also announced that the ESS Secretariat would be reconstituted into a company, initially owned solely by the Swedish government but with the aim that shares be sold 'to other parties' in the future. The company was initially given a capital injection of SEK300 million (≈€33.3 million) to be paid by the Swedish Research Council (on basis of its increased allocations) over the coming two years (Swedish Government 2009: 20, 70–1).

The budget bill for 2011, issued in October 2010, contained little news regarding ESS, but with the next year's bill, issued in October 2011, the government's financial commitment to the ESS was clearly ramped up. The bill detailed a second capital injection/shareholder's contribution of SEK300 million to the ESS company, not as line-item funding but to be paid by the Swedish Research Council, and specified in the bill because such capital injections to governmentally owned companies need to be approved specifically by the parliament (Swedish Government 2011: 26).

The 2013 budget bill, announced in October 2012 and preceding the 2012 research bill by a few weeks, entailed another request for permission to make a capital injection to the ESS company of 'up to' SEK400 million, similarly not line-item funding of its own but to be paid by the council (Swedish Government 2012a: 21–2). In the bill, the government also for the first time conveyed its expectations regarding the completion of the ESS 'preparatory phase' and stated its intention to reach a final funding decision and start of construction in 2013 (Swedish Government 2012a: 98). Anticipating a revised cost estimate at the end of the year, the government made clear that the funding so far allocated to the ESS—SEK150 million annually from 2009 onwards—would not be enough, and proposed a gradual increase of the annual allocation to the Swedish Research Council in the years 2013–6, so that it would reach an annual level of SEK 350 million in 2016 (Swedish Government 2012a: 99). The 2012 research bill

largely echoed the budget bill for 2013, stating that additional funding will be needed in the coming years to cover the Swedish part of the ESS investment, and described the government's intention to allow all such money flow through the Swedish Research Council (Swedish Government 2012b: 143–4). Thus, it appears that the increase of SEK 120 million annually to the block grant funding to Lund University to pay for the ESS, appropriated in the 2009 budget bill (mentioned above) and kept intact in the years thereafter, were not counted when the government judged its allocations to the ESS as hitherto non-sufficient.

The 2014 budget bill, presented in October 2013, called for an additional capital injection to the ESS company, necessary to secure its cash flow. The budget bill instructed the Swedish Research Council to put up SEK518 million and Lund University SEK282 million to cover a shareholder's contribution of SEK800 million, in effect an increase of the SEK400 million of capital injection detailed in the 2013 budget bill that had apparently not yet been put into effect (Swedish Government 2013: 97). In the five years 2010–4, appropriations to the Swedish Research Council included line-item funding to the ESS of a total of SEK750 million (SEK150 million annually), but SEK300 million had already been paid out (in 2010 and 2011, see above), and so in late 2013 there was only SEK450 million left to cover the SEK518 million requested in the 2014 budget bill, which left a difference of SEK68 million. As for Lund University, as noted above, it is unclear to what extent it has been given line-item ESS funding after 2010. Having had its annual appropriations for research gradually increased by no less than SEK655 million in total over the years 2007–14 (inflation-adjusted), it should probably be possible to find the SEK282 million within the existing budgetary frameworks in Lund, but it is also not clear whether the university was prepared for these expenses. According to internal budget documents, the university intends to spend some of its unusually large accumulated capital on the ESS (and on MAX IV), a piled-up surplus mostly consisting of unspent third-party funding and money accumulated by excessive overhead charges (Lund University 2013: 18) and thus money that not only could have been spent on other research but in fact is money already taken away from existing research projects. The government's instruction to Lund University to allocate SEK282 million to ESS in 2014 seems to have taken the university by surprise, since its plan was to instead allocate SEK55 million annually to the ESS over ten years (Lund University 2013: 6). While there are few clues to what this advancement of the installment means for the internal Lund University budgetary work, the instruction by the government clearly signals some desperation with regard to the cash flow of the ESS company.

