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UNDERSTANDING THE DYNAMICS OF RESEARCH POLICIES: THE CASE OF SWITZERLAND

Our paper analyses the evolution of the Swiss research policy during the last fifty years and in particular the measures taken to support private R&D activities and to foster the cooperation between academia and industry. We base the analysis on the triple helix thesis, which suggests that the three institutional spheres of State, academia and industry are becoming more closely interconnected than in the past and thus, that the role of public policies is shifting towards the creation of interfaces between them. Our results partially support this model, showing that public research policy has moved towards a more comprehensive view of the role of the State in supporting research oriented to economic needs and in promoting economic innovation; however, they show also that the relationship between public and private research and the support for private R&D have been a central issue in the Swiss research policy at least since the II world war. We conclude that, in order to develop sound conclusions on the evolution of research policies in the last fifty years, the very general arguments put forward by the Triple Helix thesis, as well as by other accounts of change in research policies, must be integrated with a much more detailed analysis of historical cases. Moreover, we think that our approach opens very interesting avenues to apply the models and methods of communication sciences to study research policy.

Key Words: research policy, triple helix, economic innovation, public policy.

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1. Introduction

The context of our study is represented by the evolution of the research policy in advanced countries during the last decades and in particular, of the policies supporting research of economic interest.

At a first sight, the picture seems to be quite simple. Many studies on research policies in advanced countries have shown that since the '80 these policies are increasingly driven by the economic impact of research activities and are thriving towards a more active support to economic innovation and to fostering the cooperation between universities and private companies in research and technology transfer (see Ruivo 1994 and Elzinga and Jamison 1995 for a review of periodisations; Larédo and Mustar 2001 for recent comparative work). Economic concerns and the success of the Japanese innovation model (Freeman 1987), as well as new theoretical insights on the structure of the innovation process (Mowery and Rosenberg 1979; Martin and Nightingale 2000) have pushed towards a more active role of the state to support technological development and economic innovation, and to a growing integration between science and innovation policies[2].

However, this account must leave room for important national variance. While the general objectives and strategies of research policies might be quite similar across countires, the way they are institutionalised depend very much on the functioning of the political institutions and of the research system in each country. To express it differently, "there are distinct national styles of science and technology policy, which reflect more general differences in policymaking and governmental regulation" (Jamison and Elzinga 1995: 576). The thesis of the convergence of national research policies towards similar model of intervention (Lemola 2002) has then to be reconsidered more carefully. Secondly, the simple account of a more or less linear sequence of "paradigms" in research policy (Ruivo 1994), from a "science-oriented" model after the IInd world war to a model centred on the strategic relevance of research for innovation appears to be oversimplified.

For example, political and economical concerns were well present in the research policy after the II world war and, in the US case, most of the state financing to research was directed through mission-oriented agen-

[2] The shift in terminology, both in OECD publications and scientific literature on the subject, from science policy to "science and innovation policy" reflects largely this change in orientation.

cies and to large technological programs, like military research; space programmes and nuclear energy programmes (Guston and Keniston 1994; Martin and Etzkowitz 2001). Moreover, the homogeneity of today's research policies in most countries seems to be largely limited to the general objectives, while at the level of institutions and funding regimes different models coexist, backed by the interests of different actors and in competition for their share of state funding. Finally, institutions and funding regimes show also a marked continuity and path-dependence (Benner and Sandström 2000a), so that the effect of earlier choices may be felt over a long period time and keep national specificities despite of general convergence trends. In this respect, Switzerland appears to be an interesting case, since the Swiss research and innovation system has been characterised for a very long time by a clear separation between public research (mostly in universities) and R&D activities in private companies. The strength of private R&D activities (especially in the pharmaceutical sector, where companies are strongly engaged also in basic research; see Da Pozzo and Von Ins 1999), a traditionally liberal economic policy and the sceptical attitude of the academic milieus towards applied research have long retained the federal state from intervention to support private R&D and transfer activities; as a consequence, technology and innovation policy has almost no tradition in Switzerland (Freiburghaus 1991).

While this situation is widely known and has also been criticised by the OECD in the two reviews of the Swiss science policy (OECD 1971 and 1989), significant changes have occurred during the last two decades. Lack of collaboration between academia and industry and difficulties in the transfer of knowledge have been identified by the Swiss Science Council as one of the major weaknesses in the Swiss R&D system (Conseil Suisse de la Science 1997), while the reinforcement of these relationships has been declared by the government to be a priority for the Swiss science policy (Conseil fédéral 1994 and 1998). Also, the support for applied R&D activities has been strengthened through the launch of the priority programs of research at the beginning of the '90 and through the reinforcement of the commission for technology and innovation (CTI)[3], the agency charged of funding applied R&D.

[3] The Commission was originally called Commission for Science and Research (Kommission für Wissenschaft und Forschung in German, Commission pour l'encouragement de la recherche scientifique in French) and it was renamed in 1998 Commission for Technology and Innovation, when its role in the Swiss research policy was also reinforced (see chapter 5.5). For sake of simplicity, we will keep the name Commission for Technology Innovation throughout the text.

It seems then that a careful analysis of the Swiss case might shed some light on a series of important questions on the development of research policies, since we can anticipate a clear evolution, but also readily identify many important national specificities. Some questions we wish to address here starting from the Swiss case are then:

- how important are national specificities in research policies? Can we speak of convergence and in which sense and for which components of research policy?
- how have research policies changed since the IInd world war? Are there also continuity elements?
- can we speak of a shift towards a more "economic-oriented" model or rather of a change in the relative importance of different intervention models?
- finally, which factors stimulated this change? Are they common to all countries or linked to national specificities?

The paper is organised as follows. In section 2 we shortly present the Triple Helix Model and we discuss is possible use for research policy studies. In section 3 we define our case study and the methods used to analyse it. In section 4 we present the organisation of the Swiss research system, which largely explains the orientation of research policy. In section 5 we analyse the evolution of the Swiss research policy during the last thirty years and we present the main changes in the institutions and support instruments. Finally, section 6 draws some conclusion both for the Swiss case and for the general field of studies.

2. Research policies and the triple helix

The triple helix model is a representation of the change in the relationships between university, industry and state in the system of knowledge production, which was proposed at the mid of the '90 by Henry Etzkowitz and Loet Leydesdorff (Etzkowitz and Leysdesdorff 2000) and which has become the starting point of a large number of empirical studies and of a series of biannual conferences on the subject[4].

[4] The four triple helix conferences have been held in Amsterdam (1996), New York (1998), Rio de Janeiro (2000) and Copenhagen (2002). For an account see: http://users.fmg.uva.nl/lleydesdorff/index.htm and the report of last conference in Leydesdorff and Etzkowitz (2003).
All on-line references have been checked February 1. 2003.

