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Scientific Research in Sweden: Orientation Toward the American Centre and Embeddedness in Nordic and European Environments

Introduction

The institutionalisation of science in seventeenth century Europe included the adoption of faith in universal validity, the cognitive presupposition that truthfulness of knowledge is independent of time and place and therefore also of its creators and their social and cultural contexts. It also included institutionalisation of the purpose of the activity as extending public knowledge as common property of humankind. And it included a moral obligation to evaluate creations irrespective of their origins and to confer recognition on creators irrespective of their location. This institutionalised cosmopolitanism entailed a potential for world-wide institutionalisation of science as a communal enterprise with participation throughout the world. This potential is moving toward realisation. It is a slow and uneven process of globe-wide institutionalisation and globe-spanning organisation, the globalisation of science (Schott, 1991b, 1993b).

Scientific practice in a society is integrated with science elsewhere in so far as researchers interact with colleagues in other places. Some of these places are intellectually salient environments. Scientists gravitate towards places of high creativity. They scrutinise works published in such places and seek to publish their own works there, sojourn there for training and collaboration, communicate with colleagues there and look to them for validation and recognition. The loci of creativity thereby become centres of attraction and, in turn, centres of collegial ties. Science has tended to have a major seat of creativity which has been the centre, although the centre has shifted. It was located in England at the time of institutionalisation of science in the seventeenth century, and then moved to France, Germany, and on to the United States (Ben-David, 1984). Scientists in the other regions make up a periphery around the centre. This centre-periphery formation has been pervasive in the contemporary scientific world system;

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even Soviet science was a periphery intellectually attached to the American centre. Although centre-periphery relations dominate, they do not account for all relations. Reality is more complex, especially if the focus switches from the global formation to the position of a particular society (Schott, 1988, 1992b, 1993b).

Scientific research in a society is integrated in various ways and extents into multiple environments. Scientific practice in the society may be mainly attached to science in the centre but may also have ties to science in other regions. Specifically, it may be integrated with science in the regions that have close affinity and intense links with the society in other spheres. Scientific ties are somewhat embedded in other kinds of links between societies (the effects of international political-economic and cultural links upon ties between scientists have been estimated as considerable; Schott, 1988).

Colleagueship in science is a bundle of several more specific and analytically distinct kinds of role-relations (Burt and Schott, 1989). The core of scientific practice is the creation and diffusion of new knowledge, based mainly on existing ideas. Therefore a most salient kind of role-relation is influence, the dissemination of ideas and their use in further creation of knowledge. Influence is rather pervasive and omnipresent. Collaboration is another kind of role-relation, denoting joint performance of research. Yet other role-relations are less intellectual in substance but essential for scientists' participation in the enterprise. Scientists emulate one another, they look to one another's performance and use that as a yardstick for self-assessment and engage in usually benign competition to excel in the performance of the scientific role. Such emulation may take the form of competition for rewards. Scientists seek validation of their findings from others. Others evaluate the validity and worth of a scientist's findings and accordingly withhold or confer recognition on the scientist as a social reward for performance. Scientists care about receiving such validation and recognition of their work.

Integration is an encompassing concept with several meanings. One kind of integration is cultural integration as shared beliefs and values. Another kind of integration is social integration as the formation of a transnational social activity. Cultural integration and social integration are analytically distinct but tend to be intertwined in reality and be mutually reinforcing. In this study, social integration refers to density of social ties, especially of communication associated with a transnational division of labour and with a functional interdependence which is occasionally denoted system integration (Angell, 1968). I shall focus on social integration in science, i.e. the formation of a transnational scientific enterprise. Scientific practice in a locale is transnational in so far as collegial ties are not merely local but also transcend national boundaries so that the research is part of an intellectual tradition that is translocal rather than merely local. The concept of integration may be applied at several levels of aggregation of units, from the macro-level of integration of the world (which may be an aspect of globalisation; cf. Robertson, 1992; Schott, 1991b), through intermediate levels such as the integration among regions and the integration within a region, and on to more micro-levels such as the integration between a society and another region, notably an environment. I shall examine the integration between Sweden and its expectedly salient environments.

Integration is a theoretically important phenomenon because it has consequences both for the contents and for the level of research in the country. The scientists' integration into transnational networks shapes the contents and the direction of the research in the country. Furthermore, integration entails access to information useful for research and enhances awareness of translocal standards of valid and worthy science. Ben-David proposed the hypothesis that integration of research in a small country with its environment, especially with the centre, has a positive effect on research performance (1962). The hypothesis was corroborated in a comparative historical study of integration and

performance of mathematicians in Denmark and Palestine/Israel since the 1920s (Schott, 1980,1987b). The evidenced consequences of integration for research provide a scholarly rationale for examining integration.

