GERNOT HUTSCHENREITER
NORBERT KNOLL
FRITZ OHLER
MANFRED PAIER

AUSTRIA'S INNOVATION SYSTEM IN AN INTERNATIONAL COMPARISON

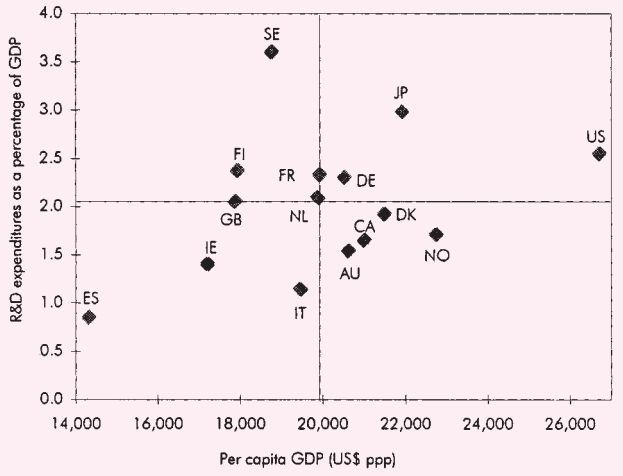
THE AUSTRIAN REPORT ON TECHNOLOGY 1997

The Austrian Report on Technology 1997, drafted within the framework of the Austrian tip program, provides a summary of facts and linkages within the Austrian innovation system. It draws on national sources of information as well as a host of international data. Austria's innovation system has been analyzed – wherever possible – from an international perspective. The Austrian Report on Technology is designed to serve as a source of information for the definition of positions and the promotion of a debate on technology policy issues. It addresses the actors of the innovation system in business, research, politics and administration as well as the general public interested in issues of technology policy.

Gernot Hutschenreiter and Norbert Knoll are economists at WIFO, Fritz Ohler and Manfred Paier are experts on technology at the Austrian Research Center Seibersdorf (ARCS). The authors would like to thank Hannes Leo for valuable suggestions. This article contains a summary of the "Austrian Report on Technology 1997". The "Austrian Report on Technology 1997" was prepared by WIFO and ARCS within the framework of "tip", a technology policy research and consultancy program initiated by the Federal Ministry of Economic Affairs and the Federal Ministry of Science and Transport (Vienna, 1998, 90 pages, ATS 350). Please send your order to the Austrian Institute of Economic Research, Mrs. Kautz, A-1103 Vienna – Austria, P.O. Box 91, phone (+43 1) 798 26 01/282, fax (+43 1) 798 93 86, e-mail kautz@wifo.ac.at.

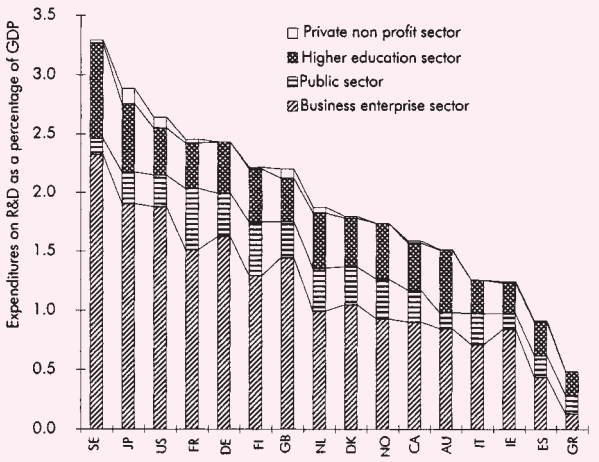
In a general sense, the level of per-capita income or productivity may be regarded as the most comprehensive indicator of the level of technological development of an economy. In this respect, Austria has performed quite impressively. Following a successful economic catching-up process, Austria today ranks among the leading industrialized countries in terms of per-capita income and productivity. However, as a highly developed, high-wage industrialized country, Austria is facing new challenges within the framework of a globalizing economy. Austria will only be able to maintain its position within the leading group of countries, if it is able to achieve a high productivity level through the use of new technologies and succeeds in reaping the advantages of specialization in human capital intensive and technologically advanced products.

Figure 1: Gross expenditure on R&D and per-capita GDP 1995



Source: OECD, Main Science and Technology Indicators; Austrian Central Statistical Office.

Figure 2: Gross expenditure on R&D by performing sectors 1993



Source: OECD, Main Science and Technology Indicators; Austrian Central Statistical Office.

THE AUSTRIAN RESEARCH SYSTEM IN AN INTERNATIONAL COMPARISON

According to the findings of economic research, the most important driving force behind long-term economic growth is technological change. In this context, private and public investment in research and development (R&D) plays a key role. The public debate usually focuses on the ratio of gross expenditure on research and development (GERD) to gross domestic product (GDP). In this context, the following facts are worth noting:

- Since the early 1990s, Austria's ratio of GERD to GDP has been stagnating at a level of about 1.5 percent. The gap vis-à-vis the OECD and EU averages, which have slightly decreased in recent years (to 2.15 percent and 1.85 percent, respectively, in 1995), has become somewhat narrower. Yet, Austria's investment in research and development remains low for a country of its per-capita income level (Figure 1).
- It would take an increase in R&D expenditure from 1.5 percent to over 2 percent of GDP for Austria to join the group of countries with an above-average per-capita income and an above-average ratio of GERD to GDP (as compared to the median).
- Against the international trend in the 1990s, Ireland and Finland have significantly increased their ratio of GERD to GDP. Over the past years, these countries have succeeded in catching up considerably or even moved to the top by international comparison. Another country which has persistently raised its ratio of GERD to GDP is Denmark.

