EMBODIED TECHNOLOGY DIFFUSION IN THE AUSTRIAN ECONOMY

GERNOT HUTSCHENREITER, SERGUEI KANIOVSKI (WIFO)

June 1999

EMBODIED TECHNOLOGY DIFFUSION IN THE AUSTRIAN ECONOMY

GERNOT HUTSCHENREITER, SERGUEI KANIOVSKI (WIFO)
WITH THE SUPPORT OF KURT KRATENA (WIFO)

Study by the Austrian Institute of Economic Research (WIFO)

An Initiative of the Federal Ministry of Economic Affairs and the Federal Ministry of Science and Transport as Cooperation between the Austrian Institute of Economic Research (WIFO) and the Austrian Research Centre Seibersdorf (ARCS)

June 1999

1999/133/S/16795

CONTENTS

Abstract

To complement the traditional science and technology indicators, the OECD has been measuring the "total R&D content" of output flows for several years. This measure not only includes direct expenditure on research and development but also the R&D content of intermediate and investment goods, both domestic and imported. In many cases, this presents a more meaningful approach to measuring levels of technology. For the first time, computations of the total R&D content were carried out for the Austrian economy. The results are presented in this study. For a small open economy, technology flows embodied in imports are particularly relevant. The fundamental change in the pattern of technology flows between 1976 and 1994 demonstrates Austria's evolution towards a knowledge-based economy.

Acknowledgements

The authors would like to thank Hannes Leo as well as the participants of the Technical Meeting between the International Institute for Applied Systems Analysis (IIASA) and the Tokyo Institute of Technology (TIT) led by Professor Chihiro Watanabe (TIT), held in Laxenburg, 7-8 March 1999, for valuable suggestions. The input-output data were provided by Kurt Kratena. The authors are especially indebted to George Papaconstantinou (Directorate for Science, Technology and Industry, OECD, Paris) for his support. Any remaining errors are, of course, ours.

1. Motivation and Goals of the Study

Industries not only differ in their direct R&D intensity (i.e. direct expenditure on research and development per unit of output) but also with respect to their use of external sources of technology. While innovative activities of some industries (such as the pharmaceutical industry) are primarily based on their own research and development, other industries receive their technology primarily from sources outside the industry. The same can be said for nations as a whole: While large advanced economies tend to rely largely on domestic research and development (although this element of autarky is eroded in the process of globalization), small or less advanced countries are much more dependent on technology developed abroad.

Direct business enterprise expenditure on R&D is an important measure, which is widely used both as a descriptive indicator and as a variable in a large array of economic models. However, measures of direct R&D by definition do not contain any information about the diffusion of technology among industries or countries, and, a fortiori, do not contribute to answering the question as to who finally benefits, and to which extent from the R&D efforts performed at a particular "location" in the economic system. Consequently, in many analytical applications, measures of direct R&D are inadequate. One area where this deficiency becomes evident is empirical research on the relationship between R&D and productivity growth to wich we will turn below.

Although statistics on direct business enterprise expenditure on R&D are provided on a fairly regular basis, measures of *total R&D content* (synonymously we will use the term *technology content*) of an industry's or country's output are not readily available. At the OECD (*Papaconstantinou – Sakurai – Wyckoff,* 1996), efforts were made to quantify the total technology content of output flows by complementing direct R&D expenditure with R&D embodied in domestic and imported intermediate and investment goods ("indirect R&D")[1]). However, the OECD study was confined to 10 OECD countries well-covered by the OECD data sets. At present, owing to deficits in its input-output and R&D statistics,

---

[1]) Total R&D content and innovation expenditure (see the contribution of Leo, 1999) are both designed to complement (direct) R&D expenditure with additional components. While total R&D content is constructed on the basis of R&D data, innovation expenditure also includes non-R&D cost elements.

Austria is not among those countries and consequently was not included in the OECD study.

This study is designed to bridge this gap. For the first time it was attempted to quantify the total R&D content of flows of goods and services in the Austrian economy. The method of computation corresponds to that applied in the OECD study mentioned above.

There are several a priori reasons why this study should be of interest in the Austrian context. On the one hand, the international dimension of knowledge and technology diffusion is of particular importance for small countries. Analogous to foreign trade, the relative importance of transborder "knowledge" or "technology" transactions can be expected to be a decreasing function of country size. On the other hand – as emphasized by the literature on catching up and convergence[2]) – this is specially true for countries behind the world technological frontier. So far, no empirical research has been done to address these issues in the Austrian context.

Moreover, – as a special aspect – there is an "Austrian performance paradox": Rather unfavorable evidence regarding R&D inputs and various structural aspects of the Austrian economy is in contrast with a favorable macroeconomic performance. In spite of low levels of investment in R&D (*Marin*, 1995), Austria's long-run economic performance in terms of growth of per-capita income and productivity has been remarkable – both when compared to its own development between the two world wars, and to that of other European countries (*Butschek*, 1999). This favorable long-term development was attributed, among others, to the successful adoption of imported technology (*Steindl*, 1977). One explanation refers – in the terminology of this study – to a supposedly higher total R&D intensity, in particular due to imports of investment goods (Austria's long-term share of capital formation in GDP is relatively high).

[2]) For a survey see *Fagerberg* (1994).

The measurement of research and development "embodied" in intermediate and investment goods ("indirect" R&D) is interesting in its own right. Today, descriptive measures of "embodied technology flows" are frequently used to complement the traditional science and technology indicators (see, e.g., *European Commission,* 1997, *OECD*, 1998). Moreover, they also serve as an input in a number of analytical applications. Among the well-known applications of measures of embodied research and development are econometric analyses of the relationship between R&D and productivity growth. *Sakurai – Papaconstantinou – Ioannides* (1996), for example, use the database provided by *Papaconstantinou – Sakurai – Wyckoff* (1996) for econometric estimates of the impact of direct R&D expenditure and R&D embodied in intermediate and investment goods on total factor productivity growth.

Let us conclude this introduction with a brief guide for the reader:

- Section 2 introduces some theoretical background. Readers primarily interested in the empirical results for Austria may skip this section and proceed directly to section 3.
- Section 3 introduces the method and the peculiarities of its implementation in a non-technical manner. Readers who wish to examine rigorously the method applied are referred to Appendix A. The data sources are documented in Appendix B.
- Section 4 presents the empirical results of the study.
- Section 5 concludes by summarizing the main findings.

2. Theoretical Background: Modeling Technology Flows

In this section[3]) we provide some background. In particular, we survey some recent developments in economic theory and discuss the channels through which technological knowledge is diffused within or across economies. Since knowledge flows are not directly observable, we give a brief account of approaches used in modeling technology flows in empirical research. Finally, we will touch upon some major economic applications of data generated to capture embodied technology flows.

2.1 Recent developments in economic theory

Modern economies are increasingly linked through international trade, foreign direct investment, migration and knowledge flows. The adoption of knowledge or innovations generated abroad is essential for the growth performance, in particular of small countries. Based on some recent developments, during the last decade economic theory has shown new interest in examining the role of knowledge dissemination in the long-term growth of nations. Since the early nineties, endogenous growth models – based on a marriage of the theories of growth and international trade – have been applied to examine the factors of long-term growth in the context of open economies.

International knowledge and technology flows are an important additional "productivity transmission channel", in particular for small open economies. This has been taken into account by new approaches in economic theory.

Traditional international trade theory has been concerned with "gains from trade" due to specialization. The latter is based on comparative advantages, which, in turn, arise from differences in factor endowments and technology across nations. More recently, economies of scale are recognized as an additional source of welfare gains (*Helpman – Krugman,* 1985). Finally, endogenous growth theory also deals with dynamic increasing returns and learning mechanisms (survey by *Grossman – Helpman,* 1995). This led to new

[3]) This section partly draws on Hutschenreiter (1998).

insights regarding the role of international linkages (including knowledge flows) as additional "productivity transmission channels" (*Helpman*, 1997).

Endogenous growth theory[4]) provides a suitable analytical framework to assess the economic impact of international knowledge flows. "R&D-based" endogenous growth models – such as *Romer* (1990) or *Grossman – Helpman* (1991) – identify innovation (in particular, the accumulation and diffusion of knowledge) as the driving force of long-term economic growth.

In their seminal work, *Grossman – Helpman* (1991) analyze two extreme cases: The first case, which is used as a benchmark, may be termed perfect informational autarky since no international diffusion of knowledge takes place. The second case is characterized by perfect (complete and costless) international knowledge diffusion. This case is akin to the frictionless transferability of technology in the standard neoclassical (Solow – Swan) growth model[5]). In the first case, knowledge capital acts as a "national", in the second case as a "global" public good. The Grossman – Helpman model leads, among others, to the prediction that international diffusion of knowledge increases the *growth rates* of output and productivity. Introducing international trade in intermediate goods into the model with perfect international knowledge diffusion impacts on the attainable *levels* of output and productivity, without affecting their growth rates.

However, it appears more realistic to assume that while basic technological knowledge is diffused across national borders, the rate of this diffusion depends on the height of the communication barriers between and on the "absorptive capacities" of the countries involved. An endogenous growth model presented by *Hutschenreiter – Kaniovski – Kryazhimskii* (1995) examines the (asymmetric) case where a small technological follower possesses the "absorptive capacity" to adopt part of the knowledge stock of a larger, technological leader, thereby raising the productivity of its own R&D activities. The

---

[4]) See the surveys by *Aghion – Howitt* (1998), *Barro – Sala-i-Martin* (1995), *Klenow – Rodriguez-Clare* (1997).

absorptive capacity of the follower is modeled as an increasing function of the knowledge accumulated in that country. It is shown that along an equilibrium growth path, the follower asymptotically approaches the rate of innovation (and of TFP growth) of the leader to which it is linked informationally.

A generalized, symmetric model of *Borisov – Hutschenreiter – Kryazhimskii* (1999) – which contains, as special cases, both the asymmetric model and the extreme cases analyzed by *Grossman – Helpman* (1991) – allows for mutual exchange of knowledge (based on the absorptive capacities of both countries). One major implication of this model is that in the long run no country can gain by impeding the flow of basic knowledge to a partner country (the rest of the world). The induced reduction of available knowledge in the rest of the world has repercussions on the country which restricts the flow of information. The long-run equilibrium growth rate of output and TFP common to both countries will fall.

Several hypotheses with respect to the impact of international technology diffusion on productivity growth can be derived from the models referred to above:

- Access to a larger pool of knowledge increases the productivity of R&D activities in the countries involved[6]), thus enhancing future productivity growth. Thus, in addition to the traditionally recognized channels of technology diffusion (international trade, foreign direct investment, etc.), a country's productivity growth is positively correlated to the degree of its openness to flows of information and to its capability to absorb and utilize knowledge produced abroad. In this process, domestic R&D may be instrumental to maintain absorptive capacities (*Hutschenreiter – Kaniovski – Kryazhimskii,* 1995, *Borisov – Hutschenreiter – Kryazhimskii,* 1999).

---

[5]) See *Streißler* (1979A).

[6]) Closely related to the analysis of innovation is that of imitation (*Grossman – Helpman*, 1991, *Helpman*, 1993, *Barro – Sala-i-Martin*, 1997). In practice, the borderline between imitation and innovation is fuzzy.

- In an open economy, international trade provides opportunities to use input goods developed abroad that qualitatively differ from domestic input goods, and thus to increase productivity.
- Both international trade and foreign direct investment provide opportunities for cross-border learning about products, production processes, market conditions, etc.

2.2 Channels of technology diffusion

Technological knowledge comprises a broad specter, ranging from basic knowledge (which may serve as an input to further applications) to applied knowledge (such as "blueprints" for new products). Some forms of knowledge – called "tacit knowledge" by *Polanyi* (1967) – are non-codifyable and thus do not render themselves to "impersonal" modes of transfer. Knowledge is also embodied in artefacts.

Just as there are different forms of technological knowledge there is a variety of channels for the diffusion of technology:

- First of all, technology is traded on markets. However, there is a broad consent in the economic literature that markets for technology are inherently imperfect (*Geroski*, 1995, *Metcalfe*, 1995). This assertion forms the basis of the neoclassical market-failure[7]) approach which has greatly influenced the economic analysis of technology policy (see, e.g., the survey by *Stoneman*, 1987)[8]). The market-failure approach can be traced back to *Nelson* (1959) and *Arrow* (1962). In his seminal paper, Arrow argued

---

[7]) Probably the most fundamental form of "market failure" is the absence of a complete set of markets. *Stiglitz* (1994, p. 148) notes that there are fundamental differences between the production of knowledge and other goods, in particular: "There cannot exist a complete set of markets, and in particular there cannot exist competitive markets for commodities that have not yet been conceived, let alone invented."

[8]) Compared to the analysis of market failure in the production of knowledge (and their correction by suitable policies), the theoretical foundation of policies aimed at the diffusion of technologies is still much less developed. See the survey by *Stoneman — Diederen* (1994).

that the production of knowledge is afflicted by all three basic causes for imperfections of competitive markets – indivisibilities, uncertainty and externalities[9]).

- In addition, technological knowledge is diffused by accessing various sources of information (such as the scientific and technical literature, patent documents, databases etc.). Specifically, this applies to codifyable knowledge. Innovation surveys regularly try to identify and assess the importance of outside sources of information. The use of modern information and communication technologies and services such as the internet leads to rapid increases in such information flows.

- Another important channel for the diffusion of knowledge (including tacit knowledge) is the mobility of personnel. Humans move across firms within a country and – through migration – across national borders taking along their knowledge and skills[10]).

- Technological knowledge is diffused in embodied form through trade in goods and services. Embodied technology diffusion is the subject of the empirical part of this study. In particular, technology is diffused through trade in intermediate and investment goods.

---

[9]) First, R&D projects are often characterized by large fixed costs. The division of labor in R&D may also lead to economies of scale (*Geroski*, 1995). Large fixed costs can be observed in many high technology industries (e.g., in the aerospace industry). Similarly, "learning-by-doing" represented by more or less steep learning curves leads to dynamic economies of scale. In particular, dynamic scale economies were examined in the semiconductor industry. See, e.g., the survey by *Grossman* (1990), and, more recently, *Irwin – Klenow* (1994).
Second, investment in R&D is inherently risky. Investment decision related to R&D are thus inextricably linked to risk bearing. Moreover, markets for knowledge/technology are an extreme example of markets with asymmetric information. Innovation by necessity implies information asymmetries. The analysis of phenomena related to asymmetric information (such as moral hazard or adverse selection) is at the core of the economics of information (*Hirshleifer – Riley*, 1992, *Stiglitz*, 1994). The formulation of the trade-off between risk sharing and the power of incentives for the innovative enterpreneur in *Arrow* (1962) is an early exposition of the implications of asymmetric information in the modern clad of information economics.
Third, technological knowledge has properties of a public good. We will return to this important issue in the subsection on applications.

[10]) Today, the attraction of a large number of talented students and scientists from Asian countries by US universities is a striking example. The reverse flow of graduates and skilled scientists and engineers to countries such as Taiwan or Korea is remarkable, too. A simplistic view on "brain drain" (or "brain gain") is therefore unwarranted.

- Foreign direct investment (FDI) projects are complex transactions involving a whole array of technology diffusion channels. FDI flows are a mixed bag. They involve a variety of diffusion channels (such as the sharing of blueprints, organizational and managerial know-how, equipment, personnel, etc). As *Helpman* (1997) remarks we know much more about the effects of international trade than of those of FDI. On the impact of FDI on host countries see the survey by *Blomström – Kokko* (1997).

"Localized" externalities of knowledge production are one of the causes for the emergence of industrial clusters. This was already recognized by *Marshall* (1920). See the survey by *Hutschenreiter – Peneder* (1994).

2.3 Empirical approaches to modeling technology flows

Krugman (1991, p. 53f) has cast a strongly unfavorable verdict on empirical research on knowledge spillovers: "Knowledge flows ... are invisible; they leave no paper trail by which they may be measured and tracked, and there is nothing to prevent the theorist from assuming anything about them that she likes". It is certainly true that knowledge flows are not directly observable. Consequently, they have to be proxied if they are to be included in quantitative models. Naturally, there are different approaches to modeling technology flows and no single approach seems to be able to capture all kinds of diffusion channels adequately. However, economic models using proxies for technology flows are testable with respect to their explanatory power. For this reason – and in view of recent empirical work done in that field – we do not subscribe to Krugman's outright dismissal.

In terms of a metaphor introduced by Zvi Griliches, knowledge may be described as a pool fed by the R&D activities of the actors of the system under consideration (let us, for the moment, disregard outflows from that pool). However, this pool of knowledge is not equally accessible by all actors (may they be thought of consisting of firms, industries or nations as a whole, depending on the level of aggregation we choose). For this reason, effective outside knowledge capital stocks are constructed for analytical purposes. See, e.g. the surveys by *Mohnen* (1994, 1996). In practice, effective outside knowledge capital stocks are often constructed as weighted R&D capital stocks of other firms, industries or countries. The weights applied are designed to reflect the "proximity" or the intensity of linkages between the source and the destination of knowledge flows. For this purpose, weights of different kinds are used, which in turn reflect different kinds of linkages.

- Constructing effective outside R&D capital stocks by applying weights based on observed linkages in terms of intermediate or capital goods is the most time-honored approach used in empirical research (*Terleckyj*, 1974, 1980). In this approach, intermediate or capital (investment) flows are used to reflect the distance between industries. This approach makes use of either direct flows (to capture first-round effects) or total flows (accounting for direct and indirect linkages) using Leontief multipliers familiar from input-output economics (see, e.g., *Miller – Blair*, 1985).

- In international (multi-country) analyses, international trade flows (more specifically, import shares) are used to capture the "proximity" of nations and thus to construct effective foreign R&D capital stocks. *Coe – Helpman* (1996) use this approach in a frequently cited econometric study on international R&D spillovers conducted at the aggregate level (for selected countries' manufacturing sectors). Modifying the particular assumptions employed by Coe and Helpman, this approach was also chosen by *Lichtenberg - van Pottelsberghe* (1996, 1998). *Papaconstantinou – Sakurai – Wyckoff* (1996) – as well as this study – combine this approach with the input-output based approach mentioned above, thus covering both the intersectoral and international dimension.

- Analogous to the input-output based approach, effective outside R&D capital stocks can also be constructed on the basis of informational linkages as measured by patent or innovation flows (patent or innovation counts by source and destination). For this purpose, either patent data or innovation counts derived from innovation surveys are used. A pioneering study employing patent counts by industry of origin and industry of use is *Scherer* (1984).

- Recently, empirical research has also targeted FDI flows as a channel of technology diffusion (see, e.g., *Lichtenberg - van Pottelsberghe*, 1996 and 1998). In this approach, the structure of FDI is used to model technological linkages among countries. To a great extent, this type of linkages concerns international knowledge flows involving headquarters or subsidiaries of multinational companies.
- A rather distinct way of constructing effective outside R&D capital stocks makes use of the notion of "technological proximity". *Jaffe* (1986, 1989) has measured technological proximity of pairs of firms by the vector distance of their respective structures of patent activities (patents by technological category). This measure reflects the structural similarities in the technological activities of firms. Of course, the same approach can be applied at other levels of aggregation.

Let us finally note that *Cohen - Levinthal* (1989) have modified Griliches' pool metaphor in one essential aspect. In order to make use of the outside stock of knowledge, the receiving unit needs to have what Cohen and Levinthal call "learning" or "absorptive capacities". In order to built and maintain these capacities, firms have to conduct their own, in-house R&D activities.