While after the "first academic revolution" at the end of the 19th century the university system has emerged as a distinct "organizational field" in society, regulated mostly through peer review and academic recognition (Benner and Sandström 2000), the triple helix model suggests that its boundaries are increasingly eroding, both at the organisational and at the normative level. Thus, criteria of social and economic relevance are integrated into the academic normative system, while universities are moving towards an "entrepreneurial model", playing an increasingly important role in economic development through a systematic exploitation of the knowledge they produce (Etzkowitz et al. 2000). This organisation form overcomes the linear model of economic innovation, based on the distinction between the production of knowledge and their application (both institutionally and temporally), towards a more complex economy of knowledge, where university and industry are active in all phases of the process of knowledge production and application and cooperate through a series of institutional arrangements, including cooperation agreements, joint ventures, spin-off, technological parks, etc. Thus the three spheres of industry, academy and policy are increasingly overlapping, "with each taking the role of the other and with hybrid organisations emerging at the interfaces" (Etzkowitz and Leydesdorff 2000: 111).

A closer look to the literature shows that the model has two quite different inspiration sources: the first one is the use of the system theory of Luhmann to interpret the knowledge production system in terms of interaction and coevolution between different sub-systems (the three helices); the second one, more empirically oriented, is the model of the entrepreneurial university developed by Henry Etzkowitz on the MIT example (Etzkowitz 2002). In fact, its fathers acknowledge readily this composite nature of the model and the fact that the "triple helix" metaphor is used with very different meanings, ranging from the simple idea that state, industry and academia interact in the production of knowledge to much more complex interpretations in terms of mixing functions and coevolution (Leydesdorff and Etzkovitz 1998).

While the main focus of the triple helix movement is certainly the study of knowledge production and of innovation, there are also some interesting implications for research policy studies.

The first interesting feature is of course the focus on the trilateral interactions between state, industry and academia, placing the three spheres on an equal footing, without taking one of them as the driver of the system. This is something relatively new, since a large part of the lit-

erature has focused on the bilateral interaction between state and scientific community as the principal structure and motor of the science policy, thus leaving largely outside its analysis the issues of support to private research and of public-private interaction[5]. To the other side, work based on the national systems of innovation model (Lundvall 1992, OECD 1999) tend to consider research policy as an instrument to support economic innovation in firms and thus to lose its specificity of being a public policy oriented to multiple goals and the fact that a large part of research policy (at least in terms of financial means, but also of objectives and strategies) is oriented to support public research and not innovation activities.

A second interesting feature is the hypothesis of mixing functions, i.e. that is not possible to clearly separate between the functions of public and private research and, as a consequence, between the policies oriented to support the two; this is of course extremely relevant for the Swiss case, where the separation between the two domains was for a long time (and still is partially) a central ideological feature of research policy.

This implies also, at a normative level, that the reinforcement of the interactions between industry and academy through funding structures (e.g., technological programmes), but also through new regulatory arrangements (e.g. in the area of intellectual property rights) and through the creation of interface structures becomes a central issue for research policies, since it will improve the working of the triple helix and thus of the innovation process (cf. Etzkowitz and Leydesdorff 2000).

However, it is important to notice that the Triple Helix is a very high-level description of the knowledge production system, which also open to different interpretations. We will then use if largely as a general reference for our case study, rather than as detailed analytic model[6].

[5] We may in particular cite all the work based on the principal-agent model, which analyse the mechanism of delegation of some tasks in science policy to bodies managed by the scientific community like the research council (Guston 1996; Braun 1993).

[6] This point was fiercely discussed at the last Triple Helix Conference in Copenhagen, where some speakers denied that the Triple Helix is a scientific model: "To summarize our evaluation, we would argue that the Triple Helix is not a model: it is one of those accounts philosophers of science would call a high level theory" (O'Malley et al. 2002). In their answer, Leyesdorff and Etzkovitz (Leyesdorff L., Etzkovitz H. (2003) stress the value of the model as a stimulus to develop case studies and to look differently to the reality, thus discovering new phenomena. Of course, these views represent two completely different positions on the epistemological status of a model and on its main features.

3. Methodology and sources

We choose as a research method that of the individual case study (Berg 1998), i.e. the detailed analysis of a specific case. In terms of the classification of Stake (Stake 1994), the interest of our study is both *intrinsic*, since we wish to gain new insights on the functioning of the Swiss research policy, and *instrumental*, since expect some contributions to the general and theoretical debate on the subject.

The method of case study is the dominant approach in research on the triple helix, as it is documented by the proceedings of the past triple helix conferences and we might argue that this richness of analysis is one of the strengths of the triple helix movement. However, this choice needs some justification, both for the selection of the country and of the method.

At first, Switzerland is an interesting case because of the features of its research system – where large multinational companies coexist with a strong university sector – and of its research policy, with almost no federal state support to private research. Moreover, in historical terms the Swiss research policy model in the '60 and the '70 kept a very clear separation between public and private research and this makes the evolution towards more integrative models particularly interesting. Finally, the Swiss case is poorly documented both in the Swiss and in the international literature, since there are very few recent works published on the subject[7].

Secondly, comparative national case studies have of course the advantage that it is much easier to distinguish between common trends and national specificities (see Larédo and Mustar 2001 for recent work in this direction), but they are mostly limited to shorter periods (with the notable exception of Braun 1997) and it is very difficult to grasp the specific working of each national system. Then, with the choice of an individual case study we wish to privilege the depth of our analysis and the selection of a long-term perspective spanning over more than a 50 years period, which is coherent with the hypothesis of strong path-dependency of research policies.

[7] The only works published since the '80 are Benninghoff and Braun 2001, Benninghoff and Ramuz 2002, Lepori 2002 and Fleury and Joye 2002.

3.1. Delimitation of the field

The broad domain of our research is research policy, defined as *the set of objectives, institutions and mechanisms used by the state to support research activities (both in the public and private sector) and their use for general social, economic and political objectives* (modified from Calvert and Martin 2000). This definition underscores the fact that the scope of research policy goes beyond the support of public science and includes also economic considerations and instruments oriented to private companies, but is narrower than the approach based on national systems of innovation, which includes almost all policy measures related to economic innovation, like fiscal instruments or regulations of labour market.
While giving some general information on research policies, we focus more specifically on the measures and instruments oriented towards the needs of private companies and to the transfer of research results towards economic innovation, as well as on the rationales for the State intervention to support research of economic interest.

3.2. Institutional levels

In our study, we focus on the strategies and actions of the Swiss federal state (the Confederation), leaving outside the role of regional authorities and especially of the Cantons. This is an important limitation since in Switzerland the Cantons are important actors for the regional innovation policies, in particular through incentives and fiscal measures supporting innovative enterprises. Moreover, they strongly influence the research policy through their responsibility for the cantonal universities.
However, there are also good reasons for this choice. The first one is that the debate on research policy and especially on support to research economic interest as been conducted almost exclusively at the national level[8]; of course the cantons have played an important role as actors in this process, but essentially by limiting the scope of the action of the federal state in research policy. This choice is then coherent with our focus on research policies: the situation would have been of course completely dif-

[8] In Switzerland, research policy is the explicit competence of the federal state and all the direct measures to support research (not through university support) are taken by the Confederation. This is major difference with Germany, where the Länder have direct responsibility on research policy and cofinance the German research council DFG (Braun 1997; Schimank 1994).

ferent if we had studied science and innovation policies. The second reason is that we wanted to privilege historical analysis and this is only possible at the national level, since cantonal policies are poorly documented.