However, the structure of R&D expenditures, which is not usually considered in the general discussion, is just as important as its level. For this reason, major structural characteristics of the Austrian R&D system are highlighted in an international comparison. Among the particular features of the Austrian situation, we note the following:

Austria's investment in research and development remains low for a country of its per-capita income level. However, the structure of R&D expenditures, which tends to attract less attention, is just as important as its level.

- The share of the business community in overall research and development is relatively small. In the advanced industrialized countries the major part of R&D is performed by business enterprises. In the R&D intensive countries their share is in the range of two thirds to three fourths. With a business enterprise sector share of 56 percent (1993), Austria ranks among the bottom third of the OECD countries (Figure 2).
- In Austria, the share of GERD funded by government was 49.1 percent in 1995. This is the highest share among the advanced European OECD countries reviewed.
- The share of higher education R&D in public R&D expenditure in Austria is unsurpassed at the international level and financed almost entirely from public funds. Hence, the linkages of the higher education sector with

the business enterprise sector or with other establishments abroad are weak in terms of flows of funds.

- Austria is among the countries with a rather modest interaction between the business enterprise sector and other sectors. The share of externally performed R&D in total R&D funded by business enterprises in Austria is the lowest of all OECD countries.
- Data on R&D funded from abroad in general show only a low degree of internationalization or globalization of R&D. For the EU as a whole, the share of GERD funded from abroad was 6.5 percent in 1995. In Austria, the percentage of GERD funded from abroad was 2.5 percent in 1995, which is still well below both the EU average and that of other small open economies.
- The internationalization of Austrian research, in particular that of the higher education sector, is still at a relatively low level. The development of Austria's participation in the R&D programs of the EU is an auspicious sign in this respect.

The interactions between the components of the innovation system (universities – business enterprises – research institutes) are rather weak in Austria. The share of externally performed R&D in total R&D funded by business enterprises is the lowest of all the OECD countries reviewed.

As mentioned above, the interactions between the components of the innovation system (universities – business enterprises – research institutes) are generally weak in Austria. From an "innovation systems" research perspective, it is precisely the intensity and quality of these interactions between the various elements of the system which emerges as a pivotal point of technology policy.

SPECIALIZATION PATTERNS OF THE AUSTRIAN INNOVATION SYSTEM

A country's ability to innovate should not just be equated with research and development. Austria's human resources are a crucial factor in the generation and absorption of technological knowledge. The level qualification of the human resources available is a key to the international competitiveness of enterprises and the long-term growth potential of an economy. A one-sided focus on education, i.e., on the supply side (key word: share of university graduates) is not expedient from the point of view of technology and employment policy.

Austria's innovation system and locational quality

A survey conducted by WIFO (*Aiginger – Peneder,* 1997) among the managers and board members of major manufacturing as well as some service enterprises operating in Austria provides insights into the strengths and weaknesses of Austria as an industrial location. Among the 15 top-rated factors of locational quality (Top 15), there are only a few which can be attributed to the strength of Austria's innovation system. Positively valued aspects in this context are the availability of highly qualified and well-trained human resources and management's initiative and readiness for innovation. The Top 5 of the locational quality factors, however, are political stability, public safety, cultural and recreational facilities, environmental quality and legal certainty. Deficiencies in the innovation system are considered to be deficiencies of locational quality. Thus, shortcomings with regard to telecommunication costs, availability of venture capital, adaptability and openness to reforms, research facilities of international quality, acceptance of new technologies and openness of the telecommunication markets are listed among the 15 low-scoring locational quality factors (Low 15).

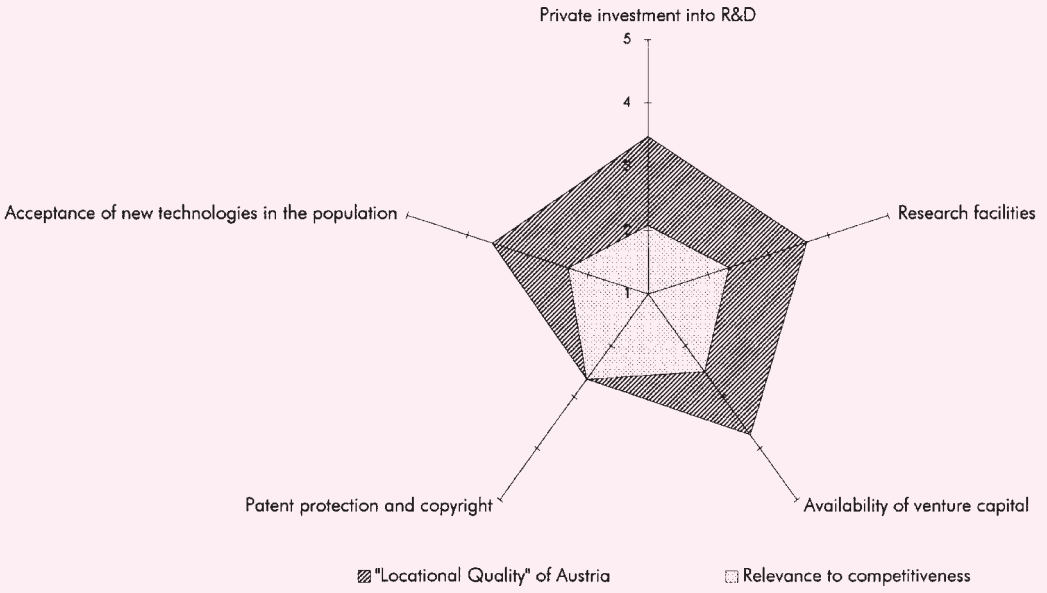
There is a gap between the importance attached by the managers questioned to technology-related factors of competitiveness of a country like Austria ("relevance to competitiveness") and the valuation of the perceived actual "locational quality of Austria" (Figure 3). The valuation was carried out on the basis of a scale ranging from 1 ("high") to 5 ("low"). Private R&D investment, research facilities, the availability of venture capital and the acceptance of new technologies therefore do not correspond to their importance to competitiveness. In the area of intellectual property rights (patent protection and copyright) the current situation is perceived to meet the requirements.