There is no one-to-one correspondence betweeen the different approaches to construct effective outside R&D capital stocks and the technology diffusion channels involved. However, there are some rough correspondences:

- Approaches using flows of goods are well-suited to capture "vertical" embodied technology diffusion. It has to be noted, however, that trade in goods and services may often go hand in hand with learning processes (*Grossman – Helpman*, 1991). More specifically, *Lundvall* (1992), for example, views supplier-user linkages as a major vehicle of technological learning and innovation[11]). In this case, we are not confined to "downstream" technology diffusion. Rather, "upstream" transmission of knowledge plays an important role.

- Patent-based approaches are well-suited to deal with immaterial knowledge flows which are not necessarily related at all to trade in intermediate or investment goods.
- At the other end of the specter, the "technological proximity" approach is particularly well-designed to model immaterial (disembodied) horizontal knowledge flows occuring between firms engaged in similar areas of technological activity (*Hutschenreiter - Peneder*, 1994).

2.3 Applications

Measures of technology flows are interesting as such. However, a purely descriptive use of indicators cannot tell us if (or to what extent) technology flows impact on economic variables, in particular on performance variables such as productivity, export shares, etc. However, they may serve as a data input in various analytical applications which aim at explaining such variables. These applications are based on models.

While innovation – which today is largely based on organized R&D efforts – is widely seen as factor which is key to the competitiveness of firms, it is well-understood that R&D does not impact exclusively on the economic performance of those agents actually performing these activities. Rather, R&D gives rise to (mostly positive) externalities ("R&D spillovers"). *Griliches* (1979, 1992) identifies two major sources of R&D spillovers:

First, innovative input goods are often traded at a price lower than their quality would require. This gives rise to "rent spillovers". Griliches emphasizes that the estimation of rent spillovers is inextricably linked to problems of measurement of output, which carry over to the measurement of productivity.

---

[11]) See *Schibany* (1998) on co-operation in product development by and among Austrian firms.

Second, new knowledge generated by R&D activities of one agent stimulates the development of new knowledge by others or may enhance their technological capabilities. Griliches has termed this type of spillovers "knowledge spillovers". The basic cause of knowledge spillovers is rooted in the fact that technological knowledge has – at least partly – features of a public good. On the one hand, "knowledge capital" is "non-rival" in principle, i.e. the utilization of knowledge by one agent does not infringe on its utilization by other agents (think, e.g., of a string of computer software). Second, knowledge is imperfectly excludable (see *Griliches*, 1979, or *Romer*, 1990). In practice, R&D performers often find it difficult to exclude others from utilizing the results of their R&D activities (keeping their knowledge exclusive) since knowledge leaks out of firms through a variety of channels.

However, the public goods analogy should not be overstretched: Contrary to textbook examples of public goods, technological knowledge available in principle is usually not appropriable without cost. As mentioned above, potential innovators have to be equipped with certain capabilities – termed "learning" or "absorptive capacities" by *Cohen – Levinthal* (1989) – in order to adopt and make efficient use of existing technological knowledge. Thus, the appropriation of knowledge itself is a knowledge-intensive process.

There is a huge body of empirical literature attempting to quantify R&D spillovers using a variety of approaches. Over the past decade, a number of surveys was prepared applying the results of empirical studies covering the whole specter of approaches available[12]).

In the wake of the pioneering work of *Solow* (1957), a vast number of "growth accounting"[13]) studies have attempted to quantify the contribution of changes in factor inputs (in the most simple version labor and capital) and "technical progress" to output growth. This approach has its roots in the neoclassical Solow – Swan growth model (see,

[12]) See, e.g., *Griliches* (1992, 1998), *Klette – Moen – Griliches* (1999), *Mohnen* (1994, 1996).

[13]) For a critical review of "growth accounting" by one of its pioneers, see *Abramovitz* (1996). *Grossman – Helpman* (1991) attack the growth-accounting approach in the context of innovation.

e.g., *Barro – Sala-i-Martin*, 1995). "Technical change" or changes in "total factor productivity" (TFP) is measured as a residual (the well-known "Solow residual")[14]). Since in many empirical studies, technical change emerged as an important determinant or even as the most important single source of economic growth (see, e.g., *Barro – Sala-i-Martin*, 1995), it appeared to be a reasonable research strategy to squeeze down the residual by introducing additional explanatory variables, i.e. by augmenting the production function. For further details see *Hutschenreiter* (1995, 1998).

Econometric regression analysis based on a production function augmented by a "R&D capital stock" and one or more "spillover variables" is still the most widely used approach in estimating R&D spillovers[15]). Econometric studies of the relationship between innovation and productivity growth are conducted both at the firm and the industry level (intersectoral R&D spillovers). More recently, there has been a surge in the literature dealing with international R&D spillovers. A number of recent empirical studies point at the presence of significant international R&D spillovers. They conclude that cross-border information or technology flows have a significant impact on productivity growth[16]).

In the context of this study it is worth noting that the data provided by *Papaconstantinou – Sakurai – Wyckoff* (1996) were used by *Sakurai – Ioannides – Papaconstantinou* (1996) in pooled regressions across countries and industrial sectors for both the seventies and eighties. According to their estimates, only direct R&D contributed to TFP growth in the manufacturing sector (average rate of return 15%). The diffusion of technology from outside the manufacturing sector did not play a significant role in its productivity growth. This result is at odds with those of numerous other studies in the field. The results obtained for the service sector were radically different, however. In the (unweighted) regression,

---

[14]) Rather, the "Solow residual" represents a "bundle of variables" (*Kendrick*, 1991, p. 150) and was succinctly termed a "measure of our ignorance" by *Abramovitz* (1956, p. 11).

[15]) For further details on the specifications in use, see Hutschenreiter (1995).

embodied R&D turned out to be significant and exhibited high rates of return (130% in the seventies and 190% in the eighties). In this context, acquired investment goods emerged as the most important source of productivity gains in the service sector. In particular, the authors found that the rates of return on acquired R&D were particularly high in the information and communication segment of the service sector (transport, communication, finance, insurance, real estate, business services). Accordingly, *Sakurai – Ioannides – Papaconstantinou* (1996) support the hypothesis that in high-technology industries productivity growth is to a great extent driven by immaterial knowledge spillovers, whereas in the service sector spillovers through acquired investment goods are predominant. With respect to the international dimension, *Sakurai – Ioannides – Papaconstantinou* (1996) – in accordance with other studies – find an inverse relationship between the contribution of imported R&D to a country's TFP growth and country size. In small countries, the contribution of imported technology sometimes exceeds spillovers within the country. Extremely high rates of return were estimated for R&D embodied in imported intermediate and capital goods of the information an communication service sector (over 400% in the seventies and 300% in the eighties). In countries such as Denmark, Australia, the Netherlands and Canada, imported technology played a dominant role.

Another recent application of the embodied technology flow data compiled by *Papaconstantinou - Sakurai - Wyckoff* (1996) can be found in *Ioannides – Schreyer* (1997).

---

[16]) See, e.g., the well-known study by *Coe - Helpman* (1996), but also *Coe – Helpman – Hoffmaister* (1997), *Bernstein – Mohnen* (1998), *Lichtenberg - van Pottelsberghe* (1996, 1998), *Keller* (1997), *Eaton – Kortum* (1996), *Eaton – Gutierrez – Kortum* (1998).

3. Method and Implementation

The method applied here to quantify the total technology content of flows of goods and services in the Austrian economy follows that of the OECD study by *Papaconstantinou – Sakurai – Wyckoff* (1996) in order to provide opportunities for international comparisons (on the procedure of computation see Appendix A: "Method of computation").

Basically, this approach rests on the following assumptions:

International comparability is somewhat reduced by the following facts: First, we had to rely on Austrian data not harmonized by the OECD (this applies to both the R&D data and the input-output tables). Second, the Austrian study had to be conducted at a higher level of aggregation than the OECD study. Once more, these constraints are due to the aggregation level of both the available R&D and input-output data, in particular of the capital flow matrix (for details see Appendix B: "Data sources").

- Direct R&D expenditure is a proxy for technology embodied in products.
- Intersectoral input flows, as captured by the input-output tables, are the carriers of technology across industries and economies.
- The "import proportionality" assumption asserts that the imports of a certain input good from a given country are distributed proportionally across all receiving sectors by applying the share of the country of origin in total imports of the respective product to all receiving industries.

The *total R&D content* of the output of industry j (also called the *total technology content* of its output) is defined by the sum

$$TTTL_j = R_j + TINT_j^d + TINV_j^d + TINT_j^m + TINV_j^m \quad .$$

The first component of the sum on the right-hand side is *direct expenditure on R&D* of the industry, R_j. The other four components together make up *acquired technology*. $TINT_j^d$ represents R&D embodied in domestic intermediate inputs purchased by the industry,

$TINV_j^d$ represents R&D embodied in domestic capital goods purchased by the industry, $TINT_j^m$ represents R&D embodied in imported intermediate inputs purchased by the industry and, finally, $TINV_j^m$ stands for R&D embodied in imported capital goods purchased by the industry.

In the following we give a brief non-technical description of the four components of acquired technology (for an exact exposition see Appendix A: Method of computation).

$TINT_j^d$ captures the R&D content embodied in domestic intermediate input purchases by industry j. It is calculated as a weighted sum of the direct R&D intensities (expenditure on R&D per unit of gross output) of all other domestic industries, the weights being the total (direct and indirect) domestic intermediate input requirements of industry j (for all domestic intermediate goods other than i).

$TINV_j^d$ is the R&D content embodied in domestic investment goods acquired by industry j. It is defined as the sum of direct R&D intensities of all other domestic industries weighted by industry j's domestic purchases of the respective investment goods multiplied by the total respective input requirements of industry j.

$TINT_j^m$ measures the R&D content of foreign intermediate input purchases by industry j. This component is a weighted sum of the direct R&D intensities of all industries in trade partner countries, with weights equal to demand of industry j for imported intermediate good i from a given country of origin.

Similarly, $TINV_j^m$ measures the R&D content of foreign investment goods purchases by industry j. Here, foreign direct R&D intensities are weighted by the demand of industry j for imported investment good i from a given country of origin.

Due to the restrictions imposed by a lack of data for Austria, some adaptations had to be made in the implementation. In particular, this concerns the level of aggregation (see Box

"Data Sources"). Due to abscence of R&D data available for the service sector, in the present study – just as in the OECD study by *Papaconstantinou – Sakurai – Wyckoff* (1996) – direct R&D expenditure refers to the manufacturing sector only. Consequently, the total R&D content is underestimated by neglecting both the direct expenditure on R&D of the service sector and the technology content of service inputs.

4. Results: The Structure of Embodied Technology Diffusion in Austria

4.1 The structure of total R&D content

Figure 1 shows the structure of the total R&D content of aggregate output. Total R&D content comprises direct R&D expenditure of the manufacturing sector and R&D embodied in intermediate and investment goods originating in the manufacturing sector and absorbed by all sectors (including the service sector). In Austria, direct expenditure on R&D of the manufacturing sector (the conventional R&D measure) amounts to nearly half of the total R&D content of the aggregate output of all sectors. In 1994, 45.2% of the total R&D content were accounted for by direct R&D and 54.8% by R&D embodied in domestic and imported intermediate and investment goods. The most important component of indirect research and development is R&D embodied in imported and domestic *intermediate goods* (23.2% and 16.4%, respectively). The shares of imported and domestic *investment goods* are significantly lower (8.3% and 6.8%, respectively). The increase in the share of imported technology is due to the growth of R&D embodied in imported intermediate goods. In contrast, the share of direct R&D does not follow a clear trend: It increased to over 50% between 1976 and 1983, and dropped again to the level of the mid-seventies between 1988 and 1994 (45.6%)[17]).

In Austria, direct R&D expenditure accounts for nearly half of the total R&D content of output. The most important component of "indirect research and development" are imported and domestic intermediate goods. Over time, the share of imported technology is increasing.

Figure 2 shows the structure of the total R&D content of manufacturing output only. It includes direct expenditure on R&D of the manufacturing sector and technology originating in and acquired by the manufacturing sector. Of course, direct expenditure on

[17]) The data for 1994 are not strictly comparable to those for previous years, however.

R&D accounts for a considerably higher share (between 60% and 70%) of total R&D content in this definition.

4.2 Total R&D intesity in an international comparison

Total technology intensity (defined here as the ratio of total R&D content to gross output of the manufacturing sector) is, for many purposes, a more meaningful measure of the technology level of a nation's or (industry's) production than direct R&D intensity. In particular in small and lagging countries, it is likely to be considerably higher than direct R&D intensity. Consequently, international comparisons based solely on direct R&D intensities are likely to understate the technology level of the production systems of such countries.

In the seventies and eighties, Austria experienced a dynamic process of catching up in terms of total technology intensity (Figure 3). The latter has more than doubled between 1976 and 1988, increasing at a higher rate than that of any other country in the sample, thus approaching that of Canada. This process was mainly driven by a surge in direct R&D investment and, to a lesser extent, by embodied technology imports.

However, this process of catching up started from a relatively low initial level. In spite of an above-average increase, Austria's total technology intensity is, therefore, comparatively low by international standards. Between 1988 and 1994, this process lost much of its momentum. While the ratio of R&D embodied in intermediate goods to gross manufacturing output continued to expand, direct R&D intensity was stagnating.

Between 1976 and 1988, Austria caught up significantly in terms of total technology intensity. Later on, growth lost its momentum. Compared to other OECD countries, Austria is still lagging behind.

The ratio of technology acquired through the purchase of intermediate and investment goods to direct R&D expenditure varies considerably across countries (*Papaconstantinou – Sakurai – Wyckoff,* 1996). "Acquired technology" ("indirect research and development") is defined as the R&D content of intermediate and investment goods, irrespective of whether they are produced domestically or abroad.

Direct expenditure on R&D tends to be relatively high in the large, research-intensive countries such as the United States and France, where the ratio of "indirect research and development" to direct R&D expenditure is approximately 2:3. For Canada, a country with a relatively low ratio of expenditure on R&D to GDP, and strong informational and trade links to its large neighbour, the United States, the inverse relation (3:2) holds. In Australia, a largely resource-based economy, the ratio of acquired R&D to direct expenditure on R&D is as high as 2:1. In this specter, Austria holds a middle ground with a ratio in the vicinity of 1:1. To a considerable extent, the differences observed across countries are due to the varying shares of R&D embodied in imports, i.e. on the weight of international technology diffusion through intermediate and investment goods.

These country differences can also be highlighted by decomposing the ratio of total R&D content to direct expenditure on R&D which is called the "technology multiplier" by *Papaconstantinou – Sakurai – Wyckoff* (1996). Table 1 shows that Austria's technology multiplier (2.2 in 1994) is higher than that in the large economies included in the OECD sample. Only Canada and Australia show significantly higher technology multipliers.

As expected for a small open economy, the ratio of R&D embodied in *imported* intermediate and investment goods to direct expenditure on R&D is higher in Austria (0.7 in 1994) than in large countries. This fact is a reflection of the relatively important role of imports. The ratio computed for Austria is in the same range as that of the two countries in the sample which are most comparable to Austria: It is also 0.7 (1993) for the Netherlands, and 0.6 for Denmark. For both Canada and Australia, the ratio is 0.8.

Austria's ratio of R&D content of imported intermediate and investment goods to direct expenditure on R&D exceeds that of large countries. However, it is in a range typical for small open economies, however. There is no evidence for Austria realizing gains from imported technology in excess to those of comparable countries.

The figures presented show that Austria participates more in international technology diffusion than large countries. However, they do not provide evidence for a particularly strong "leverage effect" exerted by imported technology putting Austria to a particular advantage vis-à-vis comparable small open economies.

In 1976, the service sector was still lagging far behind the manufacturing sector as a receiver of indirect R&D. By 1994 it was at a par already.

According to Table 1 the ratio of R&D embodied in capital goods to direct R&D was between 0.3 and 0.4 in the period observed. This is a quite common value (comparable to Denmark, the Netherlands, France, Germany).

According to *Papaconstantinou – Sakurai – Wyckoff* (1996) the United States have the highest share of technology acquired through investment goods (over 40% in 1990), and Denmark the lowest. In Austria, the share of technology acquired through investment goods is above 40% in the service sector, and between 10% and 20% in the manufacturing sector.

4.3 Total R&D content and gains in technology intensity by industries

Total R&D content varies significantly across industries. In absolute terms, electrical machinery is by far the single most important industry in terms of total R&D content (nearly ATS 10 billion in 1994), followed by chemicals, transport equipment and non-electrical machinery (Figure 4). Between 1976 and 1994 we observe a rapid – approximately tenfold – increase in the total R&D content in the electrical machinery industry.

In addition to the levels, Figure 4 also shows the structure of total R&D content by industry. A remarkable change in the composition of total R&D content can be observed in the transport equipment industry in the early nineties which saw a rapid expansion in R&D embodied in imported intermediate goods. This can be seen as a reflection of the consolidation of Austria's automotive industry, in particular of the substantial expansion of activities of subsidiaries of multinational car-manufacturing companies.

Table 4 shows, for each year under observation, the five industries which reaped the largest gains in technology intensity by means of acquiring embodied technology from outside sources (domestic or imported). In 1994, these industries consisted of transport equipment, instruments, electrical machinery, non-electrical machinery, and chemicals. The Top-3 industries are the same (and in the same rank order) in all four years under examination. non-electrical machinery was among the Top-5 in all four years. After 1983 the chemicals industry has replaced the fabricated metal industry.

Table 4 shows that in 1994 total acquired technology contributed 2.2 percentage points to the total technology intensity of the transport equipment industry. This contribution is decomposed further in the contribution of domestic acquired technology and imported acquired technology, respectively. Domestic acquired technology contributed 0.3% and imported acquired technology 1.9% to the industry's technology intensity. The share of the largest foreign contributor in imported acquired technology, Germany, was 54% in 1994.

Among the Top-5 industries included in Table 4 there appears to have occured a substantial increase in the gains in technology intensity from acquired technology between 1988 and 1994. In most industries, this is due to increases in both the acquisition of domestic and imported technology. In general, the contribution of imported acquired technology is much higher than that of domestic acquired technology.

4.4 Trends in the use of acquired technology

In this study, we define "acquired technology" as the total R&D content embodied in intermediate and capital goods, irrespective of whether they are produced domestically or abroad.

In the two decades observed, one of the most significant trends in the overall use of acquired technology is the increasing importance of the service sector as a destination of embodied technology flows, i.e. as a user of technology generated elsewhere (Figure 5). Between 1976 and 1994, the importance of the service sector as a destination of embodied technology flows, i.e. as a user of technology generated elsewhere, increased significantly. In 1976, the service sector (other services, excluding utilities & construction) received 35% of total indirect research and development[18]), while manufacturing still was by far the most important destination of embodied technology flows: Light manufacturing, heavy manufacturing and machinery together accounted for 48% of total acquired technology. This pattern has undergone significant change: By 1994, the service sector share went up to 44% and thus was almost at a par with the manufacturing sector. As expected, the share of the primary sector diminished continuously, while the share of utilities and construction was stable for a decade.

Box 1: Sector classification

Sectors	Industries
Primary Sector	Agriculture and forestry, Mining
Light Manufacturing leather,	Food and tobacco, Textiles and
	Wood and furniture
Heavy Manufacturing clay	Paper and printing, Chemicals, Stone,
	and glass, Basic metal
Machinery	Fabricated metal, Non-electrical machinery, Electrical machinery,
Transport,	
	Instruments
Utilities & Construction	Electricity, gas and water, Construction
Other Services	Transport and storage, Communication and Other Services

[18]) For the sector classification see Box 1.

4.5 The role of technology imports

For a small country like Austria, international technology diffusion potentially plays an important role in the long-term growth process. As shown above, technology acquired from abroad has a relatively greater weight in small open economies than in the larger economies. Let us therefore take a closer look at technology imports.