3.3. Time period

The time period considered spans from the II world war until the end of the XX century, since we believe that a careful historical analysis for a sufficiently long time period is essential to avoid conclusions based on short term developments or on too simple reconstructions of past policies.
Our starting point is the debate on the support economic oriented research during the II world war, with the creation of the CTI in 1944.
Periodisation is of course a difficult task; while there are a lot of periodisations of research policy at the international level (see for example Ruivo 1994 and Elzinga and Jamison 1995), we prefer to adopt a division based on some key events concerning the support to economic oriented policy in Switzerland:

- the creation of the Swiss Science Council in 1965, which is the first institution devoted to develop the strategies of science policy and marks the beginning of a period of intense development at the institutional level;
- the oil shock and the vote on the new constitutional articles on education and research in 1973, which largely changed the political and economical context of research policy;
- the creation of the State Secretariat for Science and Research in 1989, as the beginning of new attempts to coordinate research policy;
- the Federal act on the Universities of applied sciences in 1995 beginning the reinforcement and restructuring of the economically-oriented research policy.

Period	Begin
1944-1965	Creation of the Commission for Technology and Innovation
1965-1973	Creation of the Swiss Science Council
1973-1989	Oil shock and vote on the constitutional articles on education and research
1989-1995	Creation of the State Secretariat for Science and Research
1995-2000	Federal act on the Universities of applied sciences

Figure 1. Periodisation of the Swiss research policy

3.4. Sources

Our sources differ markedly according to the period considered. For the period until the end of the '60, there are a number of quite complete studies available; two of them - the newly published book of Fleury and Joye (2002) on the creation of Swiss National Science Foundation and the 1971 OECD review of the Swiss research policy (OECD 1971) – are particularly useful for the topic presented here. The works of Peter Hug are also important for the history of the Swiss nuclear programme (Hug 1998). The analysis of this period is then mainly based on available studies.

For the '70 and the '80 there are also some studies (see in particular Latzel 1979 and Hill and Rieser 1983), but they are not centred on economic-oriented research. More useful is certainly the 1989 OECD review of the Swiss research policy (OECD 1989), which contains a quite complete analysis of the functioning of the CTI. To complete this information, we had recourse to published documents and reports of the epoch and in particular to two very important reports on the future of the CTI at beginning of the '70 which largely summarize the debate at that time (CERS 1971; CSS 1972). The later messages of the Federal Council to the Parliament contain in some cases also useful historical materials. These messages (Conseil fédéral 1987, 1991, 1994, 1997, 1998, 2002), along with other official documents (see for example OFQC 1992, the objectives of the Swiss science policy of SSC and many other publications of the SSC) are our main sources for the '80 and '90, since there are practically no studies on the subject (except Freiburghaus 1991; see also Hof 2002 for some useful analysis). For this period, our work is also partially based on the experience of the author in the Swiss research policy[9] and on informal discussions and exchanges with many actors, which of course we cannot name here.

Finally, data on R&D financing in Switzerland are drawn from Lepori (2002), where time series from the end of the '60 to 1998 are available as well as some data for the preceding period, while data on scientific publications are drawn from the publications of the Centre for Science and Technology Studies in Bern (Da Pozzo et al. 2001).

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4. Some general features of the Swiss research policy and research system

Two structural features of the research system had (and still have) a profound impact on Swiss research policy. These are (1) the importance and organisation of private research activities and (2) the dominance of universities in the public research system (see figure 2).

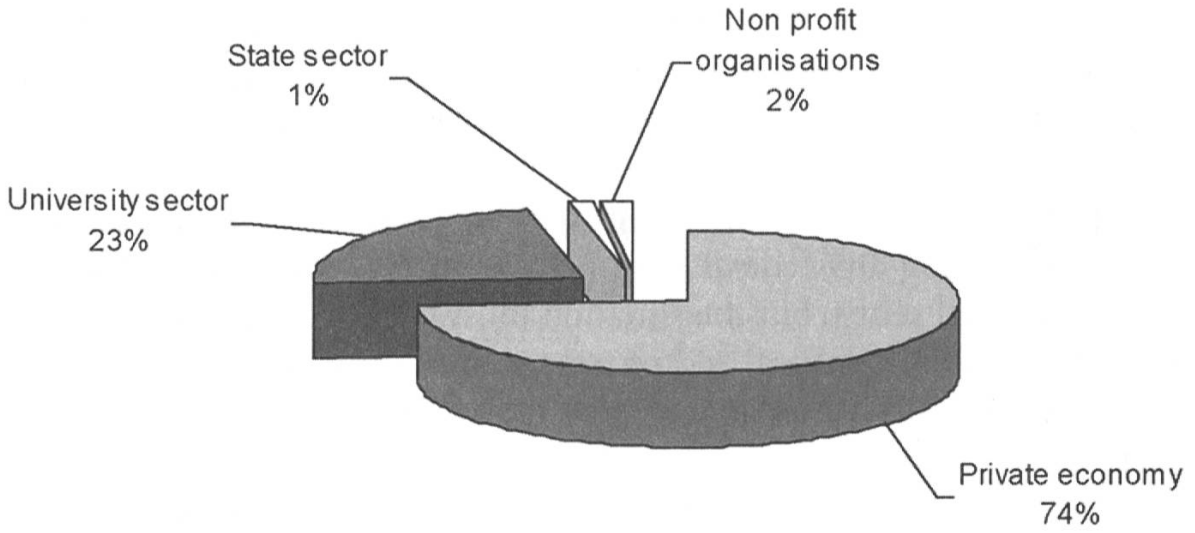

Figure 2. R&D execution in Switzerland 2000 (mio. Sfr.).
Source: Federal Office of Statistics

In an international comparison, business enterprises R&D expenditure in terms of GDP with 1,93% (year 2000; source: federal office for statistics) is one of the highest in OECD countries, almost at the same level as the USA (2,04%; 1998) and the Japan (2,18%; 1998) and significantly higher than all other European countries except Sweden (2,77%; 1997). A more detailed analysis shows that expenditures are highly concentrated in two sectors, that is in the pharmaceutical and chemical industry and in the machine industry (including electrotecnics), which account together for 70% of all industrial R&D expenditures (Office fédéral de la statistique 2002). These are of course the two main specialisation sectors of Swiss industry, where large companies are present (Novartis and Hoffman La Roche for chemistry and pharmaceutics; ABB and Sulzer for the machine industry and electrotecnics). OCDE data show also that the Swiss export is strongly specialised towards chemical industry and, to a less extent, machine and electrotecnics (OECD 1999).

Output data show however that the situation of these two sectors is quite different (figure 3). Data on scientific publications show that the

chemical and pharmaceutical industry is actively involved in basic research: in the 25 Swiss institutions which produce the largest number of scientific publication we find four companies and two privately-financed research institutes in this sector (Novartis; Hoffman-la-Roche; Glaxco; Nesté; Basler Institut für Immunologie; Friedrich Miescher Institut); except the IBM research centre in Rüschlikon there are no other private companies in this list (CEST 2001). The share of scientific publications from industry reaches 50% in pharmacology and exceeds 25% in immunology and food sciences (CSS 1999). OECD data on patents show the same specialisation pattern in the sectors agro-food, health and chemistry (OECD 1999).