The availability of highly qualified and well-trained human resources is indeed regarded as one of Austria's most substantial locational advantages. However, there are open questions with respect to the efficiency of the qualification system and its structure (see the comparative study by *Lassnigg – Pollan,* 1996).

- Austria takes 13th place among 19 OECD countries with a 5.6 percent (1994) share of total expenditure from public and private sources on educational institutions in the GDP.
- The education system shows a pronounced focus on middle-level qualifications. By international compari-

Figure 3: Locational quality of Austria

Means of answers according to a scale from 1 ("very high") to 5 ("very little")



son, the share of secondary education is above-average and that of tertiary education below-average.

- Compared with other countries, science graduates – a highly qualified segment of human resources – represent a very low share in the population and the labor force.

A country's ability to innovate should not just be equated with research and development. Human resources are a crucial factor in the generation and absorption of technological knowledge.

The introduction of a tertiary-level technical college system is expected to broaden the scope of qualifications in accordance with conditions prevailing in Austria. In addition, the new competition brought about by tertiary-level technical colleges may in the long term have a positive impact on the performance of universities.

Patent activities represent another aspect of the specialization of innovation systems. The results of a review of Austrian patent applications are in line with the findings regarding the research and development system.

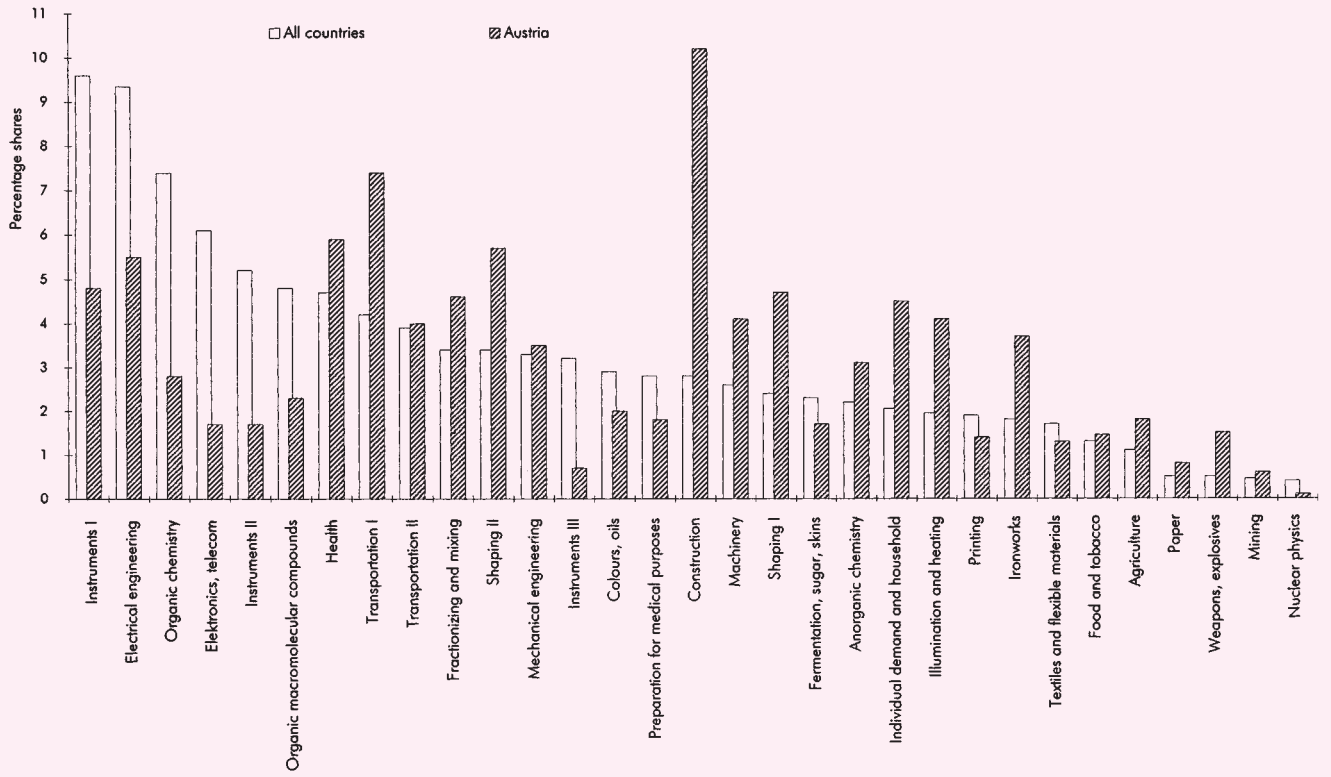
- The patent intensity (number of per-capita patent applications) is highest in the Scandinavian countries and Switzerland. Austria ranks in the lower half of the middle group of the European countries.
- By comparison, the degree of internationalization of Austrian patent activities is still rather low. However – as in other countries – it has been increasing rapidly in recent years.
- Austria's patent specialization shows some particular characteristics: the emphasis of Austria's patent applications at the European Patent Office is on technologies relating to "construction" (due to innovative enterprises which frequently occupy a significant position in the global market within their respective market niches). By international comparison, core areas of high technology, such as instrument engineering, electronics and communication, are clearly under-represented (Figure 3).

The patent intensity (number of per-capita patent applications) is highest in the Scandinavian countries and in Switzerland. Austria ranks in the lower half of the middle group of countries of the European countries. The degree of internationalization of Austrian patent activities is still comparatively low but is increasing rapidly. By international comparison, areas of high technology, such as instrument engineering, electronics and communication, are clearly under-represented.