All this leads back to the national level. Assuming that the SEK150 million increase of the annual appropriations to the Swedish Research Council launched in the 2010 budget bill made up the bulk of the Swedish investment in the ESS from 2010 onwards, and adding the increases of this annual outlay with SEK75 million in 2013 and SEK75 million additionally in 2014, it can be concluded that the Swedish government has allocated SEK675 million to ESS over the years 2010–3, and another SEK300 million in 2014, via the Swedish Research Council (see Table 3). Assuming then, on the basis of the above analysis of the budget bills, that the extra SEK120 million to Lund University in 2009 and onwards (see above) was only specified ESS funding in 2009 and has been used by the university for other purposes in the years thereafter, thus not constituting governmental money to the ESS, this would mean a total of almost SEK1.1 billion, that is approximately one-fifth of the Swedish 35% of the total construction costs (estimated to be €1.8 billion in 2013) have been covered by direct line-item appropriations in the budget bills.

Looking at Table 2, which contains a compilation of figures of shareholders' contributions and expenses from the ESS company's annual reports, this estimation makes sense. The ESS company came into existence on 1 July 2010, and all its income since then has come in the shape of shareholders' contributions from Sweden and Denmark, who own 73.684% and 26.316% of the company, respectively. According to the 2010 ESS annual report, the Swedish shareholder's contribution of SEK127 million in 2010 consisted of the assets of the ESS Secretariat at Lund University (SEK5.7 million), and two additional contributions from the Swedish government of SEK51.3 million and SEK70 million, respectively (ESS 2011: 21). It can be assumed that these were paid by the Swedish Research Council, whose reported expenses for the ESS in 2010 were SEK141 million in total (see Table 3), some of which was probably paid to the ESS Secretariat in the first half of 2010, before the ESS company as founded and for which no detailed figures hence are available.

Table 3 compares the governmental appropriations to ESS via the Swedish Research Council, announced in the 2010–13 budget bills, with the expenditure on ESS reported in the Swedish Research Council's annual reports 2010–3 and the shareholder's contributions from Sweden as reported in the ESS annual reports 2010–3. It does not include the SEK300 million that have been allocated to the Research Council for the ESS for 2014. Similarly, Table 2 does not contain the SEK800 million of shareholder's contribution to be shared by Lund University and the Swedish Research Council (see above), since these are current appropriations (2014) and cannot be confirmed by actual numbers. The SEK68 million deficit for 2014 mentioned above will therefore not be part of the following analysis.

But discrepancies also show up without taking 2014 into account. First, the governmental appropriations for ESS to the Swedish Research Council do not cover the council's actual expenditure in 2010–3: SEK76 million is missing. Although this sum is minor in comparison (it represents

Table 2. Simplified balance sheet for ESS company, 2010-2013 (SEK million)

	2010	2011	2012	2013	Sum
Shareholders' contributions	127	150	320	560	1,157
. . . of which Swedish government	*127*	*150*	*295*	*400*	*972*
. . . of which Danish government	-	-	*25*	*160*	*185*
Expenses	48	178	348	533	1,106
Cash at hand, end of the year	79	51	23	50	

Source: ESS (2011, 2012, 2013, 2014).

less than 1% of the council's annual budget), it must have been taken from other accounts within the council. The difference between the reported Swedish shareholder's contributions and the council's reported expenditure on ESS is even larger (SEK221 million) and there is no clue as to where this money has come from. There is no mention of additional payments by Lund University in its annual reports.

The Swedish expenditure for the ESS project so far—either looking at the shareholder's contributions of SEK972 million in total (see Table 2) or the SEK1.1 billion estimated above—is less than one-fifth of what the Swedish government has pledged to pay (see Table 4). Thus, the question is how the remainder is to be financed. Since the government has given no definite answer to this in its bills, another speculative number exercise is required to come to a preliminary answer, for lack of better alternatives. Assuming that the total Lund University commitment of SEK550 million holds, and that the remainder of the Swedish commitment of 35% of the construction costs for the ESS will be funded by the line-item allocation through the Swedish Research Council at the level suggested in the 2014 budget bill, so that the allocation is SEK350 million annually from 2016 and on, it can be concluded that Sweden will have paid its part of the bill around the years 2025–6, some one or two years before the ESS could become fully operational. This estimation is made as follows: first, we assume that the total remaining Swedish commitment (after SEK972 million in shareholder's contributions already paid) is roughly SEK4.8 million. Second, we deduct the SEK550 million earmarked by Lund University to be paid from 2014 onwards, and arrive at SEK4.25 billion. Third, we assume that SEK300 million is allocated in 2014 as line-item funding through the Swedish Research Council, and that this annual allocation will be SEK350 million from 2016 onwards, as indicated in the 2013 budget bill (see above), and continue so for the foreseeable future. To add up to SEK4.25 billion, the 2014 and 2015 installments of SEK300 million each will have to be followed by little less than 11 annual installments of SEK350 million, that is, until 2025 or 2026. Previous official estimations hold that the ESS will be fully operational in 2025, should construction begin in 2013 (ESS 2012: 4), and since construction has not yet started, it is reasonable to assume a delay of a couple of years.