Then, the picture of the Swiss industry being strong in R&D activities and thus refusing any federal state help or intervention (see section 5) holds in general terms, but the situation must be differentiated according to the sectors: the chemical and pharmaceutical industry has a strong research base and is well integrated with the academic world (as shown by the publication data), while the machine industry seems to be in a weaker position; also small and medium enterprises, which correspond to 75% of the total employment, don't have the same resources for R&D as large companies. As we will see in section 5, since the beginning of the '70 the representatives of these sectors took different positions towards state support for private R&D.

The counterpart is a strong university sector, composed by ten cantonal universities and the two federal institutes of technology (FIT) in Zurich and in Lausanne. The decision-making process – with the Cantons ruling their universities and the Confederation the FITs – brings a strong decentralisation of the system, lacking common rules for things like university organisation, academic careers, financial rules; this means also that there has little room for centrally defined priorities and for the establishment of centres of gravity in research[10]. Publication data show also that Swiss universities are generally very strong in research (Da Pozzo et al. 2001) and that research activity is widespread; there is then no clear distinction between research-strong universities and other universities, as it is present in other countries (Geuna 1999).

[10] The recent programme for the creation of national centres of excellence in research sponsored by the Swiss National Science Foundation has in reality led to the creation of networks of academic institutions coordinated by a leading house, rather to geographically concentrated centres.

Rank	*Publications 1994-99*	*Org. Type*	
1	University of Zurich	HE	11919
2	Eidgenössische Technische Hochschule Zürich (ETHZ)	HE	11080
3	Universiy of Geneva	HE	9737
4	University of Bern	HE	8099
5	University of Lausanne	HE	6927
6	University of Basle	HE	6795
7	European Organization for Nuclear Research (CERN)	INT	4602
8	Ecole Polytechnique Fédérale de Lausanne (EPFL)	HE	4259
9	NOVARTIS AG	IND	3338
10	Paul Scherrer Institut (PSI), Villigen	INST	2113
11	F-HOFFMANN-LA-ROCHE & Co Ltd	IND	1883
12	University of Fribourg	HE	1262
13	University of Neuchâtel	HE	1160
14	World Health Organization (WHO/OMS)	INT	1145
15	EAWAG, Dübendorf	INST	766
16	Basler Institut für Immunologie (ROCHE)	IND	638
17	F. Miescher Institut (NOVARTIS)	IND	609
18	Hospitals in Basle (mehrere Institutionen; exkl. Univ.-Spital)	INST	594
19	Kantonsspital St. Gallen	HE	542
20	IBM Corp.	IND	518
21	NESTLE Ltd.	IND	467
22	GLAXO WELLCOME (Glaxo-Smith-Kline)	IND	428
23	Inst. Suisse de Rech. Exp. sur le Cancer (ISREC), Lausanne	INST	403
24	Inselspital Bern (without Univ.-Spital)	INST	378
25	BA für Landwirtschaft (BLW) (with agricultural research stations)	INST	337
Other institutions			9177
Total		89176	89176

Figure 3. Publications of Swiss research institutions 1994-1999. Source: CEST 2001: 27.

HE: Higher education; IND: Industry; INT: international organisations; INST: public research institutes.

The weakness of the public non-university research sector is a major difference between Switzerland and other European countries like Germany and France. The most important institutes outside universities are the so-called "Annexanstalten", four institutes which are part of the domain of the Federal Institutes of Technology; three of them have principally a service function in the domain of water protection (EAWAG), materials and testing (EMPA) and forestry and landscape (WSL) along with a small part of R&D activities; the fourth one, the Paul Scherrer Institute (PSI), develops and exploits large research facilities in sectors like physics, chemistry, materials, energy and environmental research.

With 250. mio sfr. per year the R&D budget of the PSI is comparable to the largest Swiss universities. Other research institutes outside the universities include six institutes of research on agriculture, which are part of the federal administration, a group of about 20 research institutes outside the universities funded by the Confederation through the research act, as well some cantonal structures (i.e., the cantonal hospitals). Switzerland hosts also some large international research organisations, in particular the CERN and the headquarters of the World Health Organisation in Geneva.

Thus, the Swiss research system appears at a first sight to be characterised by the a clear separation of tasks between the public sector – mostly concerned with the development of new knowledge and training of skilled people for needs of industry – and the private sector, charged with the development of new technologies and its commercialisation. Fluxes of money between the two sectors are very small and, in particular, federal state financing for private R&D activities is together with Japan the lowest of all OECD countries (see figure 4).

While the real picture of the relationships between federal state and industry in R&D activities is much more complex, it remains true that the evolution towards a research policy more actively engaged towards innovation has been very strongly influenced by these structures and has then led to solutions which are specific to the Swiss system.

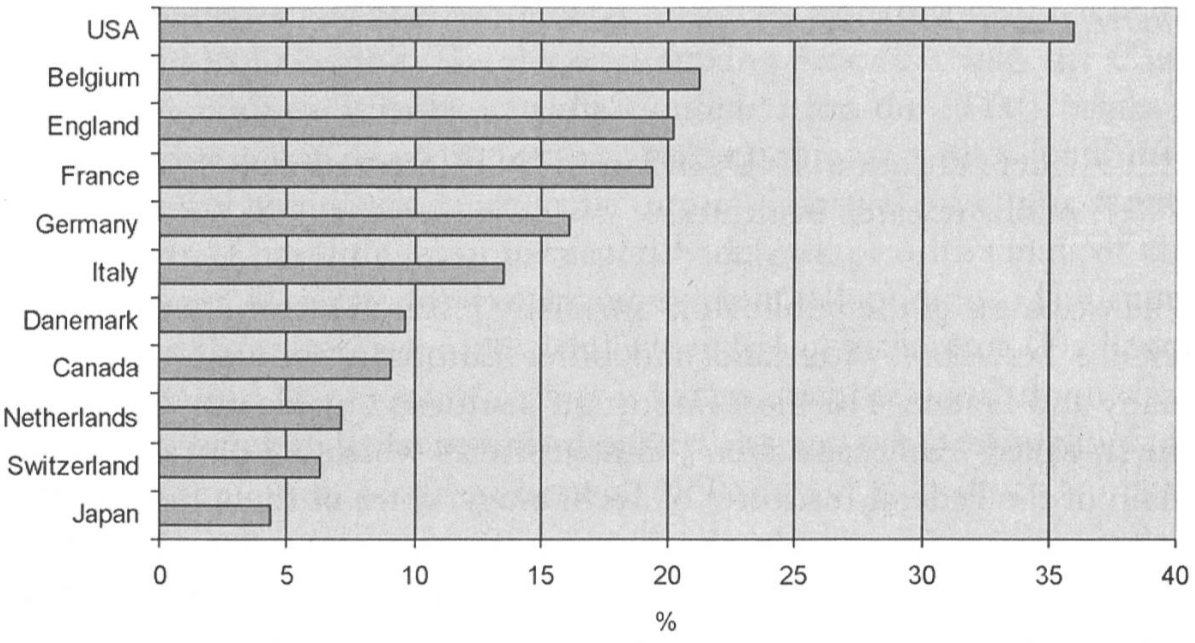

Figure 4. Percentage of state R&D financing going to private economy, 1996 Source: OECD 2000.