At a general level, an examination of the data leads to the following three observations:

- The R&D content of imported intermediates increased dramatically between 1976 and 1994. The R&D content of imported investment goods has also grew rapidly, though at a slower pace.
- In the Austrian economy, Germany plays an outstanding role as a source of R&D embodied in intermediate goods, and a still more important role as a supplier of research and development embodied in investment goods.
- The machinery sector is by far the most important recipient of technology embodied in imported intermediate goods. In contrast, the service sector (other services) is by far the most important destination of technology embodied in investment goods.

Figure 6 provides an overall picture indicating a highly skewed distribution of technology embodied in intermediates by country of origin, with Germany playing a dominant role as a supplier of embodied technology to the Austrian economy. For better visibility, the data presented in Figure 6 are shown once more in Figure 7 (R&D imports from Germany only) and Figure 8 (R&D imports from other countries, except Germany).

The R&D content of intermediate goods from Germany increased from ATS 632 million in 1976 to ATS 3,840 million in 1994 (Figure 7)[19]). This is due to the combined effect of a

[19]) For a comparison: Austria's GDP at 1976 prices (1976 = 100) has just approximately doubled (1994: 198) in the period between 1976 and 1994.

deepening international division of labor and rising R&D intensities in German manufacturing.

The R&D content of intermediate goods imported from other countries (apart from Germany) is presented in Figure 8. All other countries together have only a slightly higher share than Germany alone. After Germany (and the "other OECD" group of countries), the United States (8.3%) is the second most important supplier of technology to Austria, followed by Japan (6.7%) and France (6.2%). The "other OECD" group of countries includes several European trade partners, most notably – given its volume of trade with Austria – Switzerland. The importance of the United States as a source country may be surprising at first. However, it reflects both the structure of exports from the United States to Austria and the high R&D intensity of manufacturing in the United States. The indirect R&D imports through intermediate goods from Italy, the Netherlands and the United Kingdom are modest, being in the range between ATS 250 and 280 million (1994), respectively. This corresponds to shares of these countries in the R&D content of imported intermediate goods between 3.0% and 3.3%. The shares of the remaining countries are negligible.

Germany dominates Austria's embodied technology imports – in particular through investment goods – to an even greater extent than its manufacturing imports. The United States is the second most important partner country in this respect (apart from the "other OECD" group of countries).

The dependency of Austria's manufacturing industries on technology acquired through intermediate goods is shown in Table 2. In all industries, intermediate (as opposed to investment) goods play a dominant role in the acquisition of embodied technology. For the electrical machinery, transport equipment and chemicals industries, imports of intermediate goods hold a particularly large share in total acquired technology. At the low end of the specter we find the food and tobacco, stone, clay and glass, wood and furniture and paper and printing industries.

The distribution of R&D embodied in investment goods by country of origin of is shown in Figure 9 which indicates a still more pronounced predominance of Germany than observed in the case of intermediate goods. For better visibility, the data presented in Figure 9 are shown once more in Figure 10 (R&D imports from Germany only) and Figure 11 (R&D imports from other countries, except Germany).

In nominal terms, the R&D content of investment goods imported from Germany increased nearly fivefold from ATS 321 million in 1976 to ATS 1,531 million in 1994 (Figure 10). Thus, it is not only much lower in absolute terms than that of intermediate goods but its growth has been less pronounced.

The R&D content of investment goods imported from other countries (apart from Germany) is presented in Figure 11. The rest of the world (all countries except Germany) taken together have a somewhat lower share than Germany alone. Germany (and the aggregate "other OECD") is again followed by the United States (8.1%) as the second most important supplier, Japan (7.5%) and France (6.6%). Thus, the rank order of the Top-5 source countries is the same as that for imports of intermediate goods. The indirect R&D imports through investment goods from Italy, the United Kingdom and the Netherlands are small, in the range of ATS 106 to 51 million (1994). This corresponds to shares between 1.7% and 3.6%. The shares of the remaining countries (Denmark, Canada, Australia) are negligible.

Embodied technology imports from overseas, in particular from China and the Dynamic Asian Economies (DAE), Japan und the United States have shown particularly rapid growth in the two decades under examination. This is true for both intermediate and investment goods.

The dependency of Austria's manufacturing industries on technology acquired through investment goods is shown in Table 3. Usually, investment (as opposed to intermediate) goods play a relatively minor role in the acquisition of embodied technology. The shares of imported investment goods in total acquired technology is much more volatile than that of imported intermediate goods. It tends to be much higher in the traditional consumer goods and construction materials industries than in the machinery and chemicals industries. In 1994, in the food and tobacco, wood and furniture, stone, clay and glass industries, imports of investment goods held a particularly large share in total acquired technology.

As shown, Germany plays a dominant role as a source of embodied technology for the Austrian economy. As such, this is not surprising since Germany is by far Austria's most important trading partner. However, Germany's importance as a source of acquired technology even exceeds its weight in Austria's foreign trade. While Germany's share in Austrian imports of manufacturing goods is 42.2%, its share in research and development embodied in imported intermediate goods amounts to 45.8% (1994). For investment goods, this difference is even more pronounced: Germany supplies 51.1% of research and development embodied in imported investment goods (1994).

A comparison of source country shares in Austria's total imports of manufacturing goods with their shares in research and development embodied in imported intermediate and investment goods is provided in Figure 12. Just as in the case of Germany, the shares of the United States, Japan and, to a lesser extent, France in the R&D content of imported intermediate and investment goods significantly exceed their respective weight in Austria's imports of manufacturing goods. In contrast, Italy and, to a lesser degree the "other OECD" group of countries have lower shares in the R&D content of import flows to Austria than in imports of manufacturing goods.

In the five industries with the largest contribution of indirect research and development to total technology intensity, Germany appears as the most important source of indirect research and development in all the years examined.

For the five industries with the largest contribution of indirect research and development to total technology intensity, Germany appears as the principal source of research and development acquired from abroad in the four years under examination (Table 4), although the share of Germany decreased (in particular between 1988 and 1994). However, the position of Germany vis-à-vis Austria is not unique. Other countries show a similar pattern of "dependence". *Papaconstantinou – Sakurai – Wyckoff* (1996, p. 60) report that the United States is the principal source of embodied technology imports for all of Canada's Top-5 industries. The Top-5 industries in the other nine countries in the OECD sample have at least one additional "most important source country" (or group of countries). "Technology sourcing" in these terms is still often dominated by a single country (mutiple entry of a source country). Taking a view across countries, the United States appears most frequently as the principal source of technology imports.

4.6 Performance and acquisition of R&D

Industries performing much research and development are, in general, not the same as those which heavily acquire research and development embodied in intermediate and investment goods. While an industry's "R&D performance" is given immediately by its direct expenditure on R&D, its acquisition of embodied technology – via the structure of inter-industry intermediate and capital flows – depends on (domestic and foreign) downstream industry R&D intensities.

The "electrical machinery" industry is the biggest investor in research and development. The acquisition of indirect research and development is much less concentrated. Two service industries turn out to be the most important receivers of technology.

Table 5 confronts the Top-5 R&D-performing industries in terms of shares in total manufacturing sector expenditure on R&D with the Top-5 technology-using industries ranked according to their share in total acquired technology[20]).

[20]) Recall that manufacturing and service sector industries are treated asymmetrically in this study: Due to a lack of data, service industries do not appear as performers of R&D. However, the do appear as users of R&D embodied in goods originating in the manufacturing sector.

In 1994, electrical machinery was by far the most important R&D performing industry in Austria. This industry accounted for almost half (47.9%) of total manufacturing sector expenditure on R&D, followed by chemicals (20.3%), non-electrical machinery (10.6%), transport equipment (7.9%) and fabricated metal (4.9%). Thus, the performance of R&D is highly concentrated in Austria. Moreover, concentration appears to have increased over time: The Top-5 industries together accounted for 65.6% of total manufacturing sector direct expenditure on R&D in 1976, as compared to 84.1% in 1983, 87.3% in 1988 and 91.6% in 1994. However, this concentration rate is not unusual. Taking a view across the results for 10 OECD countries (1993) Austria ranks 7th in this respect. In the period of observation, the weight of the electrical machinery industry increased particularly rapidly and was considerably higher than its share reported by *Papaconstantinou – Sakurai – Wyckoff* (1996, p. 55) for the other OECD countries (1990) in their sample. Only in Canada the electrical machinery industry has a similar share (43.3% in 1993) as in Austria.

The distribution of acquired technology across industries is quite different from that of direct expenditure on R&D (R&D performance). Table 5 shows the respective Top-5 industries. Concentration is not only much lower in this case, but the two major users of technology in 1994 were service industries: other services (28.9%) and transport and storage (10.2%). Only then we find two manufacturing industries, transport equipment (9.8%) and electrical machinery (9.2%), followed by construction (7.2%). Over time, the two leading service industries substantially increased their share in total acquired technology while the other industries gained little or lost in importance.

Other services are the major technology-acquiring sector in all countries of the OECD sample (1993). Although also in Austria other services became the most important technology-absorbing sector, its share lags behind by international standards. In several countries, the share of other services is higher than in Austria: Australia (35.3%), France

(36.5%), Germany (31.7%), Italy (30.5%), Japan (32.4%), United Kingdom (36.3%), United States (33.8%).

4.7 Flows of acquired technology from source clusters to user industries

In analogy to the OECD study by *Papaconstantinou – Sakurai – Wyckoff* (1996) manufacturing industries were consolidated to five source clusters: Information, transportation, consumer goods, materials and fabrication. For a definition of these clusters see Box 2. The distribution of acquired technology (indirect research and development) by source clusters and acquiring industries or sectors points at the meanwhile outstanding role of the information and communication sector as a source of technology.

Austria's evolution towards a knowledge-based economy is illustrated by the change in the pattern of technology flows.

Box 2: Cluster classification

Cluster	**Industries**
Information	Electrical machinery, Instruments
Transportation	Transport
Consumer goods	Food and tobacco, Textile and leather
Materials Chemicals,	Wood and furniture, Paper and printing, Stone, clay and glass, Basic metal
Fabrication	Fabricated metal, Non-electrical machinery

Tables 6 – 9 report, for all four years observed, the distribution of acquired technology flows by source cluster and acquiring industry or sector. An examination of the data presented reveals the outstanding role of information and communication technology in total acquired technology flows.

By 1994 (Table 9), the information technology cluster was by far the most important source of acquired technology in the Austrian economy, accounting for 43.5% of total acquired technology, followed by the materials cluster (24.3%). Thus, there has been an almost perfect reversal of the pattern prevailing in 1976 (materials cluster 43.6%, information technology cluster 25.3% of total acquired technology). The shifts in technology flows from the remaining source clusters (transportation, consumer goods and fabrication) are minor. At the same time, the service sector became the most important user of acquired technology (51.6%).

In 1994, the information technology cluster was the most important source of technology, with the materials cluster lagging far behind. The reverse pattern was prevailing in 1976.

At the sector and cluster level, information technology absorbed by the service sector turns out to be the most important flow of embodied technology in quantitative terms (24.4% of total acquired technology) in 1994, whereas in 1976 this position was held by technology embodied in materials and absorbed by the manufacturing sector (23.1%). This development reflects a profound and pervasive change in the pattern of embodied technology flows. Even for the manufacturing sector, the information technology cluster is recently (1994) the most important source of embodied technology (18.0% of total acquired technology), thus outperforming the materials cluster (13.0%). In 1976, the respective shares were still 12.1% and 23.1%, respectively.

The absorption of indirect research and development originating in the information technology cluster by the service sector is the most important technology flow in quantitative terms. Even in manufacturing, the information technology cluster was the most important source of technology, leaving behind the materials cluster. Here, too, the relations have changed fundamentally since 1976.

The changes in shares between 1976 and 1994 of acquired technology from source clusters in absolute terms are shown in Table 10. The largest gain in shares between 1976 and 1994 can also be observed for technology acquired by the service sector from the information technology cluster (+12.3 percentage points). This is mainly due to the gains in shares realized by other services (+8.6 percentage points).

For all for years under examination, the structure of acquired technology flows originating in each of these source clusters by industry or sector of destination is shown in Tables 11 – 14. In 1994 (Table 14), 55.8% of the embodied technology originating in the information technology cluster . – which is by far the most important source of acquired technology – was absorbed by the service sector (31.7% by other services), whereas 41.4% went to the manufacturing sector. In 1976, these two sectors were still at a par, accounting for 47% to 48% of indirect research and development acquired from the information technology cluster. The changes in shares between 1976 and 1994 of acquired technology from source clusters in percentage points are shown in Table 15.

The evolution over time of embodied technology flows from each of the five source clusters to the individual industries of destination is shown in Figures 13 – 17. It should be noted, however, that the scales applied in these figures vary. Figure 13 illustrates the enormous increase in information technology acquired by other services. In nominal terms, this flow has increased from ATS 0.2 to 2.7 billion between 1976 and 1994. In the nineties, the electrical machinery industry, construction, non-electrical machinery as well as transport and storage also experienced rapid growth in acquired information technology.

5. Conclusions

In Austria, direct business sector expenditure on R&D accounts for not quite half of the total R&D content of output. The most important components of "indirect research and development" are imported and domestic intermediate goods, investment goods being less important in this respect. In the longer run, the share of imported technology in total R&D content is increasing. Although initially Austria was able to catch up, total R&D intensity was still low by international standards in 1994.

With a ratio of "indirect research and development" to direct R&D expenditure close to 1:1, Austria holds a middle position in the international community. In large, advanced economies, this ratio is significantly lower. As expected, the ratio of R&D embodied in imported intermediate and investment goods to direct R&D expenditure is relatively high – the same holds true for comparable small open economies, however. Thus, there is no evidence that Austria holds an extraordinary position based on above-average imports of technology. Consequently, analyses based on total R&D content cannot be expected to contribute much to the "performance paradox" mentioned in the introduction. Analyses based on innovation survey data appear more promising in this context.

Germany plays an outstanding role as a supplier of imported technology to Austria. Germany dominates technology imports – particularly through investment goods – to an even higher degree than Austria's imports of manufacturing goods. The United States is the second most important partner country in this respect (apart from the "other OECD" group of countries).

The change in the pattern of technology flows over the two decades examined provides an impressive picture of the evolution of Austria towards a "knowledge-based economy". On the one hand, the service sector has gained significantly in importance as a destination of technology flows, catching up with manufacturing by 1994. On the other hand, the weight of the information technology cluster has been increasing rapidly: Already in 1994, the information technology cluster was by far the most important source of technology, outweighing the materials cluster. Thus, the relations prevailing in 1976 have been almost completely reversed.

Indirect research and development originating in the information technology cluster and absorbed by the service sector constitutes the most important flow of technology. Even in manufacturing, the information technology cluster was the most important source of technology in 1994, thus outperforming the materials cluster. Here, too, the relations have undergone a fundamental change since 1976.

Appendix A: Method of computation

The method employed in this study to compute embodied R&D follows *Papaconstantinou - Sakurai - Wyckoff* (1996). This choice was made in order to make international comparisons feasible.

The *total R&D content* of industry j 's[21]) output is defined by the sum

$$TTTL_j = R_j + TINT_j^d + TINV_j^d + TINT_j^m + TINV_j^m \quad ,$$

R_j ... *direct R&D expenditure* of the industry, $TINT_j^d$ ... R&D embodied in domestic intermediate inputs purchased by the industry, $TINV_j^d$ ... R&D embodied in domestic investment goods, $TINT_j^m$ ... R&D embodied in imported intermediate inputs, $TINV_j^m$ ... R&D embodied in imported investment goods. The last four components – to be defined rigorously below – together make up "indirect" research and development.

The *direct R&D intensity* of an industry is defined as its direct R&D expenditure per unit of gross output, i.e.

$$r_i = \frac{R_i}{X_i} \qquad (i = 1, \ldots, n) \quad .$$

As usual, the Leontief inverse is defined by

$$B = \left(I - A^d\right)^{-1} \quad ,$$

I ... identity matrix, A^d ... matrix of domestic input coefficients. A characteristic element b_{ij} of matrix B represents the direct and indirect requirements of output i necessary to turn out one unit of final demand of good j [22]).

[21] The formulas apply for a given country. Country indices are suppressed here.

[22]) The interested reader not familiar with the basic concepts of input-output analysis is referred to *Miller - Blair* (1985) or any other standard textbook of input-output economics.

R&D embodied in domestic intermediate inputs of industy j is given by

$$TINT_j^d = \sum_{i=1, i \neq j}^{n} r_i b_{ij}^* X_j \quad .$$

Instead of the traditional "final-demand-to-output" multipliers (i.e. the elements of the standard Leontief inverse introduced above) "output-to-output" multipliers are used (for a detailed exposition of this type of multipliers see *Miller – Blair,* 1985). A characteristic element b_{ij}^* of the "output-to-output" multiplier matrix B^* is algebraically derived by dividing the columns of the Leontief inverse by its respective diagonal element. The application of output-to-output multipliers instead of the traditional Leontief multipliers avoids double-counting that part of the R&D content of industry j which is already included in R_j, the direct expenditure on R&D by industry j.

R&D embodied in domestic investment goods purchased by industy j is defined by

$$TINV_j^d = \sum_{i=1}^{n} r_i \left(\sum_{h=1}^{n} b_{ih} I_{hj}^d \right) \quad ,$$

b_{ih} ... an element of the usual Leontief inverse B, I_{hj}^d ... demand of industy j for the domestic investment good h.

R&D embodied in imported intermediate inputs of industy j is given by

$$TINT_j^m = \sum_{k=1}^{l} \sum_{i=1}^{n} r_{ik} \alpha_{ik} X_{ij}^m \quad ,$$

r_{ik} ... R&D intensity of industry i in the exporting country k $(k = 1,...,l)$, α_{ik} ... import share of country k in total imports of commodity i, i.e.,

$$\alpha_{ik} = \frac{m_{ik}}{\sum_{k=1}^{l} m_{ik}} \quad .$$

Thus, the "import proportionality" assumption is made. Finally, X_{ij}^{m} is intermediate demand of industry j for the imported intermediate input i .

R&D embodied in imported investment goods purchased by industy j is defined by

$$TINV_j^m = \sum_{k=1}^{l}\sum_{i=1}^{n} r_{ik}\alpha_{ik} I_{ij}^{m} \qquad ,$$

I_{ij}^{m} ... demand of industry j for the imported investment good i .

The computation of R&D embodied in imported goods – in contrast to domestic goods – captures only first-round effects. To capture total effects, a linked international input-output model would be required. Consequently, the volume of imported technology is underestimated in both the present study as well as the OECD study.

Appendix B: Data Sources

The OECD study by *Papaconstantinou – Sakurai – Wyckoff* (1996) is exclusively based on the OECD STAN family of databases: the Structural Analysis (STAN) Database proper, the Analytical Database for Business Enterprise R&D (ANBERD), the OECD Input-Output Database and the Bilateral Trade Database. Since Austria is not covered by either the ANBERD or the Input-Output database, this study had to draw on complementary national sources not harmonized by the OECD.

R&D Expenditure

Business enterprise expenditure on R&D (BERD) was taken from the OECD Analytical Database for Business Enterprise R&D (ANBERD) database (see *OECD*, 1997A). At present, 10 OECD countries are covered by ANBERD: Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, the UK and the US. Austria is currently not included in ANBERD. For this reason, official BERD (OFFBERD) data as reported to the OECD by the Austrian Central Statistical Office had to be used for Austria (see *OECD*, 1997B). While ANBERD provides (estimated) time series for a number of International Standard Industrial Classification (ISIC, Rev. 2) sectors, official disaggregate business enterprise R&D data for Austria are only available for 1975, 1984, 1989 and 1993. However, due to a massive break in the time series, census R&D data for 1995 published by the Austrian Central Statistical Office were used instead of the 1993 OFFBERD data.