INTERNATIONAL TECHNOLOGY FLOWS

Technological knowledge is not only disseminated within nations, but to an increasing extent also across national

Figure 4: Distribution of patent applications filed with the European Patent Office by technology areas 1987-1994



Source: *Gassler et al. (*1996).

borders. In open economies linked by international trade, foreign direct investment and knowledge flows, improvements in economic performance – productivity, in particular – do not merely depend on their domestic technological efforts (for a survey see *Hutschenreiter,* 1995). The ability of countries to absorb and intelligently utilize knowledge generated abroad is becoming a decisive factor in achieving an adequate level of economic growth. This is all the more true for small countries. However, own research and innovative efforts are necessary in order to be able to monitor, evaluate, adopt and advance international technological achievements.

The structure of Austrian exports of manufactured goods is steadily shifting towards technologically advanced goods in which Austria has been gaining market shares world-wide. This, however, has not compensated for the predictable increase of the international trade deficit in labor-intensive products due to changing comparative advantages.

International trade plays an important role in the diffusion of technology. Technological knowledge is imported along with goods and services. At the same time, a high level of technological development also creates competitive advantages for exporters and therefore has an influence on the level of income which can be achieved in an economy.

A review of Austria's foreign trade in manufactured goods according to their "technology content" (*Hutschenreiter – Peneder,* 1997) yields the following results:

- Austria's economy is known to have a persistent deficit in foreign trade in manufactured goods. It is less widely known that a large part of this deficit results from trade in human-capital intensive goods, among them also high-technology products (Table 1). In the long run, however, the international markets for technologically sophisticated goods grow at a faster pace than those for goods with a low technology content. Trade in high-technology goods, in particular, shows high growth rates.
- With a share of 52.3 percent of human-capital intensive products and a share of 8.2 percent (1994) of

Table 1: Austria's trade balance by technology category

SITC 5 to 8

	1989	1990	1991	1992	1993	1994
			Billion ATS			
Human-capital intensive	– 51,468	– 48,522	– 57,733	– 56,786	– 46,538	– 57,113
High technology	– 21,801	– 19,124	– 20,641	– 20,270	– 18,982	– 22,967
Standard technology	– 39,990	– 39,942	– 47,064	– 49,269	– 36,358	– 44,619
Other	10,324	10,544	9,978	12,753	8,802	10,473
Capital intensive	271	313	– 326	– 326	– 645	– 811
Labor intensive	– 17,876	– 23,980	– 27,933	– 26,229	– 28,523	– 35,384
Resource intensive	24,964	26,056	23,896	21,657	19,558	18,386
All other	– 251	– 532	– 430	– 412	– 515	– 739
Total	– 44,387	– 46,819	– 62,724	– 62,274	– 56,804	– 75,813

Source: WIFO. SITC rev. 3, 1989: SITC rev. 2.

high-technology products in total manufacturing exports, Austria's economy is markedly less specialized in technologically advanced products than other small open economies in Europe (such as Switzerland and Sweden).

- Austria's foreign trade reveals a pronounced "technology gap": in the OECD as well as the EU countries the export share of high-technology products is more than twice as large as in Austria.
- Austria's exports of human-capital intensive products, including both high technology and standard technology, have markedly lower unit values (revenues per unit) than those of other small open economies such as Switzerland, Sweden and Finland.
- A positive aspect, however, is the fact that Austria's exports are undergoing structural change in favor of technologically superior goods and that their world market share has been increasing. This, however, has not compensated for the predictable increase of the deficit in international trade in labor-intensive products due to changing comparative advantages.

The technology balance of payments reflects the volume of international trade in technical knowledge and services with a technology content. The most significant transactions are reflected in revenues and payments relating to patents and inventions and to the licensing of patents and know-how. The technology balance of payments shows a pattern similar to that of foreign trade in manufactured goods:

- Austria has a persistent deficit in its technology balance of payments. In 1995, the revenues (ATS 1.478 billion) covered just one quarter of the payments made (ATS 5.369 billion). Thus, the coverage ratio is one of the lowest among the OECD countries.
- A low coverage ratio in a rapid process of catching up in terms of technology may not be a cause for concern. In this case, however, it is reasonable to expect an increase in the coverage ratio in the long run. So far, no indications for such a shift are to be found in Austria.

TECHNOLOGY DIFFUSION

The diffusion of technology is the process of the dissemination of an innovation from its first use to its wide-spread application. Technology diffusion plays a crucial role in productivity growth and is of particular importance for small open economies (*Hutschenreiter,* 1998). The *"Austrian Report on Technology 1997"* treats the subject of diffusion in two areas of technology, i.e., information and communication technologies (technologies of the information society), and in selected technologies for a sustainable development. Sustainable growth is a focus of the Fifth EU Framework Programme for Research, Technological Development and Demonstration.