Table 3. Comparison of selected figures from Swedish Research Council's annual reports (2010–13) and from governmental budget bills (2010–13), in SEK million

	2010	2011	2012	2013	Sum
Governmental appropriations to ESS through Swedish Research Council (budget bills)	150	150	150	225	675
Swedish Research Council's reported expenditure on ESS (Swedish Research Council annual reports)	141	170	190	250	751
Shareholder's contributions from the Swedish government (ESS annual reports)	127	150	295	400	972

Source: Swedish Research Council (2011, 2012, 2013, 2014); Swedish government (2009, 2011, 2012a); ESS (2011, 2012, 2013, 2014).

Assuming that this calculation holds, the analysis has covered at least roughly the full amount of the pledged Swedish ESS funding. With few or no provable displacement effects (only some suspected in connection with the several hundred million SEK that the Swedish Research Council and Lund University have been instructed to pay without corresponding extra allocations from the government), our first conclusion in this section will have to be that the ESS project seems generally well funded from the Swedish side.

But the exercise of tracing the numbers above is complicated, at the limits of what is reasonable, and there are instances where the numbers do not add up. Our chief conclusion, given the aim of this article, is therefore another one: the rather advanced jigsaw puzzle of funding streams from the government to the ESS company through the Swedish Research Council and Lund University suggests that the government's plan for how to fund its ESS commitment has been developed *ad hoc* and with little or no prudent long-term planning. A possible reason is, of course, the inherent uncertainty of the project, which may have prevented the government from devising a long-term plan, but it can just as easily argued that the lack of transparency and clarity is a sign of unpreparedness. This, and the current lack of any clearly laid-out plan for how the remaining (at least) SEK4.8 billion will be funded—and how possible future cost increases will be handled—clearly add to the risks involved.

5. Conclusions

Regarding risk, one important factor remains to be introduced to the discussion. While it seems that a multilateral

funding solution for the ESS has now been reached, it must be noted that it is based on a current (2014) estimation of the costs, and that the funding commitments from partner countries do not by default include contingency. The finalization of the ESS facility is over a decade away, and as Table 4 shows, the estimated construction costs have increased rather dramatically (by roughly 50%) in just the seven years that have passed since the Swedish government announced its hosting bid. There are no reasons to expect that this trend will not continue.

In other words, investments in Big Science always carry risk, given the long time frames and the high costs, both of which accentuate the already significant uncertainty of any scientific undertaking. Any country that would seek to host the ESS or a comparable facility and take the lead responsibility for its realization will therefore be more or less 'unprepared', left to handle in the most sensible way possible the risks that are impossible to completely avoid.

A key argument of this article is, however, that Sweden shows several signs of especially severe unpreparedness and a seeming inability to handle these risks. Sweden is a small country with limited capabilities, and it lacks historical experience of hosting international Big Science facilities. The Swedish ESS campaign has been almost entirely politically driven and has failed to properly evaluate the 'fit' (or lack thereof) between the ESS and Swedish core capabilities, and as the analysis in Section 4 shows, the government has so far financed its ESS investment of roughly SEK1billion through a complicated set of funding flows where the numbers do not always seem to add up, which also signals the lack of a long-term plan and preparation for unforeseen events and cost increases.