Gross Output

Gross output data used to calculate sectoral R&D intensities are taken from the OECD Structural Analysis (STAN) database. For 1994, gross output data were unavailable for some STAN sectors in some of the countries. These aggregates were decomposed using disaggregate information for the most recent year available. The same applies to the Austrian data.

Foreign Trade

The shares of the 10 OECD countries covered by ANBERD in Austrian imports are calculated seperately on the basis of the OECD Bilateral Trade Database (BTD). The remaining countries are grouped into two categories: the "Dynamic Asian Economies" (DAE: China, Hong Kong, Malaysia, Singapore, South Korea, Taiwan, Thailand) and the Rest of the World (ROW).

Input-Output Data

Input-Output tables for Austria are available for 1976, 1983, 1988 and 1994. For each of these years the following four matrices were used in the computation of total R&D content:

domestic intermediate goods (activity x activity),

imported intermediate goods (activity x activity),

domestic investment goods (activity x activity),

imported investment goods (activity x activity).

The matrices for 1976 and 1983 are based on data published by the Austrian Central Statistical Office. The matrices for 1988 and 1994 are based on WIFO projections of these official data. From the original commodity x activity tables, activity x activity tables were derived on the basis of the industry-based technology assumption (see, e.g., *Miller - Blair*, 1985, Chapter 5). This assumption "presumes that an industry has the same input structure, regardless of its output product mix" (*Miller - Blair*, 1985, p. 166).

For Austria, input-output data (1976, 1983, 1988, 1994) are not available for the same years as disaggregate business enterprise R&D statistics (1975, 1984, 1989, 1995) but for adjacent years. As an approximation it was assumed that at the industry-level R&D intensities remained unchanged for adjacent years (1975/1976, 1983/1984, 1988/1989, 1994/1995).

Special Issues

Due to constraints imposed by the availability of data for Austria, the level of aggregation is somewhat higher than that applied in the OECD study by *Papaconstantinou – Sakurai – Wyckoff* (1996), which is based exclusively on the OECD STAN family of databases. While the OECD study uses 36 ISIC (Rev. 2) sectors – of which 22 manufacturing industries coincide with ANBERD – this study deals with 20 sectors of which 13 belong to manufacturing.

In order to increase consistency with the Austrian data, the four-digit industry "Office and computing machinery" (#3825 of ISIC, Rev. 2) was included in the three-digit industry "Electrical machinery" (#383 of ISIC, Rev. 2) throughout. The "Other manufacturing" sector was dropped due to a lack of R&D data.

Since adequate service sector R&D data are not available – like in *Papaconstantinou – Sakurai – Wyckoff* (1996) – only direct R&D expenditures of the manufacturing sector (#3 of ISIC, Rev. 2) are used. However, the remaining seven industries outside manufacturing are included as receivers (users) of technology originating in the manufacturing sector.

References

Abramovitz, M., "Catching Up, Forging Ahead, and Falling Behind", Journal of Economic History, 1986, 46(2), 385-406.

Abramovitz, M., "The Postwar Productivity Spurt and Slowdown. Factors of Potential and Realization", in OECD, Technology and Productivity. The Challenge for Economic Policy, Paris, 1991, 19-35.

Abramovitz, M., "The Search for the Sources of Growth: Areas of Ignorance, Old and New", Journal of Economic History, 1993, 53(2), 217-243.

Aghion, Ph., Howitt, P., Endogenous Growth Theory, M.I.T. Press, Cambridge, MA, 1998.

Arrow, K.J., "Economic Welfare and the Allocation of Resources for Innovation", in Nelson, R. (Ed.), The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton University Press, Princeton, 1962, 609-625.

Barro, R. J., Sala-i-Martin, X., Economic Growth, McGraw Hill, New York, 1995.

Barro, R., Sala-i-Martin, X. (1997), "Technological Diffusion, Convergence, and Growth", Journal of Economic Growth, 1997, 1(1), 1ff.

Bernstein, J.I., Mohnen, P., "International R&D Spillovers between U.S. and Japanese R&D Intensive Sectors", Journal of International Economics, 1998, 44(2), 315-338.

Blomström, M., Kokko, A., "How Foreign Direct Investment Affects Home Countries", Policy Research Paper, World Bank, 1997, (1745).

Borisov, V., Hutschenreiter, G., Kryazhimskii, A., "Asymptotic Growth Rates in Knowledge-Exchanging Economies", Annals of Operations Research, 1999, (89), 61-73.

Butschek, F., "Institutional Continuity and Economic Growth – The Case of Austria", WIFO Working Papers, 1999, (115).

Coe, D.T., Helpman, E., "International R&D Spillovers", European Economic Review, 1995, 39, 859-887.

Coe, D.T., Helpman, E., Hoffmaister, A., "North - South R&D Spillovers", Economic Journal, 1997, 107, 134-149.

Cohen, W.M., Levinthal, D.A., "Innovation and Learning: The Two Faces of R&D", Economic Journal, 1989, 99(September), 569-596.

Eaton, J., Gutierrez, E., Kortum, S., "European Technology Policy", Economic Policy, 1998, (27), 403-438.

Eaton, J., Kortum, S., "Trade in Ideas: Patenting and Productivity in the OECD", Journal of International Economics, 1996, 40, 251-278.

European Commission, Second European Report on S&T Indicators 1997, Luxemburg, 1997.

Fagerberg, J., "Technology and International Differences in Growth Rates", Journal of Economic Literature, 1994, 32(September), 1147-1175.

Freeman, C., Soete, L., The Economics of Industrial Innovation, Third Edition, M.I.T. Press, Cambridge, MA, 1997.

Geroski, P., "Markets for Technology: Knowledge, Innovation and Appropriability", in Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technical Change, Blackwell, Oxford, 1995, 90-131.

Griliches, Z., "Research Expenditure and Growth Accounting", in Williams, B.R. (Ed.), Science and Technology in Economic Growth, Macmillan, London, 1973, 59-83.

Griliches, Z., "Issues in Assessing the Contribution of Research and Development to Productivity Growth", Bell Journal of Economics, 1979, 10(1), 92-116.

Griliches, Z., "The Search for R&D Spillovers", Scandinavian Journal of Economics, 1992, 94, Supplement, 75-84.

Griliches, Z., R&D and Productivity: The Econometric Evidence, University of Chicago Press, Chicago, 1998.

Grossman, G.M., "Promoting New Industrial Activities: A Survey of Recent Arguments and Evidence", OECD Economic Studies, 1990, (14), 87-125.

Grossman, G. M., Helpman, E., Innovation and Growth in the Global Economy, M.I.T. Press, Cambridge, MA, 1991.

Grossman, G., Helpman, E., "Technology and Trade", in Grossman, G., Rogoff, K. (Eds.), Handbook of International Economics, Vol. III, North Holland, Amsterdam-New York, 1995, 1279-1337.

Helpman, E., "Innovation, Imitation, and Intellectual Property Rights", Econometrica, 1993, 61(6), 1247-1280.

Helpman, E., "R&D and Productivity: The International Connection", NBER Working Paper, 1997, (6101).

Helpman, E., Krugman, P., Market Structure and Foreign Trade, M.I.T. Press, Cambridge, MA, 1985.

Hirshleifer, J., Riley, J.G., The Analysis of Uncertainty and Information, Cambridge University Press, Cambridge, 1992.

Hutschenreiter, G., Innovation und Produktivitätsentwicklung in der österreichischen Industrie, tip Programme, Vienna, 1994.

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

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

Hutschenreiter, G., Kaniovski, Y. M., Kryazhimskii, A. V., "Endogenous Growth, Absorptive Capacities and International R&D Spillovers", IIASA Working Paper, 1995, (WP-95-92).

Hutschenreiter, G., Leo, H., "Empirical Evidence on Schumpeterian Hypotheses in Austria", in Aiginger, K., Finsinger, J. (Eds.), Applied Industrial Organization. Towards a Theory Based Empirical Industrial Organization, Kluwer Academic Publishers, Dordrecht - Boston - London, 1994, 51-61.

Hutschenreiter, G., Peneder, M., Ziele und Methoden der Clusteranalyse wirtschaftlicher und innovativer Aktivitäten", WIFO-Monatsberichte, 1994, 67(11), 617-623.

Ioannides, E., Schreyer, P., "Technology and Non Technology Determinants of Export Share Growth", OECD Economic Studies, 1997, 28(1), 169-204.

Irwin, D., Klenow, P., "Learning-by-Doing Spillovers in the Semiconductor Industry", Journal of Political Economy, 1994, 102(6), 1200-1227.

Jaffe, A.B., "Technological Opportunity and Spillovers of R&D: Evidence from Firm's Patents, Profits, and Market Value", American Economic Review, 1986, 76(5), 984-1001.

Jaffe, A.B., "Characterizing the 'Technological Position' of Firms, with Application to Quantifying Technological Opportunity and Research Spillovers", Research Policy, 1989, (18), 87-97.

Keller, W., "Trade and the Transmission of Technology", NBER Working Paper, 1997, (6113).

Kendrick, J.W., "Total Factor Productivity - What it Does and Does not Measure", in OECD, Technology and Productivity. The Challenge for Economic Policy, Paris, 1991, 149-156.

Klenow, P. J., Rodriguez-Clare, A., "Economic Growth: A Review Article", Journal of Monetary Economics, 1997, 40(3), 597-617.

Klette, T.J., Moen, J., Griliches, Z., "Do Subsidies to Commercial R&D Reduce Market Failures? Microeconomic Evaluation Studies", NBER Working Paper, 1999, (6947).

Krugman, P., Geography and Trade, M.I.T. Press, Cambridge, MA, 1991.

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., "Appropriating the Returns from Industrial Research and Development", Brookings Papers on Economic Activity. Special Issue on Microeconomics, 1987, (3), 783-820.

Lichtenberg, F., van Pottelsberghe de la Potterie, B., "International R&D Spillovers: A Re-Examination", NBER Working Paper, 1996, (5668).

Lichtenberg, F., van Pottelsberghe de la Potterie, B., "International R&D Spillovers: A Comment", European Economic Review, 1998, 42(8), 1483-1491.

Lundvall, B.-A. (Hrsg.), National Systems of Innovation, Pinter, London, 1992.

Mankiw, N.G., "The Growth of Nations", Brookings Papers on Economic Activity, 1995, 275-310.

Mansfield, E., "How Rapidly Does New Industrial Technology Leak Out?", Journal of Industrial Economics, 1985, 34(2), 217-223.

Marin, D., "Learning and Dynamic Comparative Advantage: Lessons From Austria's Post-War Pattern of Growth for Eastern Europe", CEPR Discussion Paper, 1995, (1116).

Marshall, A., Principles of Economics, Eighth Edition, MacMillan, London, 1920.

Miller, R. E., Blair, P. D., Input-Output Analysis. Foundations and Extensions, Prentice-Hall, Englewood Cliffs, 1985.

Mohnen, P., The Econometric Approach to R&D Externalities, Cahiers de recherche du département des sciences économiques de l'Université du Québec à Montreal, 1994, (9408).

Mohnen, P., Some Estimates of International R&D Spillovers, Paper Prepared for the tip Conference 1995, Vienna, 1995 (mimeo).

Mohnen, P., "R&D Externalities and Productivity Growth", STI Review, 1996, (18), 19-66.

Nelson, R.R., "The Simple Economics of Basic Research", Journal of Political Economy, 1959, 62(3), 297-306.

OECD (1997A), The OECD STAN Database for Industrial Analysis 1976-1995, Paris, 1997.

OECD (1997B), Research and Development Expenditure in Industry 1974-95, Paris, 1997.

OECD, Technology, Productivity and Job Creation – Best Policy Practices, Paris, 1998.

Papaconstantinou, G., Sakurai, N., Wyckoff, A., "Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries", STI Working Papers, 1996, (1).

Polanyi, M., The Tacit Dimension, Garden City, NY, 1967.

Rivera-Batiz, L. A., Romer, P. M., "Economic Integration and Endogenous Growth", Quarterly Journal of Economics, 1991, 106(2), 531-555.

Romer, P. M., "Endogenous Technological Change", Journal of Political Economy, 1990, 98(5), 71-102.

Sakurai, N., Ioannides, E., Papaconstantinou, G., "The Impact of R&D and Technology Diffusion on Productivity: An Empirical Analysis for 10 OECD Countries", STI Working Papers, 1996, (2).

Scherer, F. M., "Using Linked Patent and R&D Data to Measure Interindustry Technology Flows", in Griliches, Z. (Ed.), R&D, Patents, and Productivity, National Bureau of Economic Research, University of Chicago Press, Chicago, 1984, 202-212.

Schibany, A., Co-operative Behaviour of Innovative Firms in Austria, tip Programme, Vienna, 1998.

Solow, R.M., "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, 1957, 31, 312-320.

Steindl, J., "Import and Production of Know-How in a Small Country", in Saunders, C. T. (Ed.), Industrial Policies and Technology Transfer between East and West, Springer, Wien-New York, 1977, 211-218.

Stiglitz, J., Whither Socialism?, M.I.T. Press, Cambridge, MA, 1994.

Stoneman, P., The Economic Analysis of Technology Policy, Clarendon Press, Oxford, 1987.

Stoneman, P., Diederen, P., "Technology Diffusion and Public Policy", Economic Journal, 1994, 104(425), 918-930.

Streißler, E. (1979A), "Growth Models as Diffusion Processes", Kyklos, 1979, 32(1-2), 251-269.

Streißler, E. (1979B), "Growth Models as Diffusion Processes: Empirical Illustrations", Kyklos, 1979, 32(3), 571-586.

Terleckyj, N., Effects of R&D on the Productivity Growth of Industries: An Explanatory Study, National Planning Association, Washington, 1974.

Terleckyj, N., "Direct and Indirect Effects of Industrial Research and Development", in Kendrick, J.W., Vaccara, B.N. (Eds.), New Development in Productivity Measurement and Analysis, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 44, University of Chicago Press, Chicago, 1980, 359-377.