Sweden in Nordic, European and American environments

One society with several environments is Sweden. This study focuses mainly on the integration of Swedish research with science in its environments. I put forth the hypothesis that several environments are salient, that Swedish research is integrated into several environments, but that the manner and extent of integration into these environments differ according to specific conditions.

Social studies of past and present science in Sweden have focused on institutional arrangements and science policy. Now, analyses of the transnational integration of research are being started. The historical material reported in other articles in this issue of the journal shows that ties were significant with colleagues in the other Nordic countries, and also appeared more significant with Central Europe than with Southern Europe. In this century, Swedish scientists' collegial ties to the United States have intensified. In the 1980s, the scientists in the medical, natural, and technical sciences at the University of Lund apparently travelled most frequently to the United States, second most to West Germany, followed by nearby Denmark and the United Kingdom, as indicated by records of the major travel bureau (Cederlund, 1990: 25). In the 1970s and 1980s Swedish scientists have collaborated most frequently with colleagues in the United States, then the United Kingdom, West Germany, Denmark, France, Finland, Norway, Italy and then Canada, as indicated by jointly authored articles (Kungliga Vetenskapsakademien, 1989: 71; see also Luukkonen et al., 1991). Much travel and collaboration has been embedded in transnational institutional arrangements such as intergovernmental and interuniversity cooperation agreements (Kungliga Vetenskapsakademien, 1989: 10—67). The historical and contemporary evidence suggest that it may be informative to distinguish among four salient environments around Swedish science, namely the other Nordic countries, Central Europe, Southern Europe, and North America. This specification of environments, rather than another grouping of countries, is also motivated by the following geosocial and geocultural conditions.

Sweden has been culturally integrated with the other Nordic countries, Denmark, Finland, Iceland and Norway. The Swedish, Danish, Icelandic and Norwegian languages are so similar that they can be understood fairly well everywhere in these countries, thus enabling students from any Nordic country to attend courses given in any of these languages. Finnish is quite different but most educated Finns can speak Swedish. Commonalties among the Nordic societies in culture and in modes of daily life have also promoted exchanges among them. Intergovernmental collaboration has been close, and there are many institutions and organisations to promote collaboration and the exchange of ideas. Consequently there are several cultural and academic exchange agreements among them, promoting mobility and sojourns of students, research trainees, and faculty among the Nordic universities. There are also several joint Nordic research institutes, scientific societies and journals (Sivertsen, 1991). These institutional arrangements have enhanced integration.

Western Europe is another environment which is expectedly salient. It may be salient in science because it is salient in the economy and the polity where, notably, Sweden is seeking membership in the European Community. But Western Europe is not homogenous and some parts have particular affinities with Sweden in language, religion and associated spheres. Swedish is a Germanic language, so it may be informative to distinguish between the countries speaking a Germanic language and the countries speaking other languages. I shall consider Central Europe here comprising

Austria, Ireland, the Netherlands, Switzerland, the United Kingdom and West Germany. And I shall consider Southern Europe here comprising Belgium, France, Greece, Italy, Luxemburg, Portugal and Spain. Typically, higher educated Swedes have learned English and some German in school but not much French or other Southern European languages. The Swedish linguistic commonality with Central Europe coincides roughly with the major religious division in Europe insofar as Sweden shares the Protestant tradition with most of the population in Central Europe but not with Southern Europe. The shared language and religious tradition has expectedly enhanced the salience of Central European science for researchers in Sweden.

Yet another salient environment has been North America, especially the United States. North America has been the locus of greatest scientific creativity in the last half-century. Roughly half of the living Nobel laureates in the sciences work in North America. The scientific institutions in North America have exerted considerable attraction throughout the world. Students have flocked there, young researchers have sought training there, and mature scientists have sojourned there for collaboration. American science has been the centre of world science and has therefore expectedly been a salient environment of research in Sweden.

My hypothesis is thus that Swedish science is integrated into these four environments — the other Nordic countries, Central Europe, Southern Europe, and North America — because of several social and cultural conditions. Each environment derives its scientific salience mainly from its own constellation of social and cultural conditions. Scientific integration is expectedly an orientation toward creativity but it is variously reinforced and constrained by its embeddedness in geosocial and geocultural links.

Science here refers to the natural, medical and technological sciences and research refers to the creation and dissemination of contributions to world science. The data are indicators derived from the world's mainstream scientific literature as indexed in the *Science Citation Index* and from a questionnaire survey around 1991 of a sample of 507 scientists around the world[1](the survey is described in Schott, 1992a, 1992b, 1993a, which also show validity and reliability of indicators).

Performance and specialisation

Swedish scientific performance can be indicated both by the articles authored by scientists in Sweden and by the Swedish share of major contributors to science named by respondents in the survey of scientists around the world. These two indications of scientific performance are listed in Table 1, together with some societal conditions of scientific activity, namely shares of population and wealth.