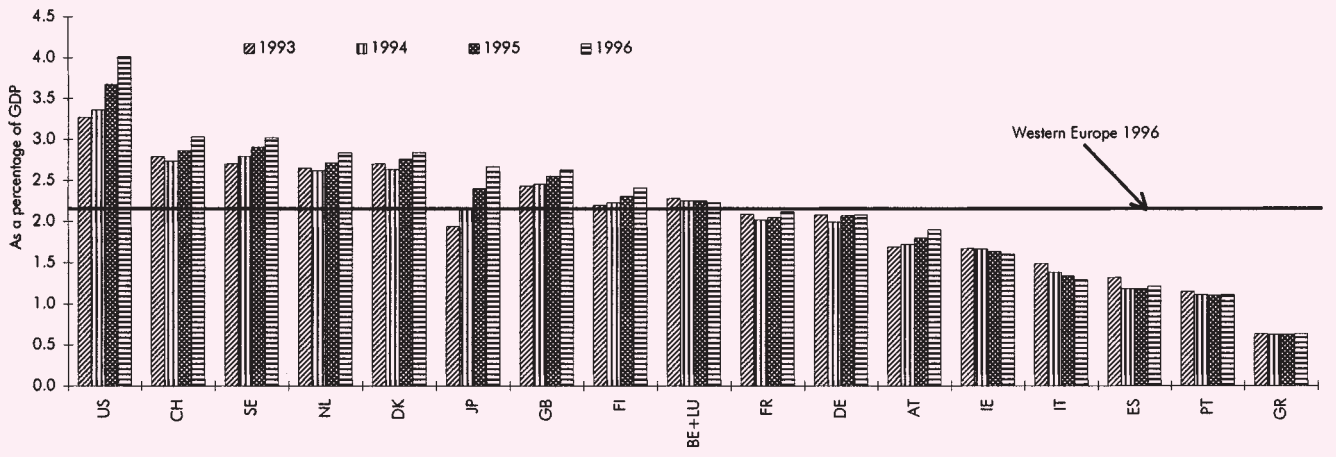
Technology diffusion plays a crucial role in productivity growth and is of particular importance for small open economies.

Information and communication technologies – comprising computer hardware, software, services and telecommunication – increasingly impact on all areas of economic and social life. Their diffusion is already largely market-driven. In contrast, the diffusion of technologies for a sustainable development has to contend with numerous problems regarding the framework conditions. This is shown in two examples relevant to Austria – combined transport and the cogeneration of heat and power.

TECHNOLOGIES OF THE INFORMATION SOCIETY

The European market for information technology (IT) accounts for some 28 percent of the world market and, on the whole, is losing some of its importance. Within Europe,

Figure 5: Expenditure on information technology in an international comparison



Source: *EITO* (1997).

the gap between IT-intensive and less IT-intensive countries keeps getting wider.

- In contrast to other countries with initially low expenditure on IT in relation to GDP, Austria has been able to catch up considerably over the last few years and to approach the western European average (Figure 4).

In contrast to other countries with relatively low initial expenditure on information technology, Austria has been able to catch up considerably over the last few years and to approach the western European average.

- The Austrian market for information and communication technologies is growing considerably faster than the EU average. This is mainly due to a rapid process of catching up in the software sector.

The telecommunication infrastructure is of particular importance today. It contributes both to an efficient handling of communication related to economic activities in a dynamic environment and to the generation of product innovations and services.

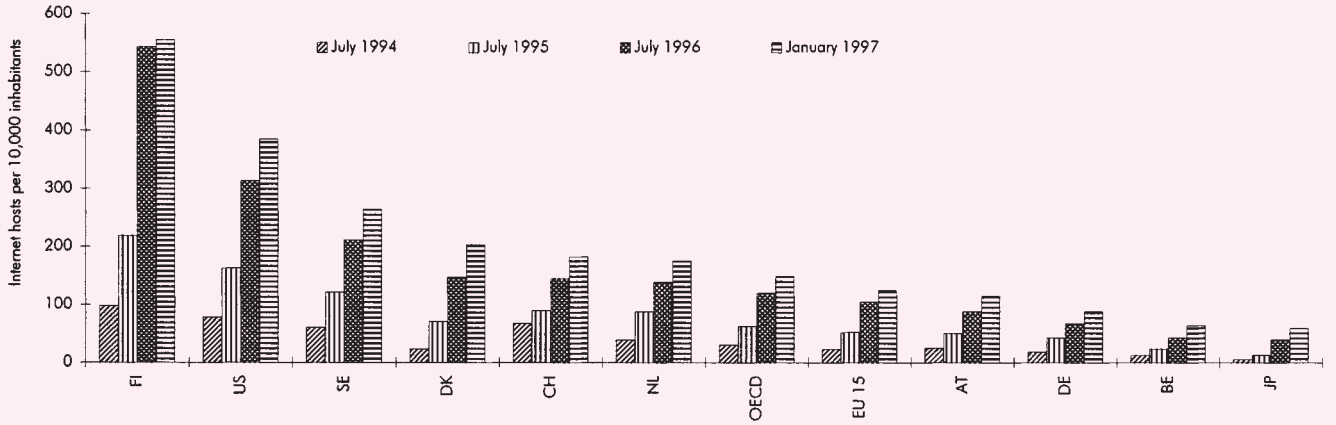
- With high annual growth rates (close to 50 percent), the development of mobile communication within the OECD has been extremely dynamic in the 1990s. Market saturation is not yet in sight.
- The establishment of a uniform digitization standard and the liberalization of access to markets in Europe have resulted in a multitude of private network suppliers. Most of mobile telephony within the EU is already carried out via digital networks.
- With high growth rates, the Internet keeps expanding as a platform for the communication of data between computers (Figure 5). The number of computers to be reached via Internet is an indicator of market penetration (January 1997: 15 million Internet hosts in the OECD countries). In early 1997, Finland had the highest number of Internet hosts world-wide in relation to its population (555). Measured by this indicator, Austria (114) ranks somewhat below the EU (124) and OECD (149) averages, but clearly ahead of Germany (88).

In view of the facilities already established for use of the Internet, such as electronic mail or access to multi-media contents (for instance in the World Wide Web), as well as of future applications, such as voice transmission and video conferencing via Internet, it can be expected that the growth rate will remain high.

In early 1997, Finland had the highest number of Internet hosts world-wide in relation to its population. Measured by this indicator, Austria ranks somewhat below the EU and OECD averages but clearly ahead of Germany.