Figure 1

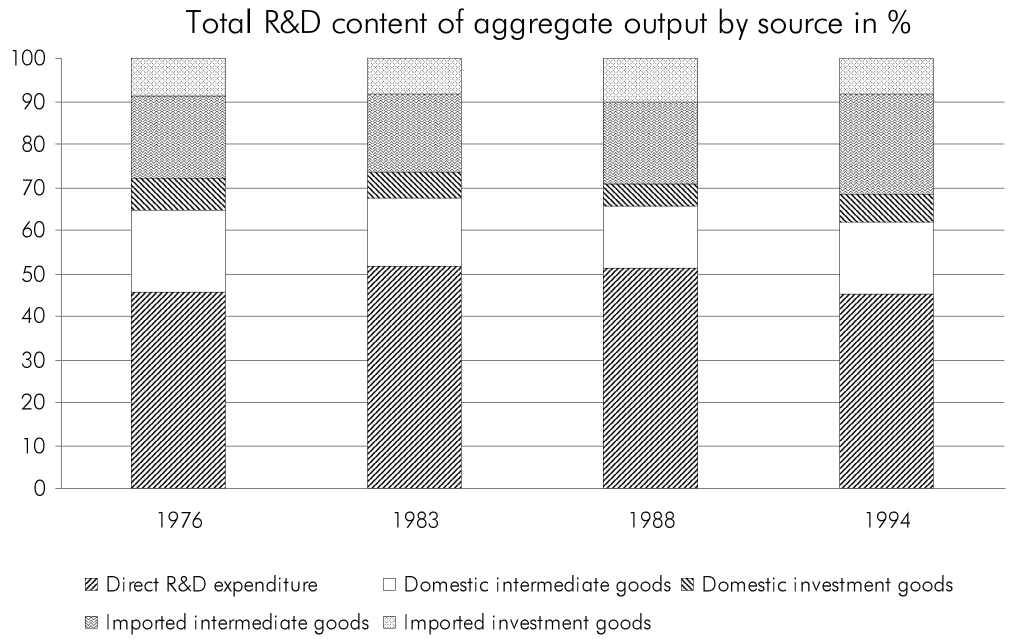


Figure 2

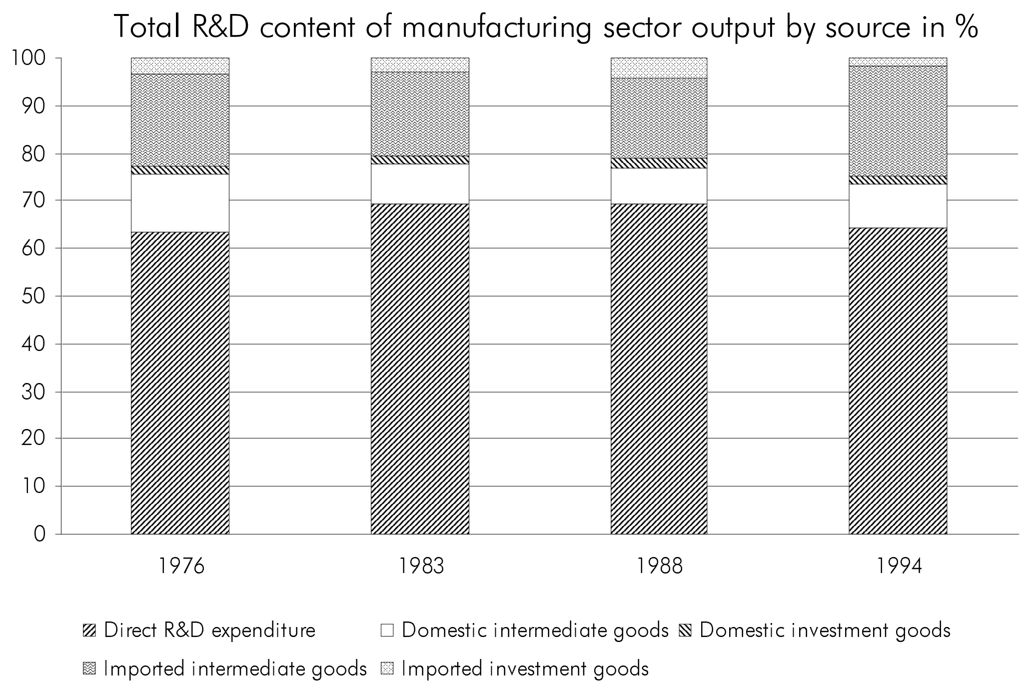


Figure 3

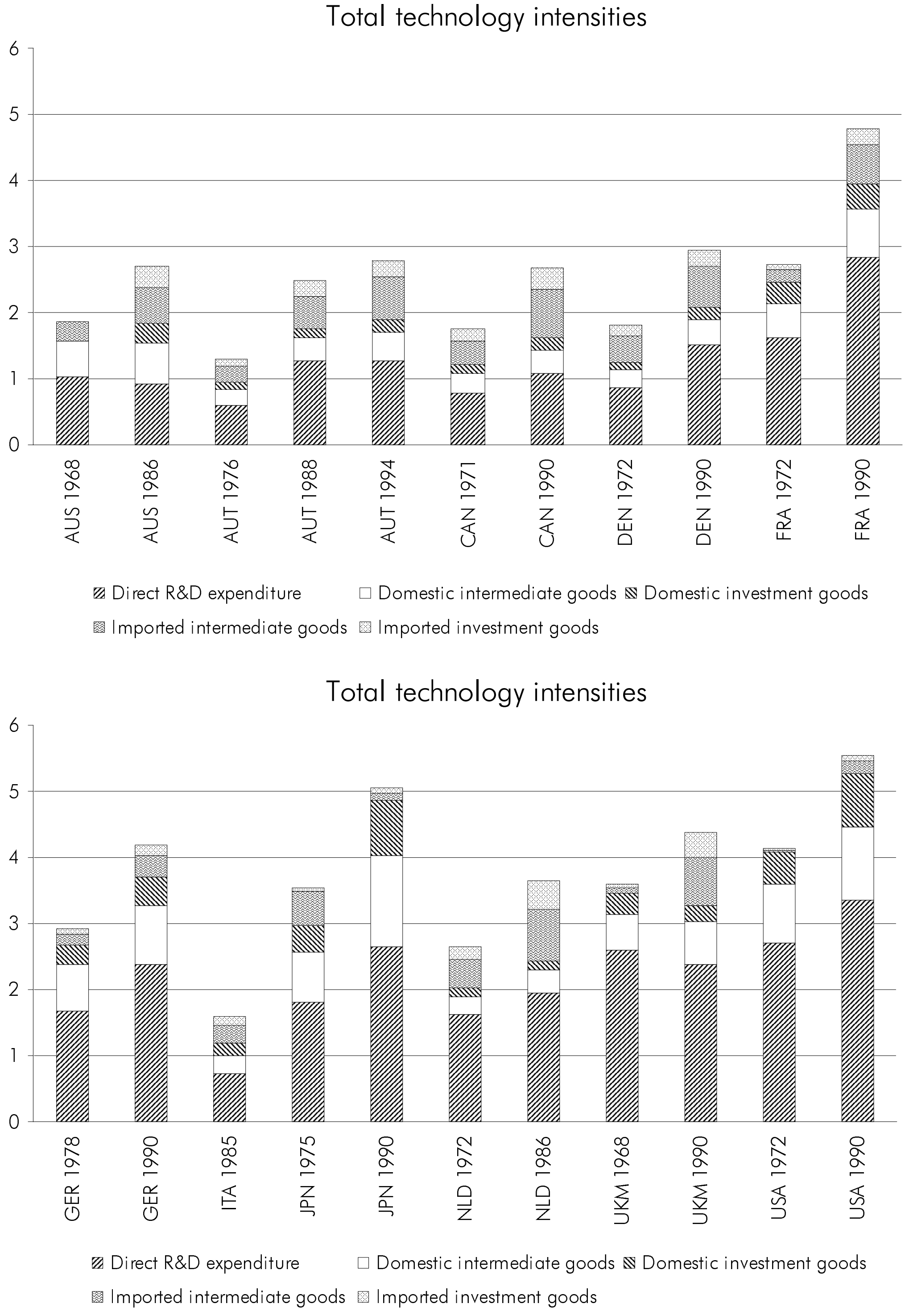

Total technology intensities
6
5
4
3
2
1
0
AUS 1968
AUS 1986
AUT 1976
AUT 1988
AUT 1994
CAN 1971
CAN 1990
DEN 1972
DEN 1990
FRA 1972
FRA 1990
Direct R&D expenditure
Domestic intermediate goods
Domestic investment goods
Imported intermediate goods
Imported investment goods
Total technology intensities
6
5
4
3
2
1
0
GER 1978
GER 1990
ITA 1985
JPN 1975
JPN 1990
NLD 1972
NLD 1986
UKM 1968
UKM 1990
USA 1972
USA 1990
Direct R&D expenditure
Domestic intermediate goods
Domestic investment goods
Imported intermediate goods
Imported investment goods

Table 1 Decomposition of the technology multiplier

Country	Year	Domestic intermediates/ direct	Imported intermediates/ direct	Domestic investment/ direct	Imported investment/ direct	Technology multiplier total/direct
Australia						
	1968	0.5	0.0	0.3	0.0	1.8
	1974	0.8	0.0	0.5	0.0	2.3
	1986	0.7	0.6	0.3	0.4	2.9
	1989	0.7	0.5	0.2	0.3	2.7
Austria						
	1976	0.4	0.4	0.2	0.2	1.2
	1983	0.3	0.3	0.1	0.2	0.9
	1988	0.3	0.4	0.1	0.2	1.0
	1994	0.4	0.5	0.2	0.2	1.2
Canada						
	1971	0.4	0.4	0.2	0.3	2.2
	1976	0.5	0.6	0.2	0.3	2.6
	1981	0.5	0.5	0.2	0.4	2.5
	1986	0.4	0.7	0.2	0.4	2.6
	1990	0.3	0.7	0.2	0.3	2.5
	1993	0.3	0.6	0.2	0.2	2.3
Denmark						
	1972	0.3	0.4	0.1	0.2	2.1
	1977	0.4	0.5	0.2	0.2	2.2
	1980	0.3	0.5	0.2	0.2	2.2
	1985	0.3	0.5	0.1	0.3	2.2
	1990	0.3	0.4	0.1	0.2	2.0
	1993	0.3	0.4	0.1	0.2	1.9
France						
	1972	0.3	0.2	0.2	0.0	1.7
	1977	0.4	0.1	0.2	0.1	1.8
	1980	0.3	0.5	0.2	0.2	2.2
	1985	0.3	0.2	0.2	0.1	1.8
	1990	0.3	0.2	0.2	0.1	1.8
	1993	0.3	0.2	0.2	0.1	1.7
Germany						
	1978	0.4	0.1	0.2	0.0	1.7
	1986	0.4	0.1	0.2	0.0	1.7
	1988	0.4	0.1	0.2	0.1	1.8
	1990	0.4	0.1	0.2	0.1	1.8
	1993	0.4	0.1	0.2	0.1	1.7
Italy						
	1985	0.4	0.4	0.2	0.2	2.2
	1990	0.4	0.3	0.2	0.1	2.0
Japan						
	1975	0.6	0.1	0.3	0.0	2.0
	1980	0.6	0.1	0.3	0.0	2.0
	1985	0.6	0.0	0.3	0.0	1.9
	1990	0.5	0.0	0.3	0.0	1.9
	1993	0.6	0.0	0.3	0.0	1.9

Source: OECD, WIFO

Table 1 (continued) Decomposition of the technology multiplier

Country	Year	Domestic intermediates/ direct	Imported intermediates/ direct	Domestic investment/ direct	Imported investment/ direct	Technology multiplier total/direct
Netherlands						
	1972	0.2	0.3	0.1	0.1	1.6
	1977	0.2	0.3	0.1	0.1	1.7
	1981	0.2	0.5	0.1	0.2	1.9
	1986	0.2	0.4	0.1	0.2	1.9
	1993	0.2	0.5	0.1	0.2	1.9
UK						
	1968	0.2	0.0	0.1	0.0	1.4
	1979	0.3	0.1	0.1	0.1	1.6
	1984	0.3	0.2	0.1	0.1	1.7
	1990	0.3	0.3	0.1	0.2	1.8
	1993	0.3	0.3	0.1	0.1	1.8
USA						
	1972	0.3	0.0	0.2	0.0	1.5
	1977	0.4	0.0	0.2	0.0	1.7
	1982	0.4	0.0	0.2	0.0	1.7
	1985	0.3	0.0	0.2	0.0	1.6
	1990	0.3	0.1	0.2	0.0	1.7
	1993	0.4	0.1	0.2	0.0	1.7

Source: OECD, WIFO

Figure 4

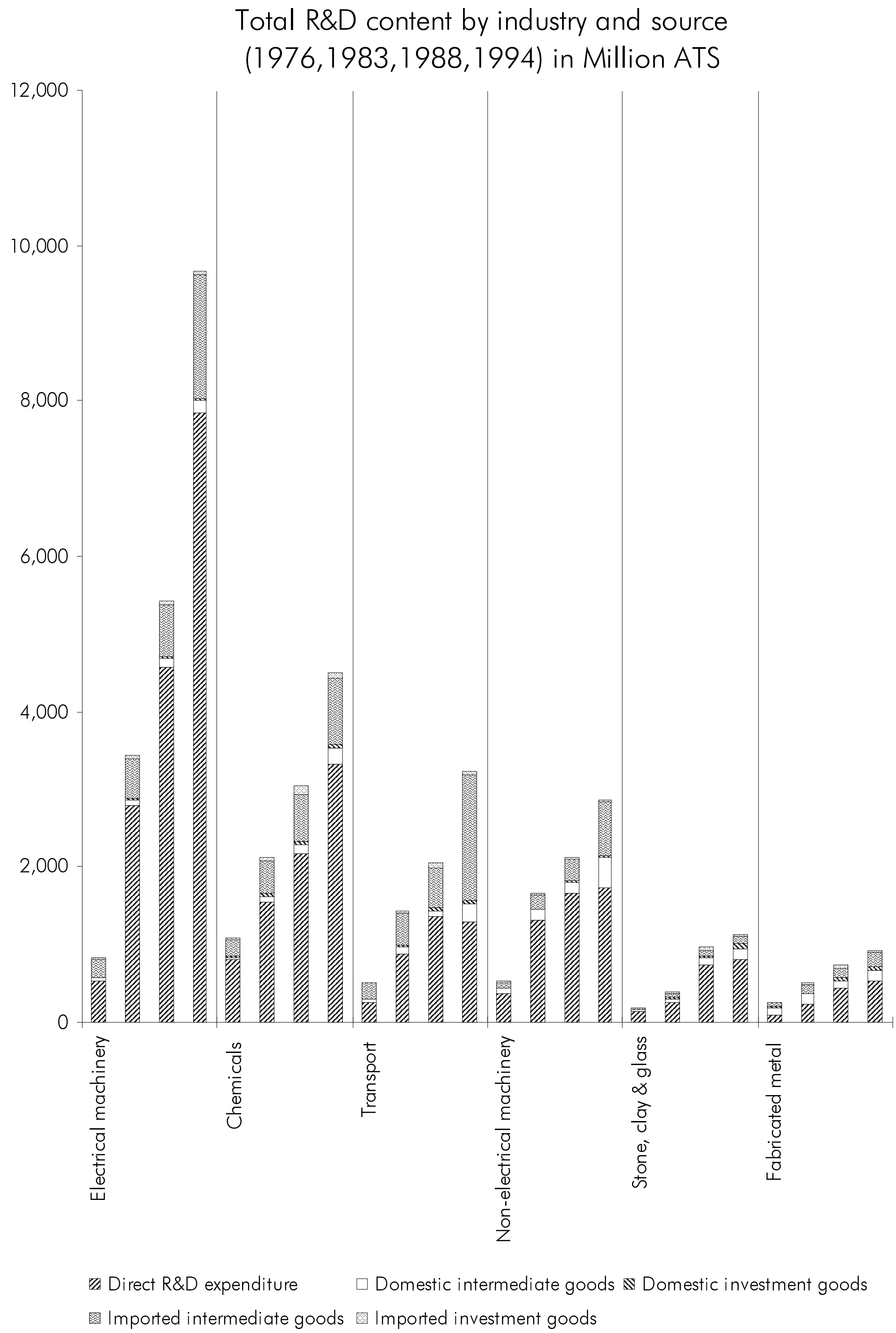

Total R&D content by industry and source
(1976,1983,1988,1994) in Million ATS
12,000
10,000
8,000
6,000
4,000
2,000
0
Electrical machinery
Chemicals
Transport
Non-electrical machinery
Stone, clay & glass
Fabricated metal
Direct R&D expenditure
Domestic intermediate goods
Domestic investment goods
Imported intermediate goods
Imported investment goods

Figure 4 (continued)

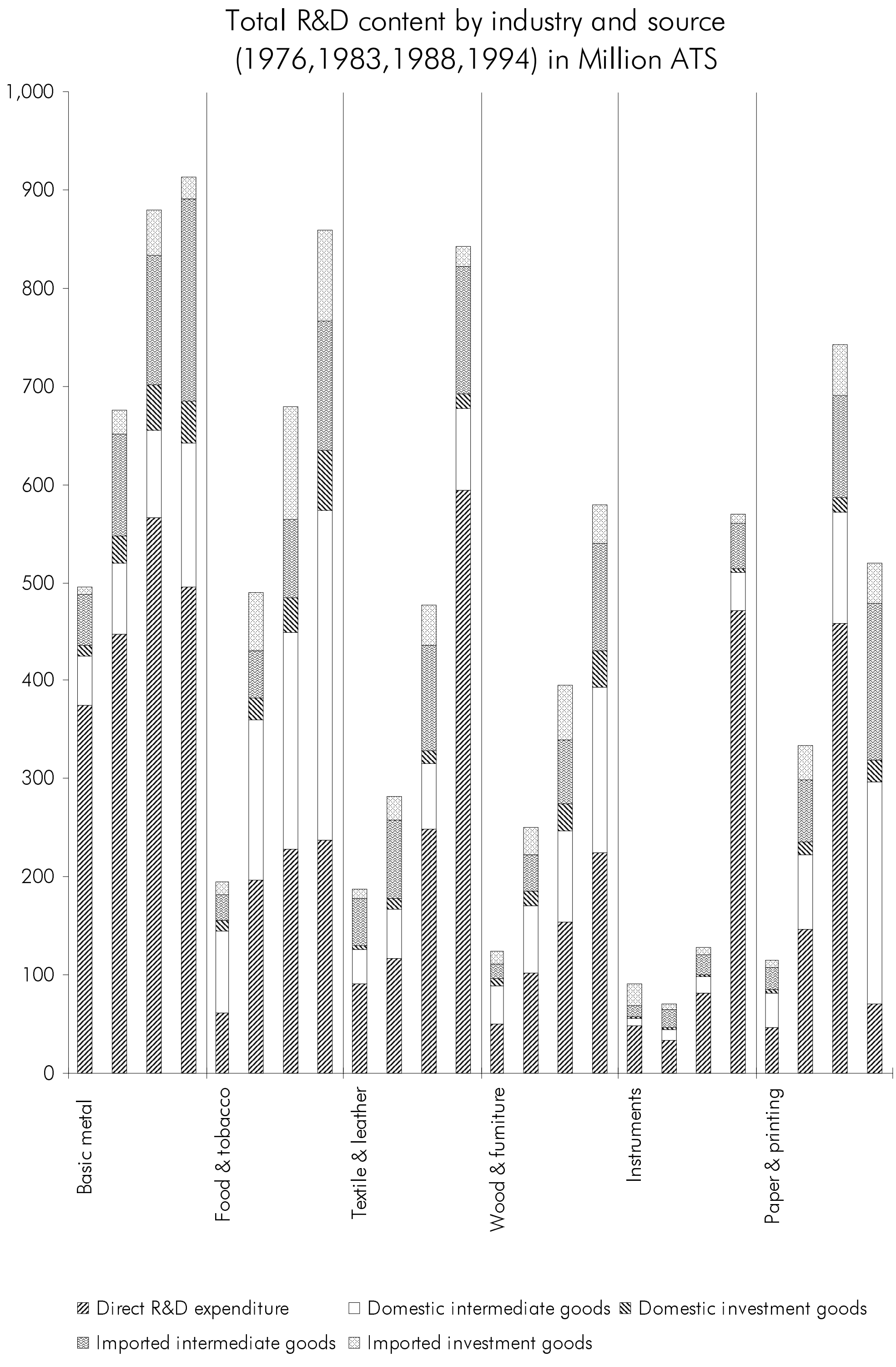


Figure 5

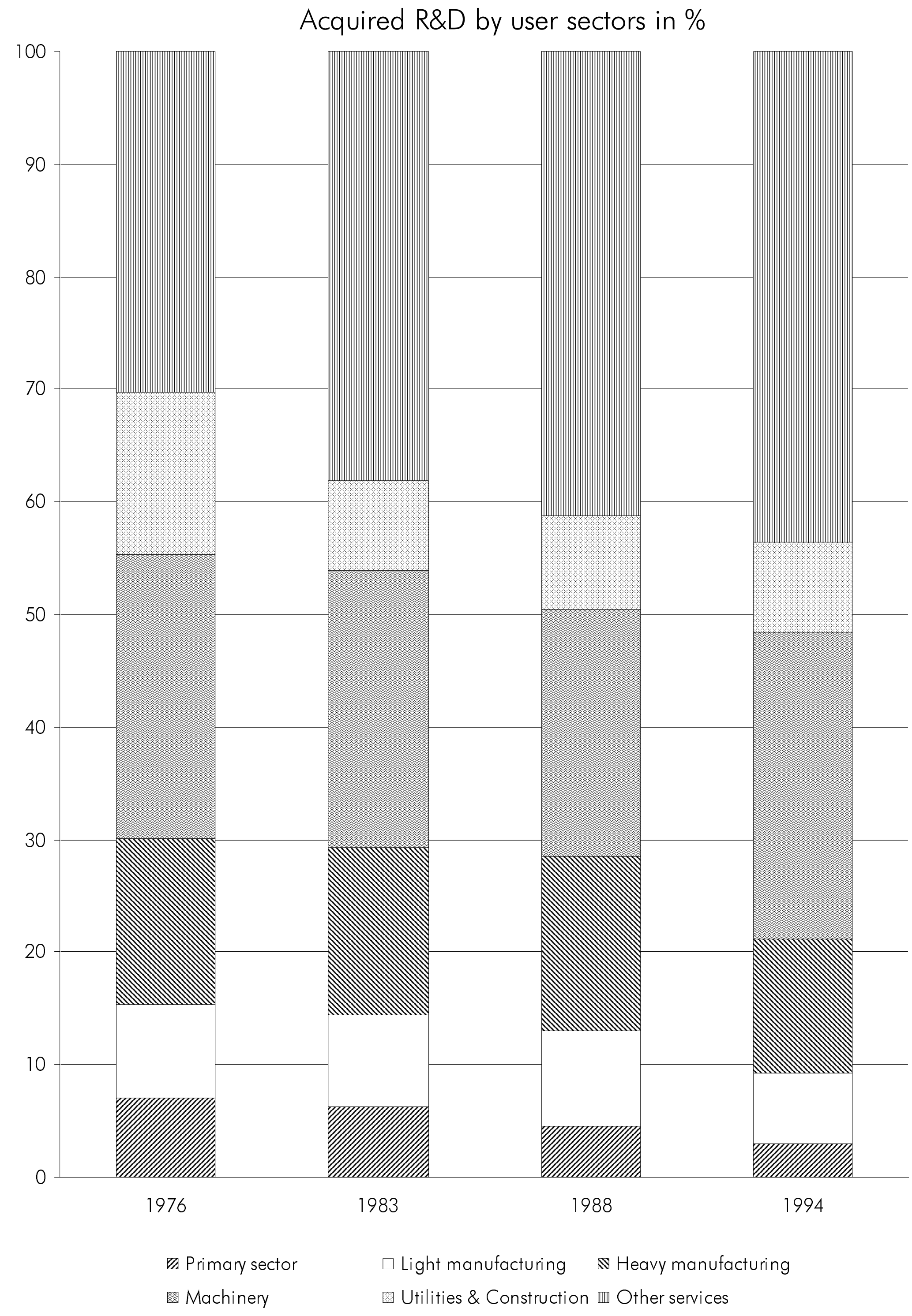

Acquired R&D by user sectors in %
100
90
80
70
60
50
40
30
20
10
0
1976
1983
1988
1994
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 6