In Table 1 the two indications of scientific performance, contributors and articles, show similar distributions (with the exception that respondents showed a considerable tendency to name contributors within their own country which can be explained by a greater awareness and more thorough understanding of local work). The similarity shows that the indications are reliable.

According to these two measures, Swedish performance has been around two per cent of the world scientific performance. Its scientific performance has been rather similar to that of the other Nordic countries and has been about one tenth of that in Central Europe. The Swedish share of world science has been more than twice its share of world economic production and roughly ten times as large as its share of the world population. None of the regions display such a high level of scientific performance relative to the economy or to the population. Sweden has had a small population which has been economically very productive and this wealth has enabled the society to invest considerable resources in scientific research. Reciprocally, science is likely to have promoted economic growth through its uses in higher education and industry in the country.

Table 1. Distribution across regions of major contributors (1991), of scientific articles published (1986), of Gross National Product (1986) and of world population (1986), in per cent.

	Scientific performance		GNP	Population
	Major contributors	Articles published		
Sweden	2.3	1.74	.75	.17
Other Nordic countries	1.3	2.01	1.31	.29
Central Europe	18.0	17.6	10.9	3.0
Southern Europe	8.5	9.4	9.7	3.7
North America	41.6	40.9	31.3	5.4
Rest of the world	13.4	28.3	46.0	87.4
Respondent's country	15.0			
Total	100.1	99.95	99.96	99.96

Notes: In this and the following tables, other Nordic countries comprise Denmark, Finland Iceland and Norway. Central Europe denotes Austria, Ireland, Netherlands, Switzerland, the United Kingdom and West Germany. Southern Europe here denotes Belgium, France, Greece, Italy, Luxembourg, Portugal and Spain. North America denotes Canada and the USA. The rest of the world denotes Eastern Europe, the Soviet Union, Asia, Africa, Latin America, etc.

Sources: Survey of scientists around the world (see above and footnote 1), dataset derived from *Science Citation Index* (Stevens, 1990); *World Bank* 1991; Shoup, 1981; Taylor & Jodice, 1983; United Nations, 1988.

Table 1 also shows that not only has wealth been concentrated in a small part of the population on earth, but scientific research has been even more concentrated. Research has been concentrated in North America, much has been performed in Central Europe, some in Southern Europe, and less in the other Nordic countries. This is consistent with evaluations made by respondents in a survey of scientists in the European Community (Franklin, 1988). Respondents rated the level of scientific achievement in the United States, Japan and the countries in the European Community. European scientists considered the highest level of achievement to be in the United States, followed by the United Kingdom, Japan, France, the Netherlands, Belgium, Denmark, Italy, Ireland, and Greece, among the rated countries (Franklin, 1988: 59, 342). Actually, the scientific gap between the capitalist developed countries and the poor countries has widened in recent decades (Schott, 1991b).

The scientific performance of a region is of course a condition affecting its volume of collegial ties. The scientific smallness of the other Nordic countries limits the volume of ties and the immensity of North American science enhances the volume of ties with scientists in Sweden. Integration with the various environments will therefore be examined both as the volume of Swedish ties with each environment, which is partly due to the scientific size of the environment, and as the relative intensity of the Swedish ties with each environment, where intensity is adjusted for size of the environment.

To ascertain trends in Swedish performance and specialisation in the global division of scientific labour, the Swedish share of world scientific knowledge creation is indicated by the percentages in Table 2, with a disaggregation into disciplines and, as another disaggregation, into basic science and applied science (Stevens, 1990).

Table 2 indicates in the row for all disciplines that the Swedish scientific performance relative to the world has increased over the years, from about 1.6 % in the mid-1970s to about 1.7 % in the mid-1980s. There has evidently been some specialisation in Swedish research insofar as disciplines have differed from the overall percentage and their trajectories have differed. Clinical medicine has been emphasised in Sweden. Biomedicine has been more typical, close to the percentage for science as a whole. Compared to these medical disciplines, the other disciplines have been less cultivated in Sweden.

Table 2. Percentage of articles written by Swedish authors of all published articles, 1973—1986, by discipline and type of research.

	1973	1975	1977	1979	1981	1983	1986
Clinical medicine	2.60	2.74	2.67	2.74	2.69	3.02	2.99
Biomedicine	1.59	1.86	1.67	1.60	1.63	1.67	1.74
Biology	.60	.61	.68	.93	.81	.91	1.06
Chemistry	1.15	1.12	1.05	1.00	1.03	.89	1.00
Physics	1.00	.96	.82	.93	.82	.89	.94
Earth & space science	.74	.87	.57	.63	.61	.71	.82
Technology	.88	.87	1.05	1.27	1.21	1.01	1.08
Mathematics	.95	.72	.81	.82	.72	.66	1.05
All disciplines	**1.53**	**1.61**	**1.56**	**1.61**	**1.58**	**1.68**	**1.74**
Basic science	**	**	**	**	1.36	1.41	1.52
Applied science	**	**	**	*'	2.12	2.31	2.31

Source: Dataset derived from *Science Citation Index* and compiled by CHI research (cf. Stevens 1990)

The least emphasised disciplines have been biology and earth and space science. The disciplines that have been increasingly emphasised are clinical medicine, biology and technological science. There has also been some specialisation in applied science versus basic research. Swedish research, compared with science elsewhere in the world, has focused more on applied science.