5. The evolution of the Swiss research policy 1945-2000

5.1. 1945-1965: policy for science and technological development

As in many other European countries (Braun 1997), direct state support to research activities (not as a part of the general university financing) began in Switzerland in the period across the II world war. Not surprisingly given the economic problems during the 30ies and the war, economic concerns were at the forefront. The federal government received then in 1934 the formal competence to support industrial research activities, as an instrument to create workplaces and against unemployment. However, industry was against state support, fearing that the state would try to control their research activities (Hug 1998).

This refusal led to a funding model, where the federal state finances the public part of research projects realised in cooperation between academia and industry and serving direct industrial needs; the private companies finance their share of the projects, but keep the exploitation rights of the results. This model was implemented in 1944 with the creation of the commission for the encouragement of scientific research (CTI); in 1945, the CTI was given a first credit of 4 mio. sfr., an amount which was comparable to the total annual budget of the ETHZ in the same year (Heiniger 1990). However, the CTI lost very quickly its importance in the period after the war. Firstly, the attempts to create a research council supporting academic research succeeded in 1952 with the foundation of the Swiss National Science Foundation (SNF; Fleury and Joye 2002). Secondly, the favourable economic climate – Switzerland did not suffer from the war destructions and thus recovered much more quickly than other European countries – made federal state intervention against unemployment superfluous and thus reinforced industry's scepticisms against CTI. In the subsequent years, the SNF budget grew very quickly, reaching 67 mio. Sfr. in 1970, while the CTI budget stagnated between 1 and 2 mio. Sfr. in nominal terms.

However, in the same period the Swiss federal state engaged in the biggest technological support programme of his history, namely in the field of nuclear energy. Officially, the objective was to develop a Swiss nuclear industry; however, military interests for a Swiss atomic bomb played probably an important role, even if they were never stated officially. The financial engagement was substantial; the newly created commission for atomic energy was granted in 1945 a budget of 18 mio. Sfr for the period

1947-1951; according to Peter Hug the total costs of the development of the atomic technology in Switzerland from 1944 to 1966 amounted to 615 mio. Sfr, of which 87% where financed by the federal state (Hug 1998). The private industry was actively involved in the programme; the two major companies in the Swiss machine industry, Brown Boweri (BBC) and Sulzer, participated in 1955 in the creation of the Reaktor AG, a company which should have developed a Swiss nuclear reactor.

This attempt failed due to technical difficulties, but also to the concurrence between the two companies. In 1959 BBC decided to develop nuclear technology in Germany cooperating with Krupp; in 1960, the Reaktor AG came back to the federal state as the Institute for Research on Reactors, which became in 1989 part of the Paul Scherrer Institut. In 1964, the Swiss electricity companies decided to build nuclear plants with American licence, thus bringing the attempts to develop a national industry to the end. The conclusion is that research policy in this period matched both the interests of academia and of the dominant industry sectors. Academia benefited from the increasing support from the SNF. The chemical and pharmaceutical industry having sufficient financial means for his R&D activity, as well as good connections to the universities and especially the ETHZ, was mostly interested in the output of trained personnel from the universities. At the same time, the Confederation took almost all costs of the development of a whole technological sector in the machine industry through the nuclear programme. This was of course possible in a period of favourable economic conjuncture and of positive federal state accounts; the percentage of the federal budget dedicated to research (excluding higher education financing) grew from 0,6% in 1950 to 2,6% in 1970 (Lepori 2002).

5.2. 1965-1973: institutional restructuring and new issues

During the second half of the '60 the Swiss research policy went through its most important period of institutional innovation, laying down the structures which are still present today. The major events were the creation of the Swiss Science Council (SSC) in 1965, the beginning of federal support to cantonal universities in 1966, the creation of the Swiss University Conference and of the Division of Science and Research (later Federal Office for Education and Science; FOES) in 1969. Thus, for the first time, the federal state administration had bodies with competences to develop concepts and instruments for the science policy, gaining autonomy from the interests of

academia and industry. In 1969 too, the federal parliament created the commission for science and research, while the association of private industry (the "Vorort") created its commission for science and research.

Early in this period the discussion on support to research oriented to economic needs surfaced again; in 1966 the CTI submitted a report to the federal government, stressing that the federal support to applied research should be put in a broader context than the fight against unemployment, while in 1967 the deputy to the parliament Eric Choisy proposed the creation of a Swiss national foundation for applied research. The OECD survey of 1969 states the existence of a debate on this issue, as well as the existence of different positions in the industrial milieus (OECD 1971). In 1968 the federal council charged the CTI to prepare a new conception for the support to economic oriented research; following this report in 1971 (CERS 1971), in 1972 the Swiss Science Council published his recommendations. The SSC report distinguishes between three objectives of state support for research, i.e. a) the encouragement of research linked to higher education teaching and to the development of human knowledge b) the support to research oriented to social and political problems and c) the support to research serving the economic innovation. While the state was clearly legitimate to support the first two kinds of research, much care had to been taken in the third domain to order to respect the private initiative and the freedom of industry and commerce (CSS 1972). The search for an institutional solution proved also very difficult. Two alternatives were in the foreground: the creation of a new institution and the assignment of the support to economic-oriented research to SNF. The SSC preferred the second solution, which however would have requested a major revision of the SNF structure that was hardly compatible with its academic orientation.

The impression is that the discussion was somewhat an abstract one; the concerns about the competitiveness of the Swiss industry and the pressure of the OECD not being, in a period of (still) favourable conjuncture, strong enough to push existing actors to modify their attitudes; moreover, the issue of financing of the universities, faced with a strong increase of the number of students, and of the development of the socially-relevant research were clearly in the foreground in this period.

5.3. 1973-1989: stability and economic crisis

In 1973 the Swiss citizens accepted the new constitutional article on research, but refused with a very small difference a new article of the federal

constitution which would have given to the confederation larger competences in the education sector and, in particular, for universities[11]. Along with the financial crisis of public powers (the federal budget showing large deficits since 1971), the confrontation between the Confederation and the Cantons on the division of competences in the university sector slowed down the institutional development of research policy, so that the new federal research act entered into force only in 1984.

At the same time the economic crises of 1975-1978 and 1981-1983 (in 1975 the Swiss GDP dropped by about 7% in real terms) led to a more interventionist attitude of the federal state into economic affairs[12]. A series of programmes directed to revitalize the Swiss economy were launched in 1978 (Impulse programme I), 1982 (Impulse programme II) and 1983 (Measures to strengthen the Swiss economy), while at the same time public support was granted to structurally weak regions (especially for the watch manufacturing in the Jura region) and to mountain regions. A substantial part of these programmes were dedicated to research and innovation activities, in fields like machine industry, energy savings in buildings, management informatics. The total amount of the research and innovation measures in the three programmes was about 140 mio. Sfr (OECD 1989).