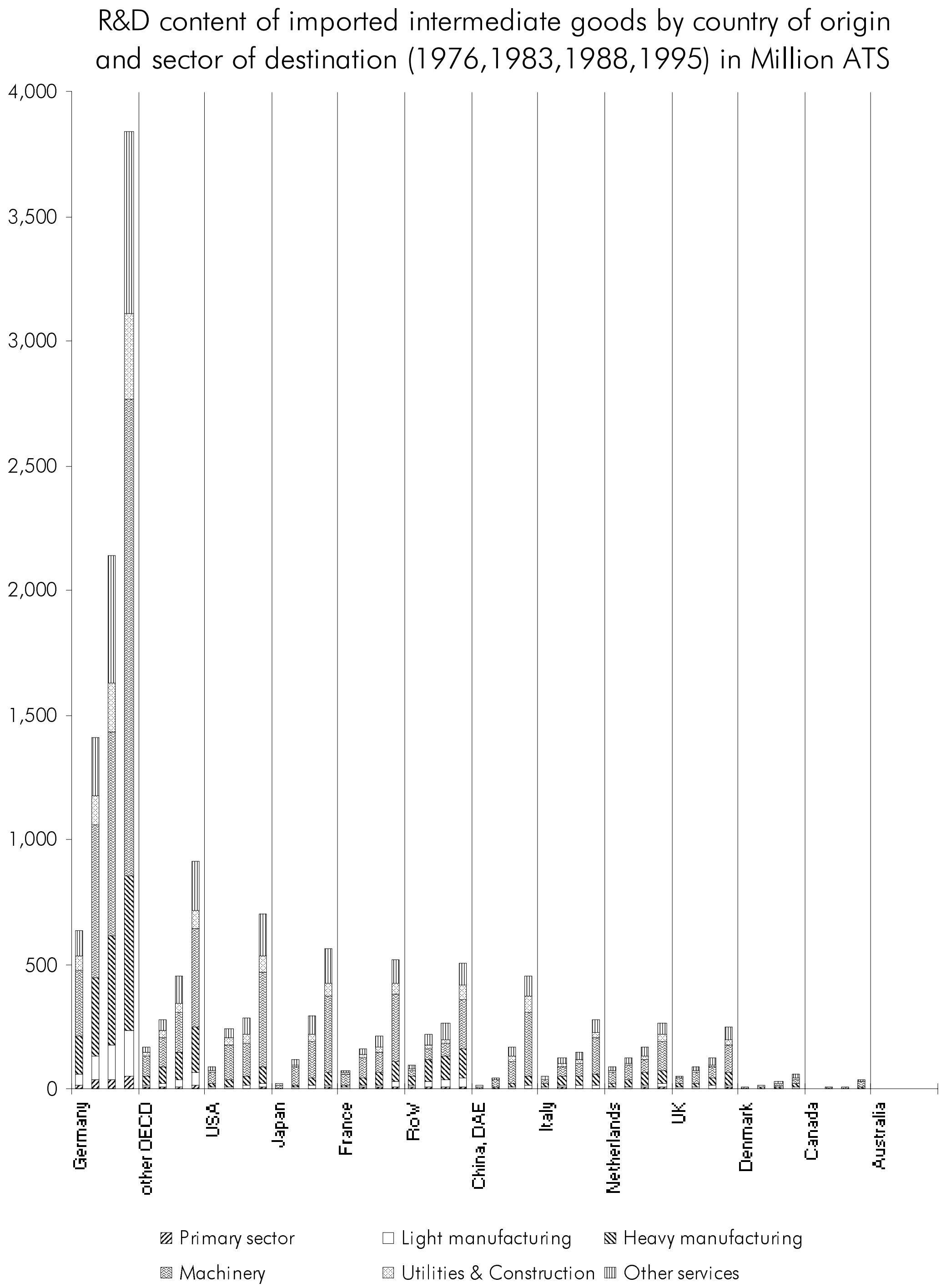
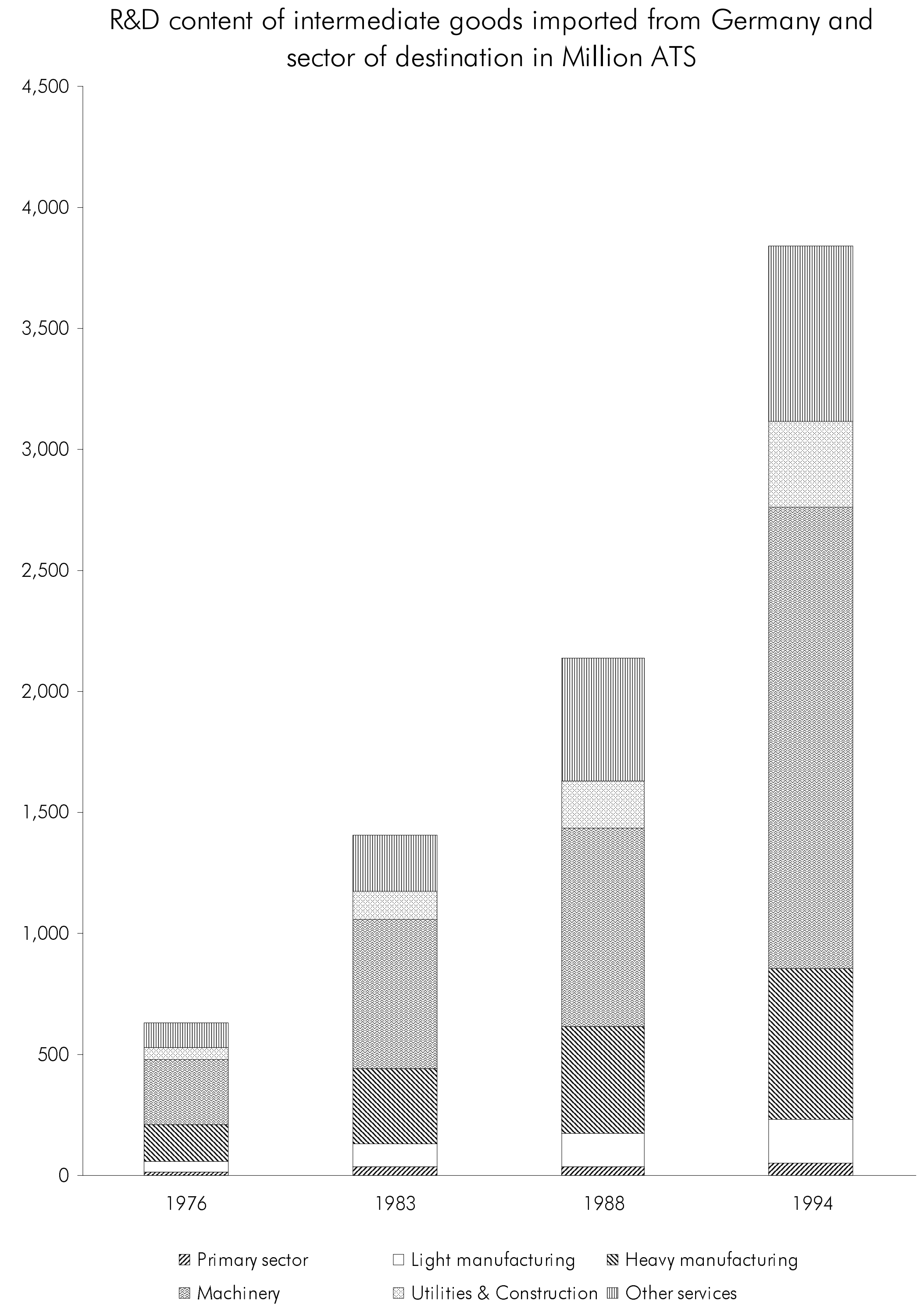

R&D content of imported intermediate goods by country of origin and sector of destination (1976,1983,1988,1995) in Million ATS
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Germany
other OECD
USA
Japan
France
RoW
China, DAE
Italy
Netherlands
UK
Denmark
Canada
Australia
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 7


R&D content of intermediate goods imported from Germany and sector of destination in Million ATS
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1976
1983
1988
1994
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Fugure 8

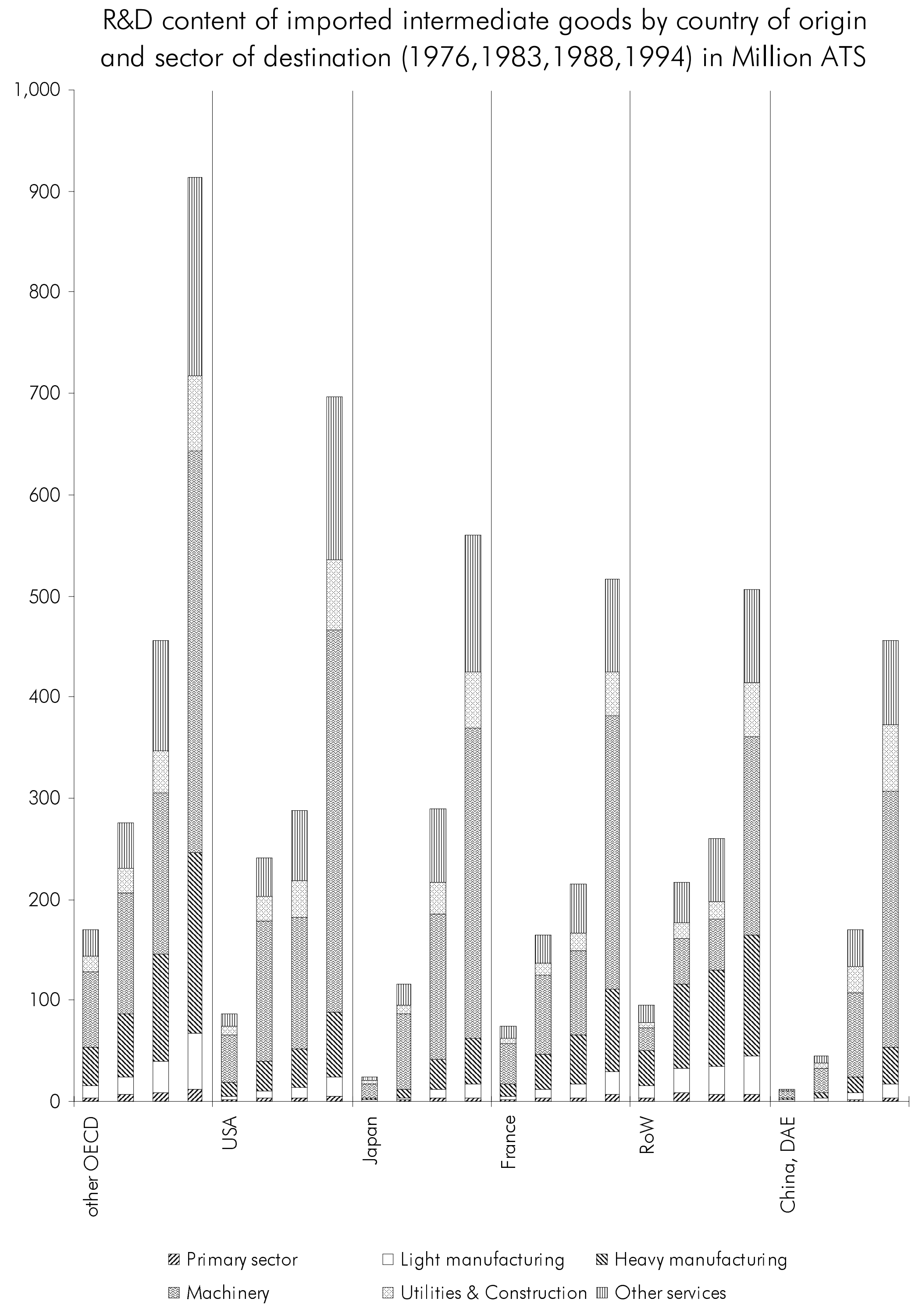

R&D content of imported intermediate goods by country of origin and sector of destination (1976,1983,1988,1994) in Million ATS
1,000
900
800
700
600
500
400
300
200
100
0
other OECD
USA
Japan
France
RoW
China, DAE
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 8 (continued with change in scale)

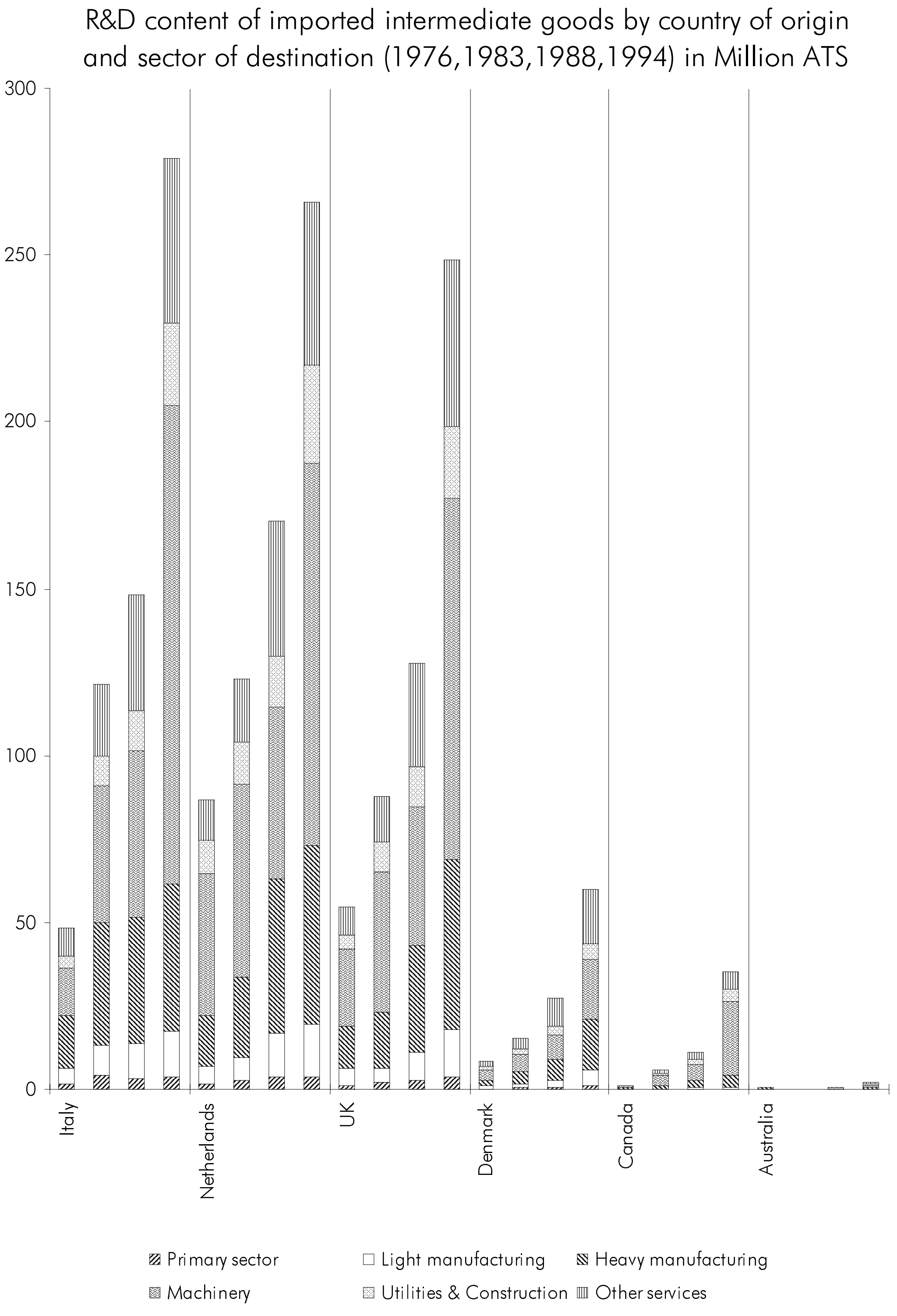


Table 2 Dependency of Austria's manufacturing industries on technology acquired through intermediate goods

Industry	Year	Share of domestic intermediate goods in AT	Share of imported intermediate goods in AT	Share of intermediate goods in AT
Food and tobacco		62.89	19.1	81.95
Textile and leather		36.20	49.7	85.91
Wood and furniture		52.50	21.7	74.16
Paper and printing		50.69	32.0	82.71
Chemicals		11.53	73.4	84.96
Stone, clay and glass	1976	52.38	20.2	72.56
Basic metal		41.62	44.0	85.63
Fabricated metal		61.45	27.1	88.52
Non-electrical machinery		46.56	43.4	89.96
Electrical machinery		16.00	77.3	93.28
Transport		19.69	77.4	97.09
Instruments		18.66	27.1	45.73
Food and tobacco		55.81	16.63	72.44
Textile and leather		30.74	49.24	79.98
Wood and furniture		45.29	25.98	71.26
Paper and printing		40.76	32.79	73.55
Chemicals		12.56	74.35	86.92
Stone, clay and glass	1983	42.67	23.22	65.89
Basic metal		31.30	46.09	77.38
Fabricated metal		44.69	39.44	84.13
Non-electrical machinery		37.80	52.64	90.44
Electrical machinery		9.93	81.57	91.50
Transport		15.77	76.73	92.49
Instruments		32.66	51.90	84.56
Food and tobacco		48.89	18.0	66.90
Textile and leather		29.03	46.7	75.70
Wood and furniture		38.60	26.2	64.80
Paper and printing		39.97	36.5	76.47
Chemicals		13.71	69.1	82.77
Stone, clay and glass	1988	33.20	25.4	58.62
Basic metal		28.35	42.2	70.56
Fabricated metal		34.84	42.3	77.13
Non-electrical machinery		29.22	59.6	88.84
Electrical machinery		13.41	78.1	91.52
Transport		11.78	73.0	84.76
Instruments		34.68	42.0	76.65
Food and tobacco		54.19	21.42	75.61
Textile and leather		33.56	52.29	85.85
Wood and furniture		47.66	30.73	78.38
Paper and printing		50.26	35.41	85.68
Chemicals		17.30	72.42	89.72
Stone, clay and glass	1994	44.15	28.68	72.83
Basic metal		35.37	49.24	84.61
Fabricated metal		36.31	45.19	81.49
Non-electrical machinery		34.15	61.53	95.67
Electrical machinery		9.72	87.01	96.73
Transport		11.88	83.13	95.01
Instruments		38.51	47.76	86.27