This analysis shows that the Swedish scientists have performed a small but slightly increasing amount of the world's research and that, in the global division of scientific labour, Swedish specialisation has emphasised medical sciences and applied science.

Influence upon and from Swedish scientists

Influence upon scientists in a region can be indicated by the citations in their articles refering to earlier publications written in the same or other regions (a row in Table 3). The diagonal in Table 3 shows that research in each region — also in Sweden — has been highly influenced by earlier results of research within the same region. Such local influence has been greatest in North America; this is the only region that has been largely autarchic. Every region — also Sweden — has been highly influenced by North America, as shown in the column for North America. North America has evidently been the world centre of scientific influence. All other regions have been rather peripheral, they have exerted little influence but have all been receptive to influence radiating from the centre. The roughly 37% North American influence on Swedish research by far exceeds the roughly 24% influence from the West European environment.

Influence upon Swedish research from the other Nordic countries has evidently been small by this absolute measure, but that is because of the smallness of the overall influentiality of the other Nordic countries. Actually, the other Nordic scientists exerted much more influence on the Swedes than on research elsewhere as shown in the second column in Table 3, so the influence from the other Nordic scientists on the Swedes has been great relative to their small overall influence. This integration in terms of relative influence is not clearly revealed in Table 3; the integration is overshadowed by the large influence of American science and obscured by the small overall influence of the other Nordic countries.

Integration in influence upon a national or regional scientific community from the community in another place can be better indicated as the observed influence (Table 3) relative to the influence that we should expect if influence were not embedded in particular relations between the places, but the influencing community and the influenced community were independent of one another. If influence were not selective, influence would just be proportional to the influencer's tendency to exert influence and also to the influencee's tendency to receive influence. This conception of influence can be formalised (such formalisation is considered in Schott, 1986, and used in studies of scientific influence, Schott, 1987a, 1988, 1993a).

Table 3. Percentage of the citations in the articles 1980—82 by each community which refer to articles 1978—82 by each community.

Citing authors	Cited authors						
	Sweden	Other Nordic	Central Europe	Southern Europe	North America	Rest of the world	Total
Sweden	**32.75**	4.15	15.38	4.42	36.62	6.68	100
Other Nordic	4.19	**29.41**	17.00	4.52	38.33	6.55	100
Central Europe	1.68	1.77	**44.01**	5.06	38.71	8.78	100.1
Southern Europe	1.65	1.81	16.30	**31.35**	40.46	8.44	100.1
North America	1.29	1.30	11.82	3.54	**75.51**	6.53	99.9
Rest of the world	1.33	1.28	14.36	4.53	36.71	**41.81**	100.2

Source: Dataset derived from *Science Citation Index* (Garfield, private communication).

Table 4. Ratio of observed citations to expected value of citations between regions.

Citing authors	Cited authors					
	Sweden	Other Nordic	Central Europe	Southern Europe	North America	Rest of the world
Sweden		1.94	.99	.96	.98	.89
Other Nordic	1.91		1.04	.94	.97	.83
Central Europe	.77	.79		1.06	.99	1.12
Southern Europe	.75	.80	.99		1.02	1.06
North America	.81	.79	.99	1.00		1.13
Rest of the world	.68	.63	.98	1.05	1.04	

Source: as for Table 3.

The conception of behavioural independence between influencers and influencees can be formalised by the model of statistical independence in a two-way table and involves computing expected values. The expected values are like those for the usual chi-square test of independence in a two-way frequency table except that we have no diagonal in the table of citations from each scientific community to the other communities. Under the model of independence, the expected number of citations from an influenced community **r** to an influencing community **c** is the product of two numbers P_rQ_c, where P_r is the tendency of **r** to cite others and Q_c is the tendency of **c** to be cited by others. The expected number can be computed from the observed citations from each community to the other communities. The diagonal-less matrix of expected numbers has the same row-sums and column-sums as the diagonal-less matrix of observed citations[2] .

The ratio of observed citations to the expected number of citations is a measure of integration in the web of influence (Table 4). Integration has been weak in so far as the measure is less than 1 and integration has been extensive in so far as the measure exceeds 1.

The first row in table 4 shows that Swedish research has been most integrated into science in the other Nordic region. Swedish researchers have been almost twice as much influenced by science in the other Nordic region than should be expected. They have not been especially integrated with science in Central and Southern Europe and in North

America but have been somewhat weakly integrated with science in the rest of the world.