The political uncertainties surrounding European collaborative Big Science have also made themselves felt in the ESS case, as several key countries (including the European leaders in neutron scattering and related research, Germany and the UK) hesitated to make binding membership pledges for as long as five years after the 2009 site decision. Although the funding for the project is now secured, these difficulties in getting major European players on board are worrisome given the suspicion, voiced above, that costs will continue to increase—will the partners be willing to increase their commitments in the future, if necessary? If not, the share to be paid by Sweden may well have to exceed 35% and the SEK5.81 billion calculated above. The analysis in Section 4 suggests that money has possibly not been specifically set aside for the project in coming governmental budgets. And although the government's unprecedented increases of its R&D appropriations over the past years might suggest, at first sight, that there is room for contingency in the budget, the room for further drastic increases in the coming ten-year period are likely limited. If the costs of the ESS skyrocket, and no contingency budget has been set aside, the government might then be forced to cut back in other areas.

Table 4. Official estimations of construction costs for ESS, 2007–14

Year	Estimated construction costs		Swedish part		
	SEK billion	€ billion	%	SEK billion	€ billion
2007	11	1.22	30%	3.3	0.37
2008	13	1.44	30%	3.9	0.43
2010	13	1.44	35%	4.55	0.5
2013	16.2	1.8	35%	5.67	0.63
2014	16.6	1.84	35%	5.81	0.65

Sources: Swedish Government (2007a; 2008b; 2009; 2014), ESS (2014).

Again, the lack of a comprehensive evaluation of the ESS project comes to the fore. If Allan Larsson was right in his judgment that the benefits of the ESS for Swedish science are minor (at least in comparison with the envisaged socio-economic benefits), an opinion voiced also by other actors in the course of the Swedish ESS campaign, then the SEK5.81 billion on ESS is perhaps a suboptimal investment for Sweden, compared to other alternatives (such as MAX IV, as suggested by some). The investment will not appear less suboptimal if the price tag is significantly increased.

Obviously, research policy is a game of prioritization, and in such games there are always losers. Against the background of the clear policy statements in the two most recent research bills (2008 and 2012) that Sweden is in need of strategic prioritization and mobilization in certain areas of research, the government's so far successful ESS campaign is a sign of strength, as it marks a move from words to action. A paradox should be noted: while displacement effects may hurt a project by creating rifts in the host country and thus inhibit success, displacement effects can also be seen as necessary consequences of the strategic (re)prioritization of resources that projects of this size demand, especially in a small country with limited resources. Given the sharpened competition in the globalized knowledge economy, it can well be argued that it would be irresponsible of the Swedish government to not take the opportunity to have a facility like the ESS built on Swedish soil, even if it means vast resource reallocations and thus significant displacement effects. Big Science policy is an intricate balancing act.

But this issue also extends to the prospects of success of the ESS project as such. From a European perspective, it can be argued that the ESS should preferably be built in Germany or the UK, to build on the competence and tradition of these European strongholds in neutron scattering. What does it say about the ESS project that Germany and the UK first withdrew their hosting bids for the ESS in 2002 and then hesitated five years after the 2009 site decision to formally enter the collaboration?

To conclude, a successful ESS will doubtlessly bring big dividends to Swedish and European science, to the Swedish economy and the region of Lund. The risks

involved, that are generally in three categories—the generic risks of Big Science, the political uncertainty of European collaborative Big Science, and Swedish unpreparedness—pose clear threats to achieving a successful ESS, and in the worst possible scenario also threats to the whole project, if costs run out of hand and major investors decide to pull out. But these risks appear, on the other hand, unavoidable in Big Science. This article therefore concludes by first reiterating that, to a considerable degree, Big Science policy seems to be about handling risks, and second, by suggesting that the Swedish government's ESS campaign in this respect, so far, should be considered a warning example.

Funding

This work was supported by the Swedish Research Council via grant 421-2012-519.