Source: WIFO

AT: Acquired Technology

Figure 9

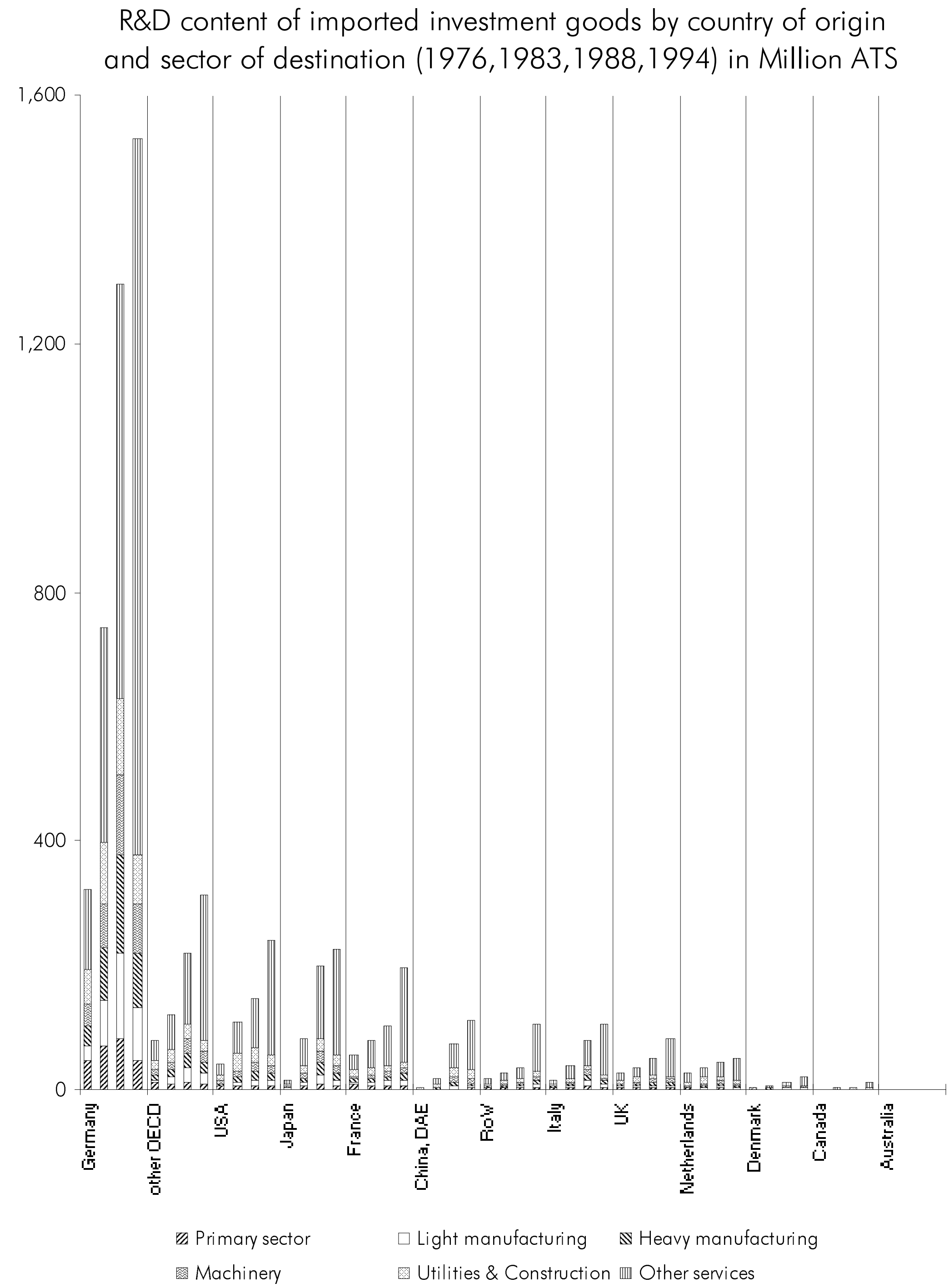

R&D content of imported investment goods by country of origin and sector of destination (1976,1983,1988,1994) in Million ATS
1,600
1,200
800
400
0
Germany
other OECD
USA
Japan
France
China, DAE
RoW
Italy
UK
Netherlands
Denmark
Canada
Australia
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 10

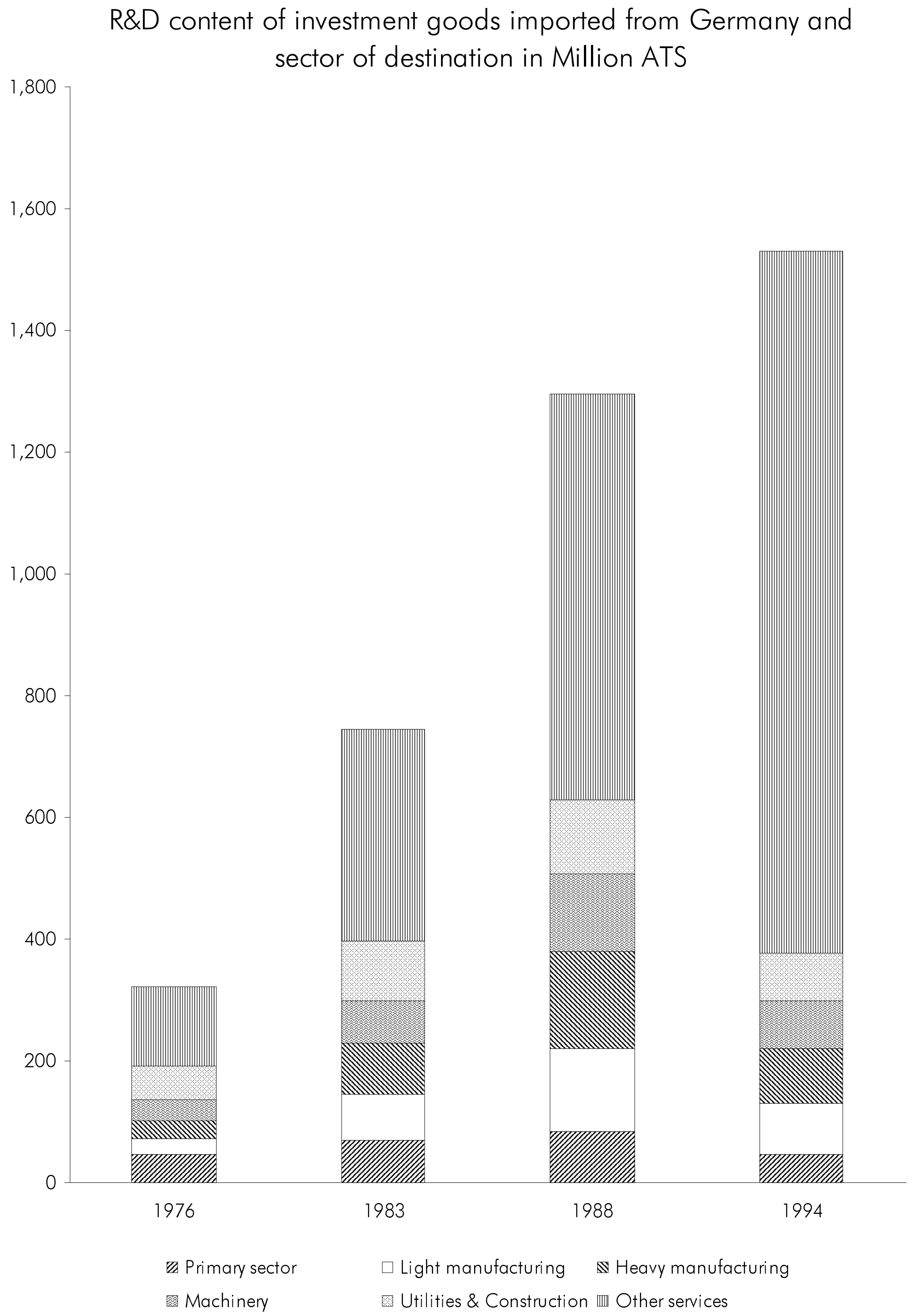

R&D content of investment goods imported from Germany and sector of destination in Million ATS
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1976
1983
1988
1994
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 11

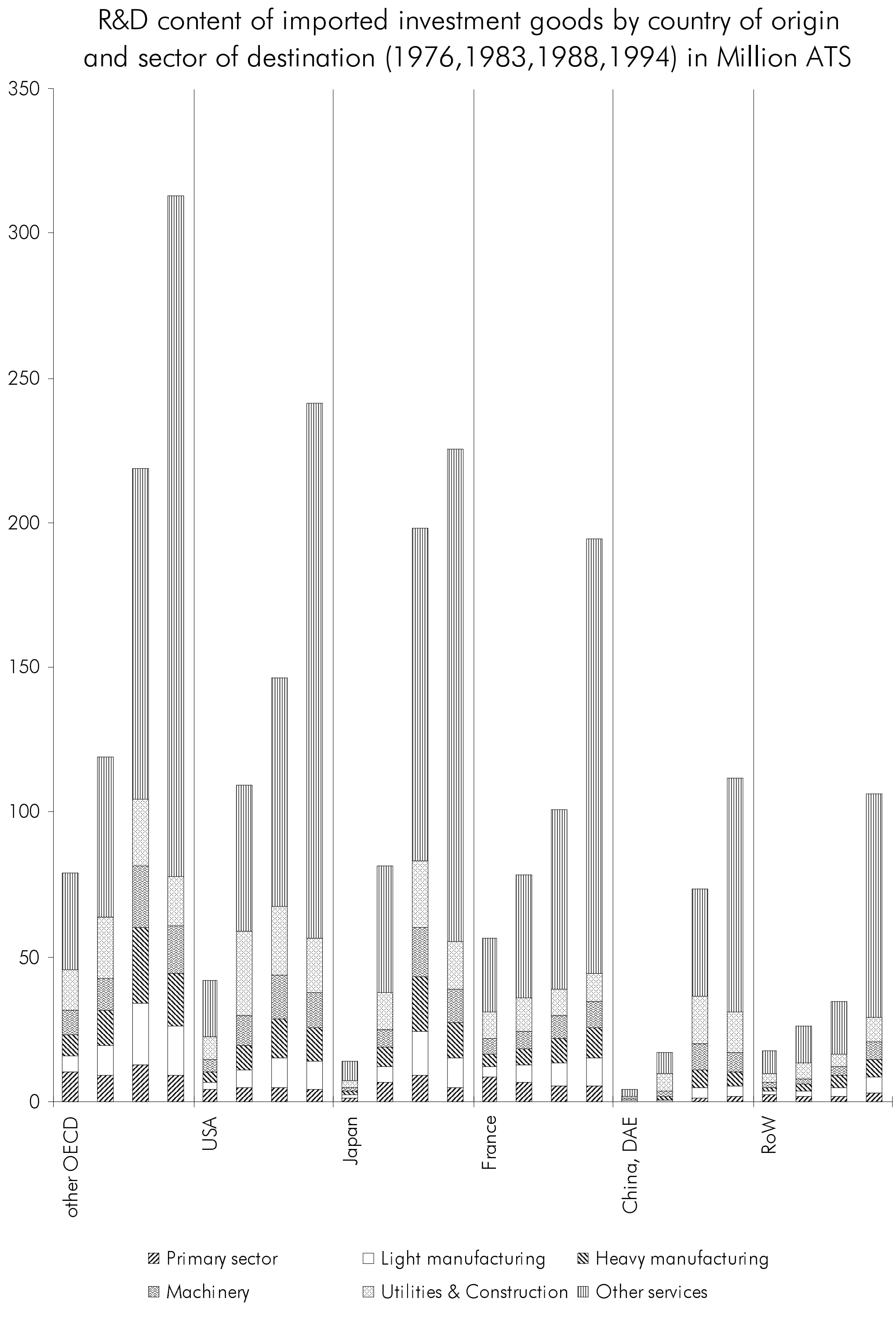

R&D content of imported investment goods by country of origin
and sector of destination (1976,1983,1988,1994) in Million ATS
350
300
250
200
150
100
50
0
other OECD
USA
Japan
France
China, DAE
RoW
Primary sector
Light manufacturing
Heavy manufacturing
Machinery
Utilities & Construction
Other services

Figure 11 (continued with change in scale)

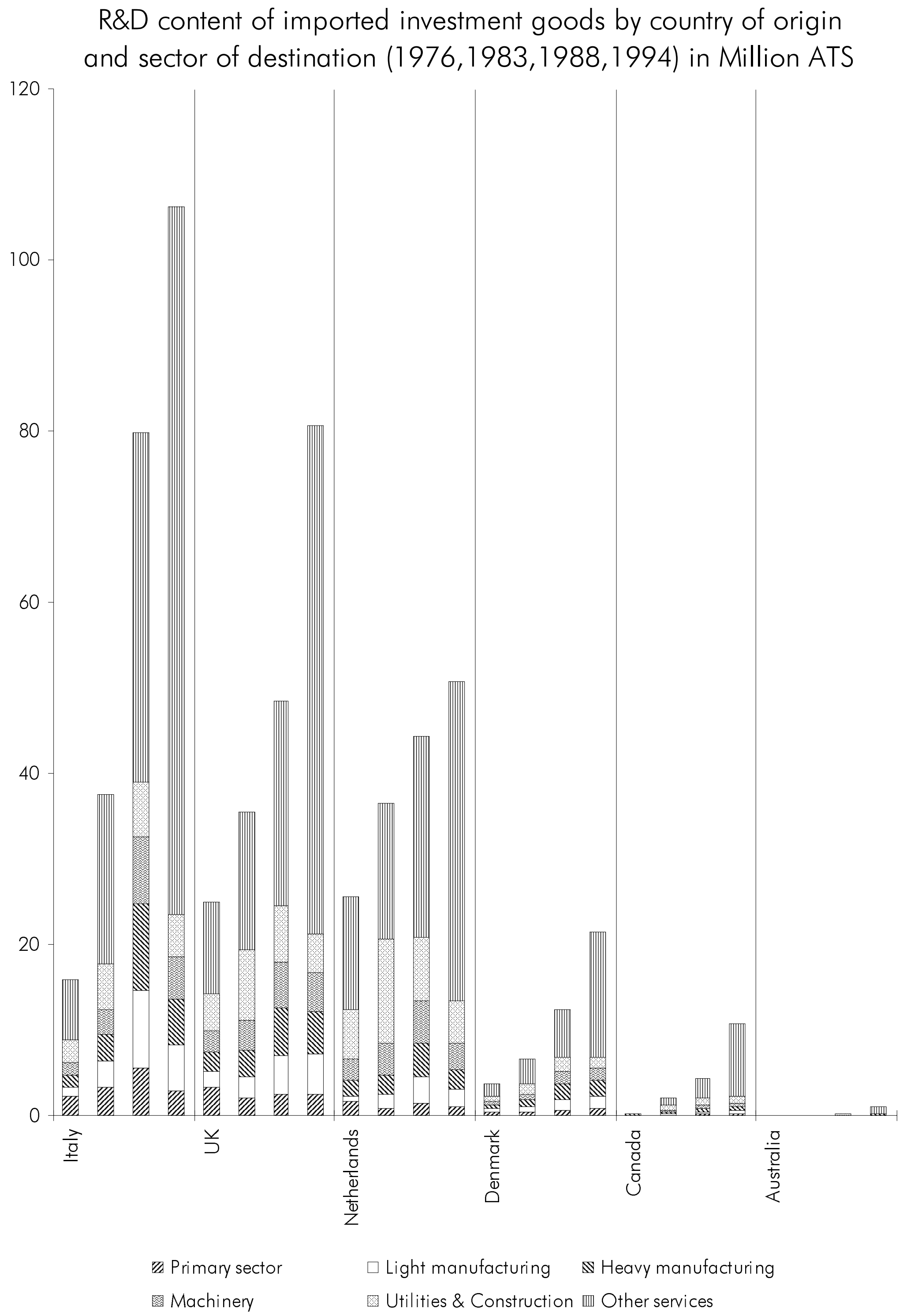


Table 3 Dependency of Austria's manufacturing industries on investment-based technology acquisition

Industry	Year	Share of domestic investment goods in AT	Share of imported investment goods in AT	Share of investment goods in AT
Food and tobacco		7.76	10.3	18.05
Textile and leather		3.36	10.7	14.09
Wood and furniture		9.82	16.0	25.84
Paper and printing		5.60	11.7	17.29
Chemicals		5.14	9.9	15.04
Stone, clay and glass	1976	10.05	17.4	27.44
Basic metal		9.01	5.4	14.37
Fabricated metal		4.37	7.1	11.48
Non-electrical machinery		3.45	6.6	10.04
Electrical machinery		1.46	5.3	6.72
Transport		1.81	1.1	2.91
Instruments		2.29	52.0	54.27
Food and tobacco		7.40	20.16	27.56
Textile and leather		5.89	14.13	20.02
Wood and furniture		10.29	18.45	28.74
Paper and printing		7.19	19.26	26.45
Chemicals		4.73	8.35	13.08
Stone, clay and glass	1983	17.27	16.84	34.11
Basic metal		12.18	10.44	22.62
Fabricated metal		6.37	9.49	15.87
Non-electrical machinery		3.76	5.80	9.56
Electrical machinery		2.35	6.15	8.50
Transport		2.55	4.95	7.51
Instruments		3.23	12.21	15.44
Food and tobacco		7.77	25.3	33.10
Textile and leather		6.43	17.9	24.30
Wood and furniture		11.77	23.4	35.20
Paper and printing		5.22	18.3	23.53
Chemicals		5.03	12.2	17.23
Stone, clay and glass	1988	18.69	22.7	41.38
Basic metal		14.69	14.8	29.44
Fabricated metal		8.27	14.6	22.87
Non-electrical machinery		3.90	7.3	11.16
Electrical machinery		1.87	6.6	8.48
Transport		4.38	10.9	15.24
Instruments		4.14	19.2	23.35
Food and tobacco		9.64	14.75	24.39
Textile and leather		5.82	8.33	14.15
Wood and furniture		10.51	11.11	21.62
Paper and printing		5.10	9.22	14.32
Chemicals		4.36	5.92	10.28
Stone, clay and glass	1994	17.00	10.17	27.17
Basic metal		10.21	5.18	15.39
Fabricated metal		9.88	8.63	18.51
Non-electrical machinery		2.25	2.08	4.33
Electrical machinery		1.24	2.03	3.27
Transport		2.29	2.70	4.99
Instruments		4.49	9.25	13.73

Source: WIFO

AT: Aquired Technology

Table 4 Largest gain in technology intensity from acquired technology

Industry	Year	Intensity				
		Total	Domestic	Imported	Largest source	Share of largest source
Transport	1976	1.010	0.217	0.793	Germany	48.7
Instruments		0.965	0.202	0.763	Germany	53.6
Electrical machinery		0.711	0.124	0.587	Germany	44.9
Non-electrical machinery		0.441	0.221	0.221	Germany	49.6
Fabricated metal		0.383	0.252	0.131	Germany	50.2
Transport	1983	1.143	0.209	0.933	Germany	56.2
Instruments		0.654	0.235	0.419	Germany	48.7
Electrical machinery		0.650	0.080	0.570	Germany	41.4
Fabricated metal		0.492	0.251	0.241	Germany	58.8
Non-electrical machinery		0.364	0.151	0.212	Germany	53.4
Transport	1988	1.226	0.198	1.028	Germany	57.2
Instruments		0.711	0.276	0.435	Germany	47.4
Electrical machinery		0.623	0.095	0.528	Germany	45.5
Chemicals		0.493	0.092	0.400	Germany	51.0
Non-electrical machinery		0.423	0.140	0.283	Germany	52.4
Transport	1994	2.213	0.314	1.899	Germany	53.9
Instruments		1.221	0.525	0.696	Germany	37.4
Electrical machinery		1.020	0.112	0.908	Germany	40.2
Non-electrical machinery		0.836	0.304	0.531	Germany	45.5
Chemicals		0.611	0.132	0.479	Germany	48.9

Table 5 R&D performance and technology use

Performers	Year	Share 1	Users	Year	Share 2
Chemicals	1976	25.8	Other services	1976	22.5
Electrical machinery		16.9	Construction		9.7
Non-electrical machinery		11.9	Electrical machinery		8.3
Transport		8.1	Chemicals		7.7
Basic metal		2.9	Transport		6.8
Electrical machinery	1983	34.7	Other services	1983	24.5
Chemicals		19.2	Electrical machinery		8.4
Non-electrical machinery		16.3	Construction		8.0
Transport		11.0	Chemicals		7.6
Basic metal		2.9	Transport		7.2
Electrical machinery	1988	40.0	Other services	1988	28.3
Chemicals		18.9	Construction		8.2
Non-electrical machinery		14.5	Chemicals		8.0
Transport		11.9	Electrical machinery		7.9
Stone, clay and glass		2.0	Transport and storage		7.1
Electrical machinery	1994	47.9	Other services	1994	28.9
Chemicals		20.3	Transport and storage		10.2
Non-electrical machinery		10.6	Transport		9.8
Transport		7.9	Electrical machinery		9.2
Fabricated Metal		4.9	Construction		7.9