The management of the research support measures was attributed to the CTI, which received substantial financial means; its annual budget grew from 1,5 mio. Sfr. in 1969 to 15,3 mio. Sfr. in 1985. In fact, the increased support to the CTI was the only measure in the impulse programme that the Vorort accepted without reservation. Thus, the combined effect of the failure of reform attempts at the beginning of the '70 and of the economic crisis was that the CTI could slowly gain of importance and (re-)establish itself in the Swiss research policy. In 1985, the parliament approved for the first time a four-year credit for the CTI, which enabled the commission to better plan its activities (previous credits were granted on an year to year basis); with 150 mio. Sfr. the amount was substantially higher than in the previous years. In 1987, the Commission was also charged to manage the Swiss participation to the European framework programmes and to EUREKA.

[11] The modification of the constitution was actually accepted by the majority of the voters, but refused by the majority of the Cantons (which is need for modifications of the consitution).

[12] This competence is given to the Confederation in article 100 of the federal constitution, which states that the Confederation shall ensure a balanced economic development and, in particular, prevent and fight unemployment and inflation; to this aim, the Confederation may in some domains depart from the principle of economic freedom.

A second train of measures started at the beginning of the '80 to support research and technology transfer in the domain of microelectronics, which was considered as a key technological area both at the international level and for the Swiss industry (the message of the federal council of 1987 cites the programmes in other countries, like the UK programme ALVEY and the European programmes ESPRIT and RACE; Conseil federal 1987). The Confederation and the Cantons participated, together with private industry, in the creation of the Fondation Suisse de Recherche en Michrotechnique (FSRM; 1978) and of the Centre Suisse d'Electronique et de Michrotechnique (CSEM; 1983), both located in Neuchâtel at the hearth of the main swatch-producing region. The mission of the CSEM, being a private company whose financing comes in equal parts from the state (Confederation and Cantons) and from private companies, is to develop high-level competences in microelectronics and to offer services for the technological needs of industry. In the same domain, the Confederation financed university research through a national research programme in microelectronics, started in 1984 and endowed with 21 mio. Sfr. . Finally, the Confederation launched in 1985 a large programme to support university training and infrastructure in informatics, endowed with 150 mio. sfr., including the creation of an high-speed telecommunications network linking the Swiss universities. The first elements of the large technological programmes which would characterize the first part of the '90 where thus laid down.

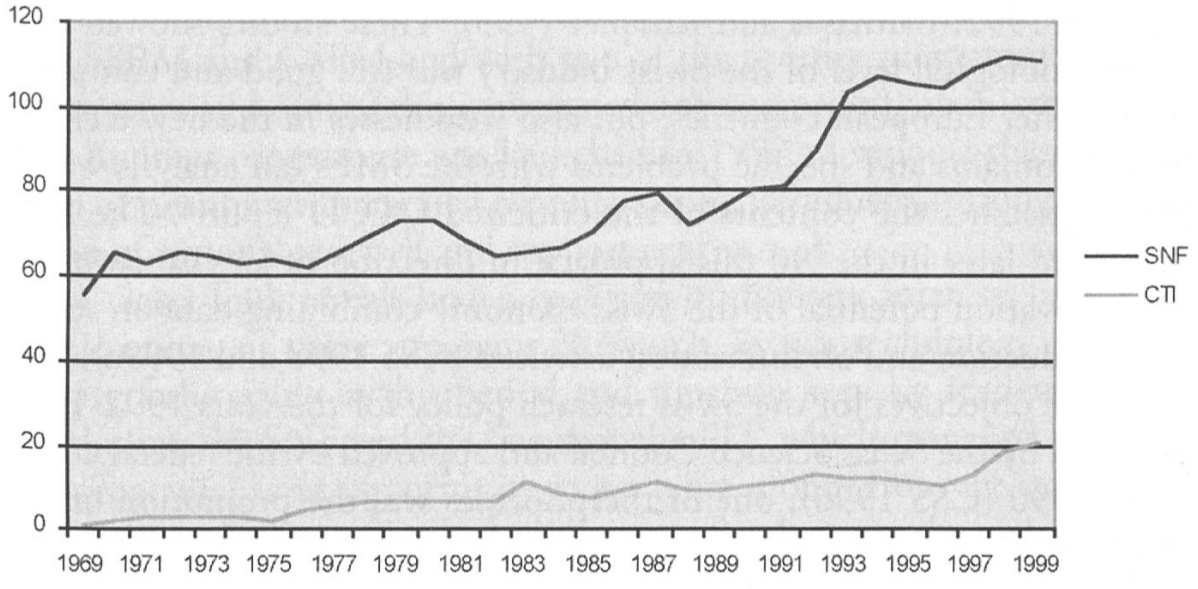

Figure 5. Budget of SNF and CTI 1969-1999 in real terms (1969 mio. sfr.). Source: Lepori 2002.

5.4. 1989-1995. The period of the technology programmes

In the years 1988-1989 the OECD realised a second review of the Swiss science and technology policy (OECD 1989). In the chapter dedicated to technology and innovation, the experts noticed that the Swiss industry in general was still in a good position, but that its technological portfolio was too conservative and that Switzerland was lagging behind in some new key technologies like information technologies and materials. They also noticed that there was a need for more active state intervention in three domains, i.e. support to small and medium enterprises, state support programs in new key technological fields and promotion of the interface between academia and industry. These remarks fiercely contested by the Swiss delegation at the review meeting; the representatives of the industry found the presentation of the situation too negative and stressed the traditional position that the state should not intervene in the private R&D (with the notable exception of the representative of machine industry)[13]. This discussion showed of course that the issue was being felt as an important one, but also that possible solutions where very controversial, especially on the evaluation of the situation and on the need to support specific technological fields.

The actuality of the issue is demonstrated also by a number of the studies, which were financed by the federal office for conjuncture (the office supervising the CTI; see OFQC 1995) and by the Swiss Science Council through its committee for technological policy (Mooser 1992; Knöpfel 1992; Balthasar and Knöpfel 1993). These studies showed that the technological level of the Swiss industry was still good and comparable to other European countries, but also weaknesses in the new technological domains and specific problems with the SMEs (an analysis which largely matches the contents of the criticized OECD report). The SSC developed later in the '90 this approach in direction of an evaluation of the innovation potential of the Swiss economy combining data on scientific production and on innovation activities (CSS 1998 and 1999a).

In the objectives for the Swiss research policy for the years 1992-1994 prepared by the Swiss Science Council and approved by the federal council in 1990 (CSS 1990), one of the priorities was the promotion of the technological development and the support to key technologies. The new

[13] See the minutes of the meeting between the OECD experts and the Swiss delegation reproduced in OECD 1989.

secretary of state for science and research Heinrich Ursprung, formerly president of the Federal Institutes of Technology, was one the major advocates of this more dirigistic attitude and of the definition of clear thematic orientations, which of course draws strongly on the example of other countries and on OECD work. To the other side, the department of economy and the federal office for conjuncture promoted a broader approach more oriented towards a diffusion-oriented policy. The 1992 report on technology policy of the Confederation (OFQC 1992) considered technology policy as a part of economic policy, giving thus the priority to measures oriented to reinforce the competitiveness of the Swiss economy and to the incentives to private innovation. In the higher education and research policy, the reform of the education of engineers and of the technical school was indicated to be the first priority.