Influence is of course not necessarily symmetric. The first column in Table 4 shows that the region where research has been most integrated into Swedish science is the other Nordic countries. Research elsewhere has been less integrated with Swedish science. Foreign scientists' ties to Sweden are further examined below.

These analyses of influence show that Swedish research has been a periphery influenced by the North American centre more than by any other region, even the whole West European environment. However, science in the other Nordic countries has exerted more influence upon research in Sweden than upon research in other regions so, in terms of relative influence, Swedish research has been integrated with science in the other Nordic countries. More surprisingly, Swedish research has not been more integrated with Central European than with South European research. Also contrary to the initial hypothesis about relative influence, Swedish integration with Central and Southern Europe has not been stronger than the integration with North America.

Collaboration involving Swedish scientists

Collaboration of Swedish scientists is indicated by the portion of their articles that they coauthored with colleagues at other institutions as listed in a row in Table 5. Juxtaposing the 1970s to the 1980s shows an increase in collaboration. Collaboration increased in science as a whole and in every discipline and it increased both within Sweden and with every region. However, Swedish scientists increased their collaboration more with foreigners than among themselves. In this Sweden is not unique, this trend is typical and is part of the globalisation of science (Schott, 1991b).

Table 5. Percentage of Swedish authored articles coauthored with scientists at other institutions, by region and discipline, in the 1970s (1973—1979) and 1980s (1980—1986).

		Sweden	Other Nordic	Central Europe	Southern Europe	North America	Rest of the world
Clinical medicine	1970s	43.0	3.8	3.1	.8	4.1	1.6
	1980s	47.1	5.3	4.0	1.9	5.7	2.6
Biomedicine	1970s	23.5	3.6	5.1	1.8	6.0	2.6
	1980s	26.1	4.9	8.6	3.8	10.2	4.4
Biology	1970s	9.6	3.7	3.1	1.5	2.5	1.9
	1980s	15.1	5.3	4.5	1.0	5.6	3.4
Chemistry	1970s	14.8	3.0	2.2	2.4	2.7	3.2
	1980s	20.0	2.5	3.5	3.9	4.2	5.4
Physics	1970s	8.4	7.4	11.1	4.6	8.3	5.5
	1980s	9.8	8.8	21.6	10.0	13.5	11.8
Earth and space science	1970s	7.3	6.9	10.7	2.8	14.0	5.6
	1980s	9.7	7.9	19.5	8.9	21.1	6.7
Technology	1970s	8.4	1.4	2.5	.5	3.5	1.2
	1980s	10.5	1.7	4.3	1.5	5.7	3.2
Mathematics	1970s	10.0	.7	5.4	.7	13.7	2.4
	1980s	13.2	3.7	4.7	2.2	11.9	5.7
All disciplines	**1970s**	**28.9**	**3.9**	**4.2**	**1.5**	**4.9**	**2.3**
	1980s	**33.3**	**5.2**	**6.7**	**3.2**	**7.5**	**4.2**

Note. Coauthored articles denote articles coauthored by scientists at different institutions. The percentages in each row sum to less than 100 in so far as articles had no coauthor at any other local or foreign institution.

Source: Dataset derived from the *Science Citation Index* (compiled by CHI-research, cf. Stevens, 1990).

Table 5 also shows that a considerable part of the Swedish collaboration has been with scientists in North America. In this, too, Sweden is rather typical. North America, and more precisely the United States, has been the centre in the global network of collaboration. Other regions have occupied more or less peripheral positions in this global web. Every country in Western Europe and throughout the Western world has been a periphery of the American centre of collaboration (Schott, 1991b). But comparison of North America to all of the West European environment shows that Swedish scientists have collaborated more with West European colleagues than with North American colleagues.

Swedish collaboration with scientists in the other Nordic countries has evidently been small by this absolute measure, but that is because of the smallness of overall collaboration involving the other Nordic countries. Actually, Swedish collaboration with other Nordic scientists may have been large relative to the amount of collaboration involving the other Nordic countries. Such relative intensity of collaboration is not revealed clearly in Table 5.

Integration in collaboration between regions can be indicated by the actual coauthorships relative to their expected frequency if collaboration occurred independently between scientific communities, i.e. in proportion to each community's tendency for outside collaboration. This is computed by the procedure used for Table 4. Integration in collaboration between two regions is then indicated by the ratio of the actual coauthorships to the expected value. Swedish integration with other regions, in science as a whole and in each discipline in a period, is listed in a row in Table 6. Integration was weak to the extent that the measure is less than 1 and integration was strong to the extent that the measure exceeds 1.

Table 6 shows that Swedish science in the global network of collaboration has been highly integrated with science in the other

Table 6. Ratio of observed coauthorships by region to expected value (if coauthorship were independent of regions) in the 1970s (1973—1979) and 1980s (1980—1986).