The global markets for industrial robots – as an example of information technology in production – are highly dynamic. The use of industrial robots is an essential component of the international trend towards flexible automation in production processes. The market for industrial robots is dominated by the outstanding position of Japan in the field of flexible automation, where some 60 percent of the industrial robots operating world-wide are in use (Fig-

Figure 6: Growth of the Internet



Source: *OECD (*1997), based on Network Wizards (http://www.nw.com/).

ure 6). Although the high world-wide growth rates of up to 20 percent in the 1980s seem to be a thing of the past, the estimates for the coming years once more forecast stable growth at a rate of nearly 15 percent. The degree of automation in industry is clearly increasing world-wide. Traditionally, the pioneering role in flexible automation is played by the automotive industry.

In Austria, the industrial robot intensity has significantly increased over the last decade. There has been a noticeable shift in new robot acquisition from the automotive industry to the electrical and electronics industries and to mechanical engineering and steel construction. The emphasis of automation in Austria has shifted towards enterprises with less than 200 employees.

- In the late 1980s, automation in Austria increased considerably in all industries. The industrial robot intensity has significantly increased over the last decade.
- In the 1990s, there has been a noticeable shift in new robot acquisition from the automotive industry to the electrical and electronics industries as well as mechanical engineering and steel construction. The emphasis of automation in Austria has shifted towards small enterprises with less than 200 employees. The share of companies with 500 to 1000 employees has gone down considerably.
- More than a third of the industrial robots in use in Austria are produced in Austria, another third in Germany. The supply side is highly concentrated, with the Swedish market leader reaching 17 percent, and the top 10 manufacturers of industrial robots having a 56 percent share of the market.

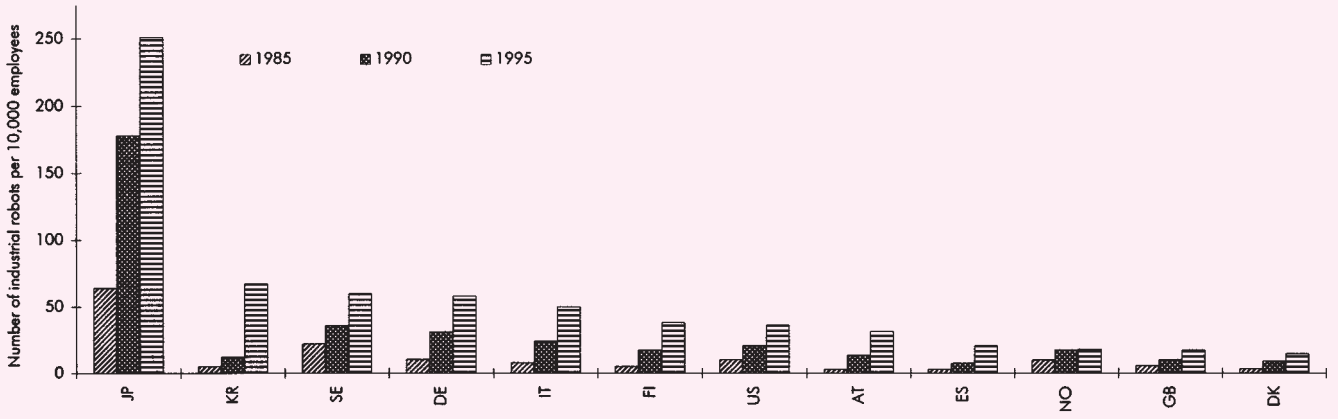
TECHNOLOGIES FOR A SUSTAINABLE DEVELOPMENT

Despite intensive discussions at the international level, technologies for a sustainable development seem to be pushed into the background in times of increased international competition and high levels of unemployment. For this reason and with reference to the current research focus of the EU, two technologies, classified as sustainable, are discussed in the following: combined freight transport and the cogeneration of heat and power.

The diffusion of information and communication technologies is already largely market-driven. In contrast, the diffusion of technologies for a sustainable development has to contend with numerous problems regarding framework conditions.

Through combined transport, the advantages of road, rail and water transport – i.e., flexible regional distribution on the one hand and an environmentally acceptable coverage of long distances on the other hand – can be utilized in an optimal manner. The framework conditions of general freight transport in Europe – price-setting without consideration of external costs of transportation, particularly of environment-related costs – lead to a continuous shift of transport volumes from the railways to the road. Combined transport in Europe focuses, above all, on the ecologically sensitive Alpine region, which forms a geographic barrier between major economic regions of Europe.

Figure 7: Industrial robot intensity in major industrial countries



Source: *UN – IFR* (1996), own calculations.

- In contrast to France and Switzerland, Austria – as the most important Alpine transit country – has succeeded in shifting transport to the railways. This creates a considerable new development potential for combined transport, in particular for unaccompanied transport by shuttle trains (between freight terminals north and south of the Alps).
- A special feature of Austria's combined transport is the high share of truck-on-train transport, which is due to a rapid growth of transit traffic to and from eastern Europe. Due to the lack of infrastructure and appropriate regulatory measures, the shift from road to truck-on-train transport is easier and quicker than the change-over to the logistically more sophisticated unaccompanied transport modes. After Austria's accession to the EU, however, truck-on-train transport has had to face a significant deterioration of framework conditions.

The cogeneration of heat and power includes various technologies for the combined generation of electricity and heat resulting in a more efficient use of primary energy. Applications of cogeneration systems range from short- and long-distance energy supply networks to the generation of process heat for industry.

- Denmark is pioneering the application of cogeneration technology. In Austria the share of cogeneration in the overall generation system, amounting to 19 percent of the total installed power capacity, also ranks relatively high by European standards.
- The potential for cogeneration in industry is already exhausted to a large degree. However, there is still a potential for a more intensive use of cogeneration in the area of public thermo-electric generation both with regard to the increase in efficiency and the diffusion of this technology.