However, in this phase, the support to key technologies was clearly at the forefront. In 1992, the Swiss parliament approved the launch of six priority programs aiming to support research in key technological areas like information sciences, material sciences, biotechnology and environmental technologies (Conseil federal 1991). With 357 mio. Sfr. for the years 1992-1995 the budget for these programs was about the double of the CTI budget for the same period. Respecting the industry's veto for direct financing of private R&D these programs financed only research projects in the universities and in the federal institutes of technology, but a clear objective was to establish strong links with private economy. Moreover, 100 mio. Sfr. were approved for the MICROSWISS program in the domain of microelectronics; together with the federal support to the FSRM and CSEM and with two of the priority programmes (power electronics and optics) this constituted a strong priority in microelectronics. Another programme was launched in 1992 to support the introduction of Computer Integrated Manufacturing in industry, through the creation of regional research and support centres.

A closer look reveals how a coalition of different interests brought to the creation of these programs. Research in key technology areas was clearly fashionable in this period and thus was seen by academic circles (including the SNF and the board of the FIT, which managed the priority programs) as an opportunity to get more money from the state; at the same time, the Vorort backed this proposition because the new programs were of interest for private industry (the alternative being discussed were big investments for new facilities at the Paul Scherrer Institute), but not too interventionist. With the exception of the biotechnology pro-

grammes, these programmes were also concentrated in the industrial sectors (informatics and machine industry) more favourable to state intervention.

The second major initiative of this period was the participation to the European framework programmes. Not being member of the EU, Switzerland signed in 1986 an agreement permitting the participation to EU projects through Swiss financing. Since 1988 the CTI financed Swiss partners according to his normal rules, i.e. excluding financing for private companies. However, in 1992 the Swiss voters refused the European Economic Area Agreement, which provided for full Swiss participation in EU research programmes. To ensure the Swiss participation the procedures to get financing were simplified and Switzerland accepted the EU financing rules, meaning that also Swiss industries would receive federal state support. Responsibility for the financing was transferred from the CTI to the Federal office for education and science, with the motivation that EU programmes were more "science-oriented" that Eureka. It is probable that the growth of these programmes was not foreseen at the epoch and that Eureka was considered to be more important. In reality, FOES financing increased from less than 10 mio. sfr. in 1992 to more than 100 mio. in the year 2000, an amount which exceeds the actual CTI budget. Given the high priority of the European policy, the parliament voted without difficulty the credits required for this participation.

A look to the participation data shows the scepticism of parts of the industry towards European programmes; about _ of the financial means for Swiss participation benefit to universities and public research institutes, while the industrial participation is dominated by the informatics sector (ASCOM, IBM research laboratories and Swisscom; Balthasar et al. 1997 and 2001). Thanks to the argument of the importance of the participation to the European programmes, the Vorort could then accept the support to Swiss industry (welcome by some of its members, like the machine industry) without endangering the general principle of no federal state support to private R&D.

5.5. 1995-2002. A new institutional setting

A major problem of the Swiss technology policy in the '80 and the '90 was its institutional fragmentation, some initiatives being of resort of the department of the internal affairs, while other activities being in the department of economy.

At the mid of the '90 began a process of reorganisation of the whole domain of technology policy and professional training which has led to a concentration of these competences in the department of economy. There are a few reasons which may explain this evolution. Firstly, at an international level, the age of large technological programs came to an end during the '90 and most European countries delegated this function to the European programmes (Larédo et Mustar 2001); the diffusion-oriented approach promoted by the federal office for conjuncture was then the (internationally) dominant one. Secondly, in 1998 a new state secretary for science and research was nominated; the main concern of Mr. Kleiber was to reform the structures of the Swiss universities (Kleiber 1999) rather than to direct research towards specific technologies. The priority programs have then been replaced since 2000 by the instrument of the national centres of excellence in research, which aim to create scientific centres of excellence in the Swiss universities; the focus has clearly shifted towards the reinforcement of the Swiss scientific place and towards basic research, a reorientation which matched the interests of the SNF and of the academic milieus.

At the same time, in 1995, the new federal law on the universities of applied sciences started a process of reform in the sector of tertiary professional training (Hof 2002; Conseil federal 1994a): the existing technical schools were grouped in seven universities of applied sciences (Fachhoschulen), which received also an explicit mandate to perform applied research and transfer of knowledge especially to local companies. Thus, the Swiss higher education sector was reorganised in two distinct filières, one more oriented to basic research and to general university training composed by the cantonal universities and the two FIT, the other to applied research and professional training composed by the Fachhoschulen.

Finally, in the framework of the reform of the federal administration, the whole field of higher education, research and technology was reorganised by concentrating all the competences in the department of internal affairs and in the department of economy. The former received all the tasks concerning basic scientific research and universities, while the second took in charge the domain of applied research and technology transfer, the Fachochschulen and the professional training. To this aim, two existing federal offices were merged in 1998 into the new Federal Office for Professional Education and Technology (FOPET), which is in some respects the counterpart in the economy department of the Federal Of-

fice for Education and Science in the internal affairs department. The two existing institutions for research funding were attached to this structure: the SNF receives his funding from the FOES, while the CTI is depends from the FOPET which hosts his secretariat. The CTI received thus an official mandate as the federal agency for the support to research oriented to economic applications (Conseil federal 1998), as well as supplementary financial means to strengthen research activities in the Fachoschulen.

Surprisingly enough, this organisation seems to match more the needs and the concepts of the '70 when the idea of a national foundation for applied research was born than the new concepts about the relationships between science and innovation, which would call for a much closer integration between the two. We could say that the conceptual integration of research policy in a wider innovation framework (see for example OFFPT 2002) has not come along with a parallel integration in the institutions of research policy and of funding mechanisms. In fact, in the last years, both the parliament and the Swiss Science and Technology Council claimed for the unification of the whole higher education, research and technology domain in a single ministry (see also Rossel et. al 1999).

6. Conclusions and open issues

In this section, we concentrate on the main continuity elements and changes across the examined period and on the implications of our analysis for the structure of research policies.

6.1. State, academia and industry

Our first remark is that the private industry has been since the IInd world war (and even before) an important actor of research policy, which has strongly influenced the strategies and measures adopted. It is enough to think to the debate on the creation of the CTI during the war period.

Moreover, trilateral coalitions between actors in industry, academia and state have played a crucial role for the set-up of research funding programs. Examples include the Swiss nuclear programme with the alliance between Brown Boweri and Sulzer, the military department and a group of university professors in nuclear physics, in particular Paul Scherrer (Hug 1998), as well as for the reinforcement of the CTI at mid '90, with a coalition between the federal office for conjuncture, the machine indus-

try and the new Fachochschulen, interested to receive support for their research.

Hence, we can readily say that the trilateral interaction between state, academia and industry characterizes the Swiss research policy for the whole period considered, but also that the three helices are far from being homogeneous, as shown by the wide differences in the attitude of the industrial milieus.

Moreover, it is apparent that the actors in research policy were always convinced that research oriented to economic needs and innovation is essential for the well-being of the country; what changed is the evaluation of the capacity of private industry to fulfil autonomously this tasks and the definition of the role of the state.