		Other Nordic	Central Europe	Southern Europe	North America	Rest of the world
Clinical medicine	1970s	.5.4	.9	.6	.8	.5
	1980s	4.8	.8	.7	.8	.6
Biomedicine	1970s	5.7	1.0	.7	.9	.7
	1980s	4.5	1.0	.8	.9	.7
Biology	1970s	11.7	1.3	2.1*	.6	.4
	1980s	13.2	1.2	.7*	.9	.5
Chemistry	1970s	6.5	.6	1.2	.7	.9
	1980s	5.3	.7	1.3	.8	1.1
Physics	1970s	5.4	.9	.7	.8	.8
	1980s	3.6	1.0	.8	.8	.9
Earth and space	1970s	6.6	1.1	.7*	.8	.7*
	1980s	5.0	1.1	1.1	.9	.6
Technology	1970s	9.7	1.2	.7*	.9	.5
	1980s	6.2	1.2	1.1	.9	.7
Mathematics	1970s	1.4*	1.3	.5*	1.1	.6*
	1980s	6.2*	.9*	.9*	.9	.9
All disciplines	**1970s**	**6.37**	**.93**	**.74**	**.83**	**.62**
	1980s	**5.39**	**.94**	**.85**	**.84**	**.70**

Note. Coauthored articles denote articles coauthored by scientists at different institution. The ratio is marked with * if the expected number of coauthored articles is 20 or fewer.

Source: Dataset derived from the *Science Citation Index* (compiled by CHI-research, cf. Stevens, 1990).

Nordic countries (collaboration has been about six times more frequent than should be expected). Swedish research has been rather typically integrated with science in Central Europe and in North America but has been rather weakly integrated in collaboration with science in Southern Europe and in the rest of the world. This differential integration has prevailed in science as a whole and also in each discipline. Table 6 also shows some changes from the 1970s to the 1980s, notably an increase in integration with Southern Europe and the rest of the world and a comparative decrease in integration with the other Nordic countries.

In short, these analyses of collaboration show that Swedish scientists have collaborated extensively with their foreign colleagues, and now much more than earlier. Collaboration has been greater with North American colleagues than with colleagues in Southern Europe, Central Europe and the other Nordic countries, but less than with the totality of West European colleagues. In terms of relative collaboration, integration has been quite strong with the other Nordic countries and somewhat strong with Central Europe. Over time there has been a comparative decline in domestic collaboration and in collaboration with colleagues in the other Nordic region. Swedish scientists' collaboration has switched toward more intense collaboration with distant colleagues. This globalisation has thus entailed a disembedding from the national and regional context.

Foreign scientists' role-relations with Swedish colleagues

The analyses up to this point have focused on the Swedish researchers' work and their orientations toward local and distant scientists. Scientists in other societies are of course also oriented toward researchers in Sweden, even though their Swedish colleagues are only a small fraction of their significant colleagues. Scientists around the world have deferred to science in Sweden, have been influenced by it and have collaborated with their colleagues in Sweden (Tables 1 to 6). Foreign scientists' ties with their Swedish colleagues can be further examined by the survey of scientists around the world (described earlier in this article and in footnote 1). Each respondent was asked to name the people, up to 20, whose ideas had influenced her/his research in recent years. The respondent then reported on six specific role-relations with each named colleague, namely the colleague's influence through her/his publications, influence through interpersonal communication, influence on problem choice, collaboration, emulation, and the respondent's caring about receiving recognition from the colleague. And, of course, the respondent reported where in the world each named colleague was located. Many of their named colleagues were local and some were in Sweden and the other Nordic countries.

To examine the consequences of *different* conditions, I shall compare the respondent's role-relations with a typical Swedish colleague to role-relations with a typical local colleague, i.e. a colleague named within the respondent's own country. In order to compare regions with *similar* conditions I shall compare respondent's role-relations with a typical Swedish colleague to their role-relations with a typical colleague in the other Nordic region.

Because of the similarity of societal conditions in Sweden and in the other Nordic countries, I expected that their two sets of role-relations are rather similar. I further expected that a role-relation with a typical Swedish colleague differs from the role-relation with a typical local colleague. More precisely, I expected an either weaker or stronger relation for each of the six kinds of role-relations. For theoretical reasons elaborated below, I put forth the following hypotheses:

1) Influence through a typical Swedish colleague's publications is stronger than influence through a typical local colleague's publications.
2) Influence through a typical Swedish colleague's interpersonal communications is weaker than influence through a typical local colleague's direct communications;
3) Influence from a typical Swedish colleague on problem choice is weaker than influence from a typical local colleague on problem choice;
4) Collaboration with a typical Swedish colleague is weaker than with a typical local colleague;
5) Emulation of a typical Swedish colleague is weaker than competition with a typical local colleague; and
6) Recognition from a typical Swedish colleague is less important than recognition from a typical local colleague.