Notes

1. The exchange rate €1 = SEK9 is a reasonable estimate and is consistently used throughout this article, with occasional round-offs.
2. The report was sent for review to 83 different stakeholder organizations, a typical procedure for similar governmental investigations in Sweden: 69 responses were collected, and among these 37 represented the research community (Granberg 2012: 135–6).
3. The exact total of the annual governmental appropriations for R&D are difficult to extract from the governmental budget bills since research expenses are scattered over several budget areas and items and sometimes combined with other outlays on, for instance higher education or administration. The following analysis therefore contains only the figures for 'research and doctoral training' in the universities and university colleges (this is one budget post) and the Swedish Research Council's outlays for 'research funding' (which excludes 'administration'), since these two outlays are those that concern the ESS.

References

Benner, M. (2012) 'Big Science in a small country: Constraints and possibilities of research policy'. In: Hallonsten, O. (ed.) *In Pursuit of a Promise: Perspectives on the Political Process to Establish the European Spallation Source (ESS) in Lund, Sweden*, pp. 159–72. Lund, Sweden: Arkiv Academic Press.

—— and Sandström, U. (2000) 'Inertia and change in Scandinavian public-sector research systems: The case of biotechnology', *Science and Public Policy*, 27: 443–54.

Berggren, K.-F. and Hallonsten, O. (2012) 'Timeline of major events'. In: Hallonsten, O. (ed.) *In Pursuit of a Promise: Perspectives on the Political Process to Establish the European Spallation Source (ESS) in Lund, Sweden*, pp. 21–30. Lund, Sweden: Arkiv Academic Press.

—— and Matic, A. (2012) 'Science at the ESS: A brief outline'. In: Hallonsten, O. (ed.) *In Pursuit of a Promise: Perspectives on the Political Process to Establish the European Spallation Source (ESS) in Lund, Sweden*, pp. 31–48. Lund, Sweden: Arkiv Academic Press.

Edqvist, O. (2009) *Gränslös Forskning*. Nora, Sweden: Nya Doxa.

ESS. (2011) European Spallation Source Annual Report 2010. Lund, Sweden: European Spallation Source.

—— (2012) European Spallation Source Annual Report 2011. Lund, Sweden: European Spallation Source.

—— (2013) European Spallation Source Annual Report 2012. Lund, Sweden: European Spallation Source.

—— (2014) European Spallation Source Annual Report 2013. Lund, Sweden: European Spallation Source.

Granberg, A. (2012) 'The ESS project as a generator of conflict and collaboration: An assessment of the official picture of costs and benefits and the research-community response'. In: Hallonsten, O. (ed.) *In Pursuit of a Promise: Perspectives on the Political Process to Establish the European Spallation Source (ESS) in Lund, Sweden*, pp. 109–58. Lund, Sweden: Arkiv Academic Press.

—— and Jacobsson, S. (2006) 'Myths or reality: A scrutiny of dominant beliefs in the Swedish science policy debate', *Science and Public Policy*, 33: 321–40.

Grande, E. and Peschke, A. (1999) 'Transnational cooperation and policy networks in European science policy-making', *Research Policy*, 28: 43–61.

Hallonsten, O. (2011) 'Growing Big Science in a small country: MAX-lab and the Swedish research policy system', *Historical Studies in the Natural Sciences*, 41: 179–215.

—— (2012a) 'Contextualizing the European Spallation Source: What we can learn from the history, politics, and sociology of Big Science'. In: Hallonsten, O. (ed.) *In Pursuit of a Promise: Perspectives on the Political Process to Establish the European Spallation Source (ESS) in Lund, Sweden*, pp. 81–108. Lund, Sweden: Arkiv Academic Press.

—— (2012b) 'Continuity and change in the politics of European scientific collaboration', *Journal of Contemporary European Research*, 8: 300–19.

—— (2013) 'Myths and realities of the ESS project: A systematic scrutiny of readily accepted "truths"'. In: Kaiserfeld, T. and O'Dell, T. (eds) *Legitimizing ESS: Big Science as a Collaboration Across Boundaries*, pp. 43–66. Lund, Sweden: Nordic Academic Press.

—— (2014) 'The politics of European collaboration in big science'. In: Meyer, M., Carpes, M. and Knoblich, R. (eds) *International Relations and the Global Politics of Science and Technology*, vol 2, pp. 31–46. Dordrecht, the Netherlands: Springer.