The discussion on the subject has been largely conditioned by the economic conjuncture. In effect, the historical reconstruction shows that the support to economic-oriented research was an important issue in three periods, i.e. during and in the years immediately the IInd world war; from the end of the '60 to the end of the '70 and at the end of the '80 and in the first half of the '90. All these periods were characterized by strong worries on the capability of the Swiss industry to stay competitive with other countries and on its capacity to finance sufficient research activities in the private laboratories. Hence the wish from some industrial milieus, but also a push from the state to intervene.

Thus, the model of research policy seems to be largely influenced by the general economic conditions. From this point of view, the period of support to basic research in universities in the '50 and the '60 was also the product of an exceptionally long period of economic growth, where state intervention to support private research activities was seen as superfluous, while in the later period a less stable conjuncture sustained a stronger involvement of the state.

6.2. Continuity and change

The second remark is that there are strong elements of continuity along the whole period considered and, moreover, that continuity and change are significantly different when we consider different dimensions of research policy, i.e. general objectives and strategies, institutions and funding mechanisms.

As for the general strategies, we can readily find an evolution from a conception where the role of the state was limited to the support to aca-

demic research, leaving to private companies the task of transferring the results to economic application, towards the idea of a more active role in the development of key technologies and, more recently, in the promotion of university-industry linkages and the transfer of results to practice. Thus state intervention should not be only conjunctural (to help industry in crisis periods), but also structural to reinforce the national innovation system, for example helping to develop specific technologies, building centres of excellences and fostering university-academia linkages.

This conceptual evolution has begun at the end of the '60, but has not been really established until the '90. From the reading of original documents, it is apparent how strongly the OECD work and the examples of other countries influenced this process; even if the recommendations of the OECD report of 1989 were harshly criticized, we can found almost the same arguments in Swiss official documents of a later period.

However, the institutional development follows partially a different logic. For example, the recent restructuring of economic-oriented research led to a separation between basic research and university training at one side, applied research, professional training and technology transfer to the other side, a model which is much more coherent with the old linear model than with the current concepts about innovation. This institutional structure depends much more on the need to share competences between two departments which were historically involved in research policy than on conceptual reflections. Also, the CTI has come through the whole historical period considered, keeping basically the same organisation and funding criteria and resisting to all attempts to replace it with another body or simply to close it down.

Thus, institutional development takes largely the form of reorganising the existing institutions (or adding new while keeping the existing ones) and is strongly dependent on the capacity to build a consensus between all the concerned actors; this means that institutions give stability to research policy, but also that contingency matters because reforms can be blocked by very specific circumstances. For example, at the beginning of the '70 time seemed to be ripe for the creation of a new fund to support applied research. However, the existence and the strength of the SNF hindered this process since creating a new fund would have weakened its position (and, of course, the universities were against this). Moreover, the financial crisis meant that no additional means were available for this task.

Finally, looking at the funding practices shows an astonishing picture

of continuity. Hence, the general principle that the state does not support private research activities has been always kept, while the funding criteria of the CTI are almost the same as in the '40. At the same time, the Confederation has repeatedly engaged in large technological programs during the '40 and '50 (in the nuclear energy field) and during the '90 (mostly in informatics and microelectronics); in both cases they were based on an institutional setting where the public sector performed research to develop technologies of direct interest to specific industries, but too risky for the (conservative) Swiss private sector.

This example shows also how a general principle (no state financing for private research) could be handled pragmatically, covering in reality a substantial support to private research and innovation through very close partnerships (as, for example, between the priority programme on biotechnology and the pharmaceutical industry). The same is of course also true for the Swiss participation to European programmes (see chapter 5.4).

Our conclusion is that research policies are complex objects with different components which are only loosely coupled; hence, the representation of coherent models for research policy is a strong simplification which might lose some central features. Moreover, paces and patterns of change of these components differ considerably, because of their nature, but also because they are subject to quite different forces. For example, funding patterns depend essentially on the situation of public finances and on budgetary practices (Lepori 2002), which means that changes in strategies could have no impact on funding simply because there are no financial means available. This means that the interactions between these components (as well as the mismatches created by their different evolution) are a central element in the functioning of research policy.

6.3. Convergence and diversity

A corollary of the preceding remark is that the thesis of a convergence between national research policies must be handled with much care, since our analysis shows that there are factors pushing towards convergence and others maintaining the national specificities.

Among the first, we can indicate the overall trends in economic development (for example the economic conjuncture) and in the research systems (the change in organisation of research and in the leading scientific and technological fields), as well as the international reflections

on research policies (especially at the OECD) and the imitation of policies of other countries (like the example of Japan in the '80; Lemola 2002).

The impact of these factors is very evident: we may cite for example the importance of the downturn of economic conjuncture at the beginning of the '70 and the choice of the main technological fields of Swiss research policy (from atomic energy to microelectronics and later life sciences), which follows closely the international trends. We also already commented on the importance of OECD work in changing the overall representation of the role of the state in economic innovation. Imitation seems to be a more complex issue: while there are clearly references to the practices of other countries in Swiss official documents, one has the impression that these are mostly used to legitimate the strategies and measures supported by national actors, rather than as inspiration source for new initiatives.

However, national specificities are also very important: for example, the particular structure of the Swiss research system and the central role of a small number of large private companies in two economic sectors has largely conditioned the research policy. Moreover, the specificities of the Swiss political system (the federal structure of the country and the search of a consensus solution as the basic rule of the political process) are essential for the development of research policy and, in particular, for its institutional organisation.

As a consequence speaking about convergence we should carefully distinguish between influence factors and impacts on policies; even if overall trends in economic and research systems are largely the same, research policies can still be very different because the mechanisms that control their institutional development are strongly country-specific and depend very much on historical developments. Thus, path-dependency in institutional development might keep diversity between countries even if driving forces are largely the same.

Finally, variance in institutional organisation and in the strategies of different actors translate into different intervention mechanisms (especially funding mechanisms) and reactions to external pressures.

Moreover, convergence might be quite different for each of the components of research policy discussed in the previous section; our findings support the hypothesis that convergence is much easier for general strategies and objectives than for institutions and funding practices. One should not then take the fact that in most countries the overall frame-

work of research policies seems to be quite similar as a sign that their functioning and instruments are also converging.

6.4. Reconsidering research policy models

Our final remark is that the Triple Helix framework has proven to be fruitful in inspiring a broader view on the Swiss research policy, which does not focus unilaterally on the State-Academia interaction. Moreover, it was useful to focus on the interactions (or frictions, to take the term used by the fathers of the triple helix) between different subsystems and on their evolution, rather than on stable models where each actor has a well defined place. Our findings clearly support the use of such an open framework for case studies instead of a more rigid analytical model, as well as the value and the richness of the national case studies approach (which allows to better understand the detailed functioning of decision processes).

However, we think that a further step is needed to describe analytically a) which are the most important subsystems and actors in research policy, b) which are their interactions (and frictions) between them and c) which are the external forces pushing on the system, how these act (e.g., through which subsystem) and which is their impact on the system's dynamics. This is also a prerequisite for a really detailed discussion of the issue of national convergence along the lines sketched in the previous paragraphs.

The work presented here can then be seen as a first step in understanding the dynamics of Swiss research policy, where we purposely privileged the collection of primary data and information to document the very diverse and country-specific functioning of the Swiss research policy, as well as we presented first attempts of interpretation.

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