Each hypothesis of a weaker or stronger role-relation is tested.

First, let us consider channels of influence. Researchers are influenced by intellectual material that they obtain through reading the literature and through more direct communication with colleagues, e.g. by attending seminars and conferences, paying visits, and by corresponding and conversing with selected colleagues. Because literature is disseminated widely but direct communication is constrained by geosocial and geocultural boundaries, it may be informative to distinguish between the channel of formal communication through publications and the channel of informal communication between scientists.

Respondents rated the two different types of influence on a scale ranging from 0 for "none" through 1 for "little", 2 for "some", and up to 3 for "great" influence from each channel.

Focusing on the formal channel, the respondent rated to what extent her/his recent research had been influenced by reading each named colleague's publications. Mean influences from local, Swedish and other Nordic colleagues were computed (Table 7, row 1). Differences between means were tested as described below the table. Influence through publications has been stronger from a typical Swedish colleague than from a typical local colleague, as expected. And influence has been similarly strong from a typical Swedish colleague and from a typical other Nordic colleague, also as expected.

Influence through informal personal communication (Table 7, row 2) has been weaker from a typical Swedish colleague than from a typical local colleague, as expected. Influence through personal communication has been similar from a typical Swedish colleague and from a typical other Nordic colleague, as expected.

Table 7. Mean intensity of role-relationship with local, Swedish and other Nordic colleagues (on a scale 0 for "none" up to 3 for "great").

	Colleagues		
Role-relationship	Local	Swedish	Other Nordic
Influence from colleague's publications	1.5*	2.0	2.3
Influence from contact with colleague	2.1*	1.8	1.8
Influence by colleague on problem choice	1.9	2.0	2.1
Collaboration with colleague	1.4*	.9	.9
Emulation of colleague	.6	.7	.8
Salience of recognition from colleague	2.2*	1.8	2.2
N of colleagues	1997	71	32

Note: Each hypothesis of a difference in a role-relationship with local colleagues compared to Swedes was tested by the t-ratio; two of the role-relationships were rather similar and four had a difference in the hypothesised direction and a one-tailed probability-value much less than .05 and thereby are statistically significant as marked with and asterisk *. Each hypothesis of similarity in a role-relationship with Swedes compared to the other Nordics was tested; for every role-relationship the t-ratio was considerably less than 1.96 and thus no significant difference was discerned.

Sources: Survey of scientists around the world (see footnote 1).

Influence is a rather encompassing concept. It comprises both influence on the choice of problems for research and influence on the solution of chosen problems. Influence on problem choice is an important phenomenon and national research policies often aim at selection of local problems, which emerge from local practical activities such as local industry or health services. Furthermore, we would also expect problem choices to be made through interpersonal exchanges rather than through reading the literature. Because interpersonal exchange tends to be more local than communication through publications (as just shown), we should expect influence on problem choice to be stronger from a typical local colleague than from a typical foreign colleague. The mean influence upon respondents' problem choice from each kind of colleagues is listed in the third row of Table 7. Influence upon problem choice has been similar from a typical Swedish colleague and from a typical other Nordic colleague, as expected. Influence upon problem choice has evidently also been similar from a typical Swedish colleague and from a typical local colleague. This refutes the hypothesis that influence on problem choice from a typical Swedish colleague would be weaker than from a typical local colleague. My interpretation is that national research policies in the respondents' countries have not been strong determinants of problem selection.

Collaboration is another kind of role-relationship, as considered earlier. The mean collaboration for the colleagues in each region is listed in the fourth row of Table 7. Collaboration has been similar with a typical Swedish colleague and with a typical other Nordic colleague, as I expected. Collaboration has been weaker with a typical Swedish colleague than with a typical local colleague, in accordance with my hypothesis.

So far this study has focused on intellectual relations with colleagues. However, scientists do not live from intellectual material alone; their performance of the scientific role also depends on motivation that is socially induced or enhanced by institutional arrangements such as social rewards that maintain and reinforce motivation for further performance. Scientists have social bonds with one another, they are social-psychologically attached to significant others and thereby feel their membership in the communal scientific enterprise. Emulation or competition is one social aspect of this participation in science. Scientists emulate others to excel in the performance of the scientific role. But emulation is more salient with some colleagues than with others. The mean emulation as rated by respondents is listed in the fifth row in Table 7. The emulation of a typical Swedish colleague has been similar to the emulation of a typical other Nordic colleague, as expected. Emulation of a typical Swedish colleague has also been similar to that of a typical local colleague, contrary to what was expected. Thus, emulation is both local and transnational.