AUSTRIA AND THE FRAMEWORK PROGRAMMES OF THE EU

The integration of Austrian research and development into the larger European context is one of the key challenges facing research and technology policy. The "Austrian Report on Technology 1997" summarizes the findings of the first evaluation of Austria's participation in European programs for research and technological development (*Ohler et al.,* 1997). This evaluation furnishes a wealth of new findings. One of the positive aspects of the European programs is that they clearly broaden the strategic opportunities for the participating enterprises, universities and research institutes.

The integration of Austrian research into the larger European context is one of the key challenges facing research and technology policy.

A criticism frequently directed against the Framework Programmes is the alleged predominance of large countries. However, the countries leading in terms of participation intensity (measured per inhabitant or per scientist) are small countries – without exception. Large countries, in contrast, show moderate participation intensities. The reason for this phenomenon is to be found mainly in the logic of consortia formation, which favors small countries.

An breakdown of the countries participating in the specific programs shows that patterns of participation are very sim-

ilar, although the original assumption had been that the focus of participation would differ greatly on account of different national fields of specialization.

It seems that every country has a group of firms and institutes which are ready and able to engage in international research co-operation, irrespective of the country's structure of research and industry. Thus, the Framework Programmes have a strong impact on the development of the European research landscape.

Which are the factors accounting for success in participation? Data available for large and influential programs reveal an extremely high correlation between the number of projects submitted and those approved. In view of the large number of project proposals meeting high quality standards, the number of applications submitted appears to be decisive.

As a consequence of the low rate of success of proposals submitted (1 : 3 to 1 : 12) and the costs incurred in their preparation, many of the proposals rejected are continued within a more restricted framework, often with support from alternative sources.

"Additionality effects" can also be identified in the area of national research and technology policy. A wealth of experience has been gathered since Austria's accession to the EU, which is now steadily diffusing and, thus, changing national policies. This concerns, above all, complex issues and programs, specific planning and completion of programs, including their evaluation, orientation towards new target groups and a broader perspective regarding research issues and innovations (recognition of learning, knowledge and skills as an essential dimension of technology, increased attention to infrastructural measures, diffusion).

A frequently voiced criticism of the Framework Programmes is the alleged mismatch of goals and expectations of participating organizations and the European Commission. An empirical investigation reveals a different picture: the goals and expectations classified as important by the participants are generally met. These are, above all, access to funding, expertise of research institutions, capability building and the creation of networks.

The Framework Programmes are oriented towards collaborative research and technological development. The Framework Programmes are, above all, accepted by organizations which are familiar with and used to regular co-operation even outside the Framework Programmes.

Research in EU projects is characterized above all by the requirement to co-operate. The quality of proposals largely depends on the ambition, the skills and experience of the persons and organizations involved. In order to sur-

Austrian participation in the Fourth Framework Programme for research, technological development and demonstration of the EU

So far, 1,150 projects involving nearly 1,460 Austrian organizations have been accepted for funding by the European Commission. Participants include 39 percent business enterprises, 36 percent universities, 18 percent non-university research organizations, 10 percent others. About 380 Austrian business enterprises are participating, 75 percent of which have so far participated in one, 25 percent in more than one project. Remarkably, there are enterprises taking part in EU projects which have not received Austrian R&D support as yet. 21 percent of business firm participations take place within the CRAFT campaign, which is specifically oriented towards the needs of SMEs with low R&D potential.

The average success rate of Austrian project applications is 30 percent. The success rate in the CRAFT campaign for SMEs is above 50 percent. Enterprises account for the highest share of Austrian participation in the Thermie Type A (energy demonstration projects, 80 percent), Esprit (information technologies, 62 percent), and BriteEuRam (industrial and materials technologies, 65 percent) programs.

Under the Fourth Framework Programme, Austrian organizations were granted more than ATS 2.23 billion by the European Commission – which corresponds to a "return" rate of nearly 70 percent. The breakdown of these funds by type of organization is as follows: 42 percent enterprises, 36 percent universities, 15 percent non-university research organizations, 7 percent others.

Cooperative behavior of Austrian participants: On average, 8 partners are involved in projects with Austrian participation – approximately 1.5 from Austria and 6.5 from abroad. Project partners are based in Germany (20 percent), the U.K. (13 percent), France (11 percent) and Italy (10 percent). 185 funded projects are led by Austrian coordinators. The highest share of Austrian coordinators is to be found in the Transport (28 percent), Thermie (energy demonstration projects, 26 percent) and Esprit (information technologies, 23 percent) programs, and within the framework of the second activity of the INCO-DC program (cooperation with developing countries, 43 percent). From among the non-Austrian coordinators of projects with Austrian participation, 29 percent come from Germany, 19 percent from the U.K., 11 percent from France and 10 percent from the Netherlands and Italy, respectively.

Source: Horvat, M., Säckl, J., BIT data base INNOman, January 1998.

Austria's Innovation System in an International Comparison – Summary

As a highly developed, high-wage country, Austria faces new challenges in a globalizing economy. Austria will only be able to maintain its position in the club of high-income countries if it is able to achieve a high productivity level through the use of new technologies and by taking advantage of specialization in human-capital intensive and technologically sophisticated products. Technological change is the most important driving force behind long-term economic growth. In this context, private and public investment in research and development (R&D) plays a key role. At 1.5 percent, Austria's ratio of gross expenditure on R&D to GDP remains low for a country of its per-capita income level. Of equal significance, however, is the structure of R&D expenditure. Among the structural features of the Austrian R&D system we find a relatively small share of the business enterprise sector in overall R&D, a comparatively large higher education sector receiving a share of government R&D funds far above the international average, and weak links between the components of the innovation system (universities – business enterprises – research institutes). The internationalization of Austria's research is still at a relatively low level. The intensity and quality of the synergy among the various elements of this system is a pivotal point of technology policy.