—— and Heinze, T. (2012) 'Institutional persistence through gradual organizational adaptation: Analysis of national laboratories in the USA and Germany', *Science and Public Policy*, 39: 450–63.

—— and Hugander, O. (2014) 'Supporting "future research leaders" in Sweden: Institutional isomorphism and inadvertent funding agglomeration', *Research Evaluation*, 23: 249–60.

—— and Silander, C. (2012) 'Commissioning the university of excellence: Swedish research policy and new public research funding programs', *Quality in Higher Education*, 18: 367–81.

Hoerber, T. (2009) 'The European Space Agency and the European Union: The next step on the road to the stars', *Journal of Contemporary European Research*, 5: 405–14.

Kaiserfeld, T. (2013) 'ESS from neutron gap to global strategy: Plans for an international research facility after the cold war'. In: Kaiserfeld, T. and O'Dell, T. (eds) *Legitimizing ESS: Big Science as a Collaboration Across Boundaries*, pp. 25–42. Lund, Sweden: Nordic Academic Press.

Krige, J. (2002) 'The birth of EMBO and the difficult road EMBL', *Studies in History and Philosophy of Biological and Biomedical Sciences*, 33: 547–64.

—— (2003) 'The politics of European scientific collaboration'. In: Krige, J. and Pestre, D. (eds) *Companion to Science in the Twentieth Century*, pp. 897–918. London: Routledge.

Larsson, A. (2005) 'Svenskt värdskap för ESS', Swedish Government Ds 2005:20. Stockholm: Swedish Government.

Lund University. (2013) Budget for 2014. Lund, Sweden: Lund University.

Papon, P. (2004) 'European scientific cooperation and research infrastructures: Past tendencies and future prospects', *Minerva*, 42: 61–76.

Swedish Government. (2007a) 'Regeringen vill bygga stor europeisk forskningsanläggning - partikelacceleratorn ESS blir störst i världen', Swedish Government, press release 27 February 2007. Stockholm: Swedish Government.

—— (2007b) Swedish Government bill 2007/08:1, Budget bill for 2008, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2008a) Swedish Government bill 2008/09:1, Budget bill for 2009, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2008b) Swedish Government bill 2008/09:50, 'Enhancing research and innovation'. Stockholm: Swedish Government.

—— (2009) Swedish Government bill 2009/10:1, Budget bill for 2010, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2011) Swedish Government bill 2011/12:1, Budget bill for 2012, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2012a) Swedish Government bill 2012/13:1, Budget bill for 2013, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2012b) Swedish Government bill 2012/13:30, 'Research and innovation'. Stockholm: Swedish Government.

—— (2013) Swedish Government bill 2013/14:1, Budget bill for 2014, Expenditure area 16: Education and university research. Stockholm: Swedish Government.

—— (2014) 'Finanseringen klar för European Spallation Source', Swedish Government, press release 4 July 2014. Stockholm: Swedish Government.

Swedish Research Council. (2008) Annual report 2007. Stockholm: Swedish Research Council.

—— (2009) Annual report 2008. Stockholm: Swedish Research Council.

—— (2010) Annual report 2009. Stockholm: Swedish Research Council.

—— (2011) Annual report 2010. Stockholm: Swedish Research Council.

—— (2012) Annual report 2011. Stockholm: Swedish Research Council.

—— (2013) Annual report 2012. Stockholm: Swedish Research Council.

—— (2014) Annual report 2013. Stockholm: Swedish Research Council.

Westfall, C. (2010) 'Surviving to tell the tale: Argonne's intense pulsed neutron source from an ecosystem perspective', *Historical Studies in the Natural Sciences*, 40: 350–98.

—— (2012) 'Institutional persistence and the material transformation of the US national labs: The curious story of the advent of the Advanced Photon Source', *Science and Public Policy*, 39: 439–49.

Whitley, R. (1984) *The Intellectual and Social Organization of the Sciences*. Oxford, UK: OUP.

Widmalm, S. (1993) 'Big Science in a small country: Sweden and CERN II'. In: Lindqvist, S. (ed.) *Center on the Periphery: Historical Aspects of 20th-Century Swedish Physics*, pp. 107–40. Canton, MA: Watson Publishing International.