Such emulation may take the form of competition for rewards. The fundamental reward in science is peer recognition, colleagues recognising the validity and worth of a scientist's work. Often a scientist cares about colleagues' recognition of her/his work, but some colleagues are more significant than others. The mean importance of recognition from colleagues in each region is listed in the last row of Table 7. Recognition from a typical Swedish colleague has been valued rather similarly to that from a typical other Nordic colleague, as was expected. Recognition has been less important from a typical Swedish colleague than from a typical local colleague, also as expected. But, evidently, caring about collegial recognition is highly transnational.

To summarise, two kinds of role-relations of the respondents with their Swedish colleagues have been unexpectedly similar to the role-relations with their local colleagues. Notably, Swedish and local colleagues have been similar in influencing the scientists in their problem choice, and the scientists have emulated a typical Swedish colleague to the same degree as they have emulated a typical local colleague. Apart from these two unexpectedly similar role-relations, the

Swedish colleagues' roles have differed from the roles played by the local colleagues as hypothesised. Specifically, the scientists have been influenced through a typical Swedish colleague's publications more than through a typical local colleague's publications. But the scientists have been influenced through a typical Swedish colleague's personal communication less than through a typical local colleague's direct communication. And the scientists have collaborated less with a typical Swedish colleague than with a typical local colleague. Also, the scientists considered recognition from a typical local colleague more important than recognition from a typical Swedish colleague. But Swedes did not differ from colleagues in the other Nordic countries: scientists' role-relations with Swedish colleagues were rather similar to the role-relations with colleagues in the other Nordic countries.

Conclusions

North American science has been the most influential environment around Swedish research. Sweden, like most other societies, has been a periphery tied to the North American centre of scientific influence. Swedish scientists have been intensely influenced by American scientific work, much more than by Wester European science. Nevertheless, their collaboration with American colleagues has been less than with colleagues in the whole West European environment combined. Thus, their collaboration has been more with their West European environment than with North America, but the influence has been stronger from North America than from their West European environment. The evidence thus shows that Sweden has been a periphery influenced mainly by the American centre.

Western Europe is not a homogenous environment, some parts are especially salient. The Swedes have been more attached to Central European science than to South European science and science in the other Nordic countries. Their small involvement with science in the other Nordic countries, however, has been due to the smallness of the scientific enterprise in this region. Taking this smallness into account, the integration with science in the other Nordic countries has actually been quite strong.

Research performance in Swedish science has grown a little from the 1970s to the 1980s, relative to the research performed in the whole world. Swedish research has been somewhat specialised, emphasising the medical sciences and applied science. The emphasis on medical science has even increased.

Swedish contributions to humankind's stock of knowledge have attracted deference from foreign scientists. Scientists have been influenced by Swedish colleagues, by the Swedes' publications and personal communications. Swedish colleagues have influenced foreign scientist's selection of problems for research and have occasionally also been collaborators. Foreign scientists have also emulated their Swedish colleagues and valued recognition from them.

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NOTES

1. Around 1991 a total of 507 scientists were surveyed, between 16 and 92 in each of the countries Bangladesh, Brazil, Chile, Czechoslovakia, Greece, India, Indonesia, Israel, Japan, the Soviet Union, the Unit-

ed States and Uruguay, typically distributed rather equally across the eight disciplines of the sciences, namely clinical medicine, biomedicine, biology, chemistry, physics, earth and space science, technological science and mathematics. Typically, in each country one or two sites (typically a city or a comprehensive university) were chosen and scientists were mostly sampled from the list provided by the geographical index of authors in the most recent issue of the Science Citation Index which enables a rather uniform and random sampling procedure, and they were classified into the disciplines according to the journals they published in (Stevens, 1990). With participation rates around 95 per cent in most countries, the respondent filled out a questionnaire , typically administered during an interview. One question asked the respondent about the principal contributors to scientific knowledge in the respondent's field. (1416 contributors were named and used for Table 1). The main part of the questionnaire tapped the respondent's circle of local and distant colleagues by asking the respondent to name the people who had influences her/his research in recent years and also to report the location of each named colleague. The role-relations, e.g. collaboration, with each named colleague were then tapped by a series of questions (used for Table 7). The reported origins of influence upon respondents in a country are similar to the origins of publications cited in articles by authors in the country as indexed in the Science Citation Index. This shows the reliability of citations as an indicator of influence among national scientific communities. Likewise, the respondents' collaborations with other scientific communities were similar to the coathorships among national scientific communities which were indexed in the Science Citation Index. This reliability was even obtained for science in regions comparatively less covered by Science Citation Index such as the Soviet Union and Latin America (Schott, 1992b, 1993a). National specialisation in research is indicated by a profile derived from the Science Citation Index which is rather reliable (Frame et al., 1977; Schott, 1993a). The other indicators based on the literature are also of sufficiently high quality (Moed, 1989; Schott, 1992a).

2 Modelling of a diagonal-less table with formulas for use in computing expected numbers is in Haberman, 1979, Ch. 7. and is implemented in publicly available software, Eliasson, 1990: 16—18.

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