A country's ability to innovate should not just be equated with R&D. Human resources are a key factor in the generation and absorption of technological knowledge. Highly qualified and well-trained human resources are regarded as one of Austria's most substantial locational advantages. However, an internationally low share of scientists and engineers in the labor force is exacerbated by an extremely low number of new science graduates. The introduction of a tertiary-level technical college system is expected to broaden the scope of qualifications. Another aspect of the specialization of innovation systems is the structure of patent activities. In accordance with the findings regarding the R&D system, we observe a relatively modest patent intensity and a modest though rapidly increasing internationalization of patent activities. Moreover, Austria's patent specialization shows particular features: the emphasis of patent applications filed with the European Patent Office is on certain niches (e.g., in the field of "construction" technology). Core areas of high technology, such as instruments, electronics and communication, are under-represented.

For open economies, the capability to absorb and use knowledge generated abroad becomes a decisive factor in achieving adequate economic growth. The creation of this capability requires own investments in R&D. Foreign trade plays an important role as a channel of technology flows. Austria is known to have a persistent deficit in its foreign trade in manufactures. It is less widely known that a large part of this deficit results from trade in human-capital intensive goods, among them also high-technology products. Austria's foreign trade still shows a "technology gap": in the OECD as well as the EU countries, the share of high-technology exports is more than twice as high as in Austria. The structure of Austria's exports is changing in favor of technologically advanced goods and their world market share has been increasing. However, this has not yet compensated for the predictable increase of the deficit in international trade in labor-intensive products due to changed comparative advantages. The technology balance of payments reflecting international trade in technical knowledge and services with a technology content shows a similar picture. The respective revenues cover about one quarter of expenditure.

The diffusion of technologies plays a crucial role in productivity growth. The issue of diffusion is dealt with in two areas of technology, i.e., technologies of the information society and selected technologies for a sustainable development (combined transport and the cogeneration of heat and power). Information and communication technologies impact all areas of the economy and society. Contrary to other countries with an initially low expenditure on information technology relative to GDP, Austria has succeeded in catching up over the last few years and has managed to approach the west European average. In Austria, the market for information and communication technology – especially its software segment – is expanding faster than the EU average. The use of industrial robots is an essential component of the international trend towards flexible automation. In Austria, the industrial robot intensity has significantly increased over the last decade and the emphasis of automation has shifted towards enterprises with less than 200 employees. In contrast to information and communication technologies, the diffusion of technologies for a sustainable development has to contend with numerous problems regarding the framework conditions.

The integration of Austria's R&D into the larger European context is one of the challenges facing research and technology policy. The European R&D Programs broaden the opportunities for the participating enterprises, universities and research institutes. Initially, the intensity of Austria's participation was moderate and characterized by a predominance of research institutions over business enterprises. Since its accession to the EU, Austria has rapidly caught up in terms of program participation. This has been confirmed by recent data on the Austrian participation in the Fourth Framework Programme. In conclusion possibilities for the improved utilization of the participants' potential and the implementation of results are outlined.

vive in the face of competition between proposals, applicants have to mobilize their best staff, their best skills and ideas, i.e., to concentrate on their core competences.

Austria has participated in the Framework Programmes from the very beginning. The First and Second Framework Programmes were of no relevance in quantitative terms, while genuine participation started with the Third Framework Programme. The Fourth Framework Programme can be considered a breakthrough (see Box "Austrian participation in the Fourth Framework Programme"). Ever since, Austria has been steadily closing the gap in terms of participation and experience.

The Fourth EU Framework Programme for research and technological development can be considered a breakthrough. Austria is steadily closing the gap in terms of participation and experience.

Participation shows a high degree of consistence: This is evidenced by the creation of networks across Europe, high "additionality" effects on the part of the participants and learning processes in the area of national policy. In the coming years, measures ought to be taken to put to use the potentials created within firms and research organizations as well as in the dissemination of results. This may contribute to closing Austria's research and innovation gap.

REFERENCES

Aiginger, K., Peneder, M., Qualität und Defizite des Industriestandorts Österreich, WIFO, Vienna, 1997.

EITO (European Information Technology Observatory), Frankfurt am Main, 1997.

Gassler, H., Kopcsa, A., Schiebel, E., Böck, N., Gheybi, P., "Verbesserter Einsatz von Patentstatistiken", Austrian Research Center Seibersdorf, 1996, (OEFZS-A-3613b).

Hutschenreiter, G., "Intersektorale und internationale 'F&E-Spill-overs'. Externe Effekte von Forschung und Entwicklung", WIFO-Monatsberichte, 1995, 68(6), pp. 419-427.

Hutschenreiter, G., "Produktivität und Technologiediffusion", Wirtschaftspolitische Blätter, 1998, 45(1), pp. 28-37.

Hutschenreiter, G., Knoll, N., Paier, M., Ohler, F., Austrian Report on Technology 1997, WIFO, ARCS, in the framework of tip, Vienna, 1998.

Hutschenreiter, G., Peneder, M., "Austria's 'Technology Gap' in Foreign Trade", Austrian Economic Quarterly, 1997, 2(2), pp. 75-86.

Lassnigg, L., Pollan, W., "Das österreichische Qualifizierungssystem im internationalen Vergleich", WIFO-Monatsberichte, 1996, 69(12), pp. 763-780.

OECD, Communication Outlook, Paris, 1997.

Ohler, F., Jörg, L., Polt, W., Guy, K., Hutschenreiter, G., Husz, M., Sieber, A., Gluske, H., Patsios, S., Evaluation of the Austrian Participation in Community RTD Programmes, Seibersdorf Report, 1997, (OEFZS-4792).

United Nations Economic Comission for Europe, International Federation of Robotics (UN – IFR), World Industrial Robots 1996. Statistics 1983-1996 and Forecasts to 1999, New York-Geneva, 1996.