Source: WIFO

Performers include manufacturing sectors only

Share 1: Share in total manufacturing R&D

Share 2: Share in total acquired tachnology

Figure 12

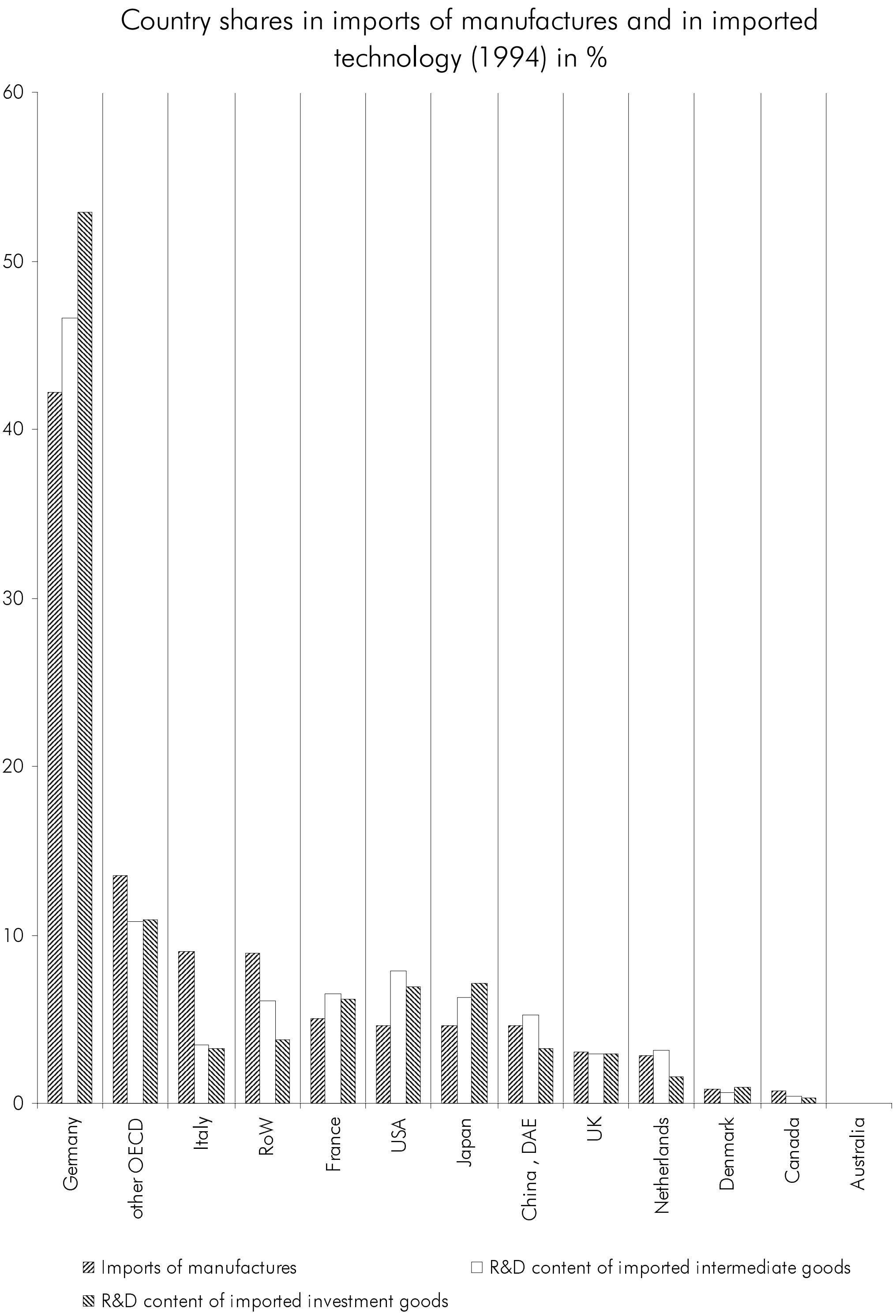

Country shares in imports of manufactures and in imported technology (1994) in %
60
50
40
30
20
10
0
Germany
other OECD
Italy
RoW
France
USA
Japan
China , DAE
UK
Netherlands
Denmark
Canada
Australia
Imports of manufactures
R&D content of imported intermediate goods
R&D content of imported investment goods

Table 6 Shares of acquired technology from source clusters in %, 1976

Industry	Source cluster					
	Information	Transportation	Consumer goods	Materials	Fabrication	Total
Primary sector	1.27	1.49	0.15	2.67	1.49	7.07
Agriculture, forestry and fishing	0.96	0.96	0.14	2.21	0.86	5.13
Mining	0.32	0.52	0.00	0.46	0.63	1.93
Manufacturing sector	12.09	7.05	0.58	23.08	5.39	48.20
Food and tobacco	0.34	0.39	0.11	2.19	0.62	3.64
Textile and leather	0.14	0.22	0.26	1.74	0.27	2.63
Wood and furniture	0.28	0.33	0.05	1.08	0.31	2.04
Paper and printing	0.41	0.14	0.02	0.99	0.30	1.87
Chemicals	0.45	0.47	0.05	6.00	0.80	7.76
Stone, clay and glass	0.32	0.17	0.01	1.00	0.34	1.85
Basic metal	0.44	0.18	0.01	2.17	0.49	3.29
Fabricted metal	0.87	0.31	0.02	2.74	0.58	4.53
Non-electrical machinery	1.38	0.39	0.01	1.96	0.57	4.31
Electrical machinery	6.08	0.22	0.01	1.68	0.33	8.33
Transport	1.06	3.85	0.02	1.30	0.54	6.77
Instruments	0.33	0.38	0.00	0.22	0.24	1.17
Service sector	11.92	9.09	0.55	17.81	5.37	44.73
Electricity, gas and water	1.62	0.95	0.02	1.16	0.89	4.63
Construction	2.47	1.40	0.03	4.74	1.14	9.78
Other services	5.17	4.44	0.46	9.77	2.77	22.61
Transport and storage	2.33	1.68	0.03	1.96	0.45	6.45
Communication	0.33	0.62	0.01	0.19	0.12	1.26
Total	25.29	17.63	1.28	43.56	12.24	100.00

Source: WIFO

Table 7 Shares of acquired technology from source clusters in %, 1983

Industry	Source cluster					
	Information	Transportation	Consumer goods	Materials	Fabrication	Total
Primary sector	1.77	0.93	0.15	1.99	1.47	6.32
Agriculture, forestry and fishing	1.57	0.78	0.15	1.67	1.16	5.33
Mining	0.21	0.15	0.00	0.33	0.31	0.99
Manufacturing sector	14.34	6.83	0.53	18.12	7.74	47.56
Food and tobacco	0.63	0.54	0.11	1.68	0.95	3.90
Textile and leather	0.23	0.14	0.25	1.20	0.39	2.20
Wood and furniture	0.35	0.28	0.04	0.81	0.50	1.97
Paper and printing	0.76	0.16	0.02	0.94	0.64	2.51
Chemicals	0.60	0.30	0.04	5.78	0.85	7.57
Stone, clay and glass	0.43	0.23	0.01	0.78	0.37	1.82
Basic metal	0.66	0.16	0.01	1.60	0.60	3.04
Fabricted metal	0.90	0.31	0.02	1.55	0.98	3.75
Non-electrical machinery	1.80	0.54	0.01	1.35	1.01	4.71
Electrical machinery	6.57	0.22	0.01	1.17	0.44	8.41
Transport	1.16	3.93	0.02	1.10	0.96	7.17
Instruments	0.25	0.02	0.00	0.17	0.05	0.50
Service sector	14.49	10.09	0.58	13.92	7.05	46.12
Electricity, gas and water	2.82	0.82	0.01	0.76	0.64	5.05
Construction	2.35	0.85	0.03	3.34	1.43	7.99
Other services	7.12	4.60	0.51	7.97	4.31	24.51
Transport and storage	1.23	2.70	0.03	1.72	0.59	6.26
Communication	0.97	1.13	0.00	0.14	0.06	2.31
Total	30.60	17.85	1.26	34.04	16.26	100.00

Source: WIFO

Table 8 Shares of acquired technology from source clusters in %, 1988

Industry	Source cluster					
	Information	Transportation	Consumer goods	Materials	Fabrication	Total
Primary sector	1.37	0.61	0.07	1.36	1.19	4.60
Agriculture, forestry and fishing	1.20	0.50	0.07	1.11	0.99	3.87
Mining	0.17	0.11	0.00	0.25	0.20	0.74
Manufacturing sector	13.61	6.64	0.46	17.68	7.55	45.93
Food and tobacco	0.78	0.51	0.13	1.53	1.15	4.11
Textile and leather	0.22	0.13	0.16	1.15	0.42	2.08
Wood and furniture	0.46	0.26	0.03	0.87	0.59	2.21
Paper and printing	0.79	0.18	0.02	1.00	0.60	2.60
Chemicals	0.85	0.32	0.03	5.75	1.06	8.01
Stone, clay and glass	0.57	0.22	0.01	0.80	0.48	2.08
Basic metal	0.72	0.13	0.01	1.51	0.50	2.85
Fabricted metal	0.82	0.19	0.01	1.15	0.71	2.87
Non-electrical machinery	1.77	0.62	0.01	1.10	0.84	4.34
Electrical machinery	5.41	0.17	0.02	1.80	0.49	7.89
Transport	1.06	3.89	0.01	0.81	0.67	6.45
Instruments	0.16	0.02	0.00	0.20	0.05	0.43
Service sector	16.11	9.33	0.56	15.57	7.89	49.47
Electricity, gas and water	2.39	0.23	0.01	0.44	0.46	3.53
Construction	2.76	0.78	0.03	3.30	1.33	8.21
Other services	8.05	4.27	0.50	10.27	5.25	28.34
Transport and storage	1.32	3.54	0.03	1.46	0.79	7.13
Communication	1.59	0.51	0.00	0.10	0.06	2.26
Total	31.09	16.58	1.10	34.60	16.63	100.00

Source: WIFO

Table 9 Shares of acquired technology from source clusters in %, 1994

Industry	Source cluster					
	Information	Transportation	Consumer goods	Materials	Fabrication	Total
Primary sector	1.21	0.24	0.06	0.83	0.65	3.00
Agriculture, forestry and fishing	1.01	0.18	0.06	0.64	0.52	2.41
Mining	0.20	0.06	0.00	0.19	0.13	0.59
Manufacturing sector	18.02	8.71	0.49	12.97	5.25	45.44
Food and tobacco	1.06	0.28	0.14	0.92	0.74	3.14
Textile and leather	0.24	0.05	0.11	0.68	0.18	1.26
Wood and furniture	0.59	0.13	0.04	0.65	0.38	1.79
Paper and printing	1.04	0.11	0.02	0.72	0.38	2.28
Chemicals	0.91	0.16	0.04	4.25	0.59	5.96
Stone, clay and glass	0.62	0.12	0.01	0.59	0.31	1.65
Basic metal	0.68	0.06	0.01	1.09	0.27	2.11
Fabricted metal	0.86	0.09	0.01	0.63	0.45	2.03
Non-electrical machinery	3.13	0.74	0.02	0.91	0.86	5.66
Electrical machinery	7.13	0.14	0.04	1.49	0.42	9.22
Transport	1.50	6.82	0.02	0.86	0.64	9.85
Instruments	0.26	0.01	0.01	0.18	0.04	0.50
Service sector	24.25	8.25	0.67	10.55	7.84	51.56
Electricity, gas and water	2.10	0.15	0.01	0.28	0.28	2.83
Construction	4.01	0.54	0.03	2.23	1.12	7.93
Other services	13.76	3.08	0.56	6.64	4.93	28.97
Transport and storage	3.33	4.08	0.06	1.32	1.47	10.25
Communication	1.04	0.40	0.01	0.08	0.04	1.58
Total	43.48	17.21	1.22	24.35	13.75	100.00

Source: WIFO

Table 10 Absolute changes in shares of acquired technology from source clusters between 1976 and 1994

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	-0.06	-1.25	-0.08	-1.84	-0.84
Agriculture, forestry and fishing	0.05	-0.79	-0.08	-1.56	-0.34
Mining					
Manufacturing sector	5.92	1.66	-0.10	-10.11	-0.14
Food and tobacco	0.72	-0.11	0.03	-1.27	0.12
Textile and leather	0.10	-0.17	-0.15	-1.06	-0.09
Wood and furniture	0.32	-0.19	-0.01	-0.43	0.07
Paper and printing	0.63	-0.03	0.00	-0.27	0.08
Chemicals	0.47	-0.31	-0.01	-1.75	-0.21
Stone, clay and glass	0.30	-0.05	0.00	-0.41	-0.04
Basic metal	0.24	-0.12	0.00	-1.08	-0.22
Fabricted metal	-0.01	-0.22	-0.01	-2.12	-0.14
Non-electrical machinery	1.75	0.35	0.01	-1.05	0.30
Electrical machinery	1.04	-0.08	0.03	-0.19	0.08
Transport	0.45	2.96	0.01	-0.44	0.10
Instruments	-0.07	-0.37	0.00	-0.04	-0.19
Service sector	12.33	-0.84	0.12	-7.26	2.48
Electricity, gas and water	0.48	-0.80	-0.01	-0.88	-0.61
Construction	1.54	-0.86	0.00	-2.51	-0.02
Other services	8.60	-1.36	0.09	-3.13	2.16
Transport and storage	1.00	2.39	0.03	-0.64	1.02
Communication	0.71	-0.21	0.00	-0.11	-0.08

Source: WIFO

Table 11 Shares of acquired technology from source clusters in %, 1976

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	5.04	8.44	11.63	6.13	12.13
Agriculture, forestry and fishing	3.79	5.46	11.29	5.06	7.02
Mining	1.25	2.97	0.34	1.07	5.11
Manufacturing sector	47.83	40.00	45.58	52.98	44.03
Food and tobacco	1.34	2.22	8.64	5.02	5.03
Textile and leather	0.56	1.24	20.27	4.00	2.19
Wood and furniture	1.09	1.84	3.99	2.49	2.49
Paper and printing	1.62	0.81	1.88	2.28	2.45
Chemicals	1.77	2.66	3.82	13.77	6.53
Stone, clay and glass	1.28	0.97	0.68	2.31	2.82
Basic metal	1.73	1.01	1.13	4.97	4.01
Fabricted metal	3.45	1.77	1.47	6.30	4.77
Non-electrical machinery	5.47	2.19	1.04	4.50	4.63
Electrical machinery	24.06	1.26	0.95	3.85	2.73
Transport	4.18	21.86	1.45	2.99	4.42
Instruments	1.29	2.17	0.25	0.50	1.95
Service sector	47.13	51.56	42.79	40.89	43.84
Electricity, gas and water	6.40	5.37	1.22	2.67	7.29
Construction	9.77	7.95	2.53	10.87	9.29
Other services	20.43	25.21	36.37	22.42	22.62
Transport and storage	9.22	9.54	2.23	4.50	3.66
Communication	1.31	3.49	0.44	0.44	0.99
Total	100.00	100.00	100.00	100.00	100.00

Source: WIFO

Table 12 Shares of acquired technology from source clusters in %, 1983

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	5.80	5.22	11.77	5.85	9.05
Agriculture, forestry and fishing	5.12	4.39	11.54	4.89	7.15
Mining	0.67	0.83	0.23	0.96	1.90
Manufacturing sector	46.86	38.26	42.22	53.23	47.61
Food and tobacco	2.06	3.02	8.47	4.92	5.82
Textile and leather	0.74	0.78	19.82	3.52	2.40
Wood and furniture	1.13	1.56	3.41	2.38	3.05
Paper and printing	2.47	0.90	1.43	2.76	3.91
Chemicals	1.95	1.67	3.26	16.98	5.25
Stone, clay and glass	1.42	1.31	0.52	2.29	2.27
Basic metal	2.16	0.91	0.87	4.70	3.72
Fabricted metal	2.93	1.72	1.22	4.55	6.05
Non-electrical machinery	5.88	3.03	0.95	3.96	6.23
Electrical machinery	21.47	1.21	0.78	3.44	2.70
Transport	3.80	22.01	1.37	3.24	5.89
Instruments	0.83	0.13	0.13	0.50	0.32
Service sector	47.34	56.52	46.01	40.91	43.33
Electricity, gas and water	9.21	4.57	0.81	2.23	3.97
Construction	7.68	4.74	2.09	9.80	8.81
Other services	23.26	25.77	40.78	23.42	26.52
Transport and storage	4.01	15.10	2.01	5.06	3.66
Communication	3.18	6.33	0.32	0.41	0.38
Total	100.00	100.00	100.00	100.00	100.00

Source: WIFO

Table 13 Shares of acquired technology from source clusters in %, 1988

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	4.42	3.66	6.73	3.92	7.17
Agriculture, forestry and fishing	3.86	3.03	6.54	3.19	5.94
Mining	0.56	0.63	0.19	0.73	1.23
Manufacturing sector	43.76	40.04	41.80	51.08	45.42
Food and tobacco	2.52	3.10	11.98	4.44	6.92
Textile and leather	0.72	0.78	14.85	3.32	2.51
Wood and furniture	1.49	1.57	3.02	2.50	3.54
Paper and printing	2.54	1.11	1.78	2.90	3.64
Chemicals	2.74	1.92	3.07	16.61	6.35
Stone, clay and glass	1.82	1.30	0.75	2.32	2.91
Basic metal	2.31	0.76	0.70	4.36	2.99
Fabricted metal	2.64	1.12	1.00	3.33	4.25
Non-electrical machinery	5.69	3.74	1.02	3.18	5.05
Electrical machinery	17.38	1.03	2.13	5.20	2.96
Transport	3.41	23.50	1.20	2.35	4.01
Instruments	0.51	0.12	0.29	0.58	0.29
Service sector	51.82	56.30	51.47	45.00	47.42
Electricity, gas and water	7.70	1.40	0.70	1.26	2.79
Construction	8.89	4.73	2.32	9.54	8.01
Other services	25.89	25.75	45.48	29.69	31.54
Transport and storage	4.24	21.36	2.62	4.22	4.73
Communication	5.11	3.07	0.34	0.28	0.34
Total	100.00	100.00	100.00	100.00	100.00

Source: WIFO

Table 14 Shares of acquired technology from source clusters in %, 1994

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	2.79	1.40	5.31	3.40	4.72
Agriculture, forestry and fishing	2.33	1.03	5.05	2.63	3.76
Mining	0.46	0.37	0.26	0.77	0.96
Manufacturing sector	41.44	50.63	40.03	53.27	38.21
Food and tobacco	2.43	1.64	11.82	3.79	5.37
Textile and leather	0.54	0.29	9.27	2.80	1.29
Wood and furniture	1.36	0.76	3.27	2.67	2.73
Paper and printing	2.39	0.65	2.01	2.97	2.75
Chemicals	2.10	0.95	3.21	17.45	4.32
Stone, clay and glass	1.43	0.67	0.93	2.44	2.22
Basic metal	1.56	0.36	0.79	4.46	1.99
Fabricted metal	1.98	0.51	0.96	2.58	3.25
Non-electrical machinery	7.19	4.30	1.60	3.73	6.28
Electrical machinery	16.39	0.81	3.69	6.11	3.02
Transport	3.45	39.62	2.01	3.55	4.67
Instruments	0.60	0.07	0.47	0.73	0.31
Service sector	55.77	47.96	54.67	43.33	57.07
Electricity, gas and water	4.83	0.88	0.80	1.17	2.05
Construction	9.23	3.15	2.86	9.14	8.14
Other services	31.66	17.91	45.62	27.26	35.85
Transport and storage	7.66	23.68	4.74	5.41	10.71
Communication	2.39	2.34	0.64	0.34	0.32
Total	100.00	100.00	100.00	100.00	100.00

Source: WIFO

Table 15 Absolute changes in shares of acquired technology from source clusters between 1976 and 1994

Industry	Source cluster				
	Information	Transportation	Consumer goods	Materials	Fabrication
Primary sector	-2.25	-7.03	-6.32	-2.73	-7.42
Agriculture, forestry and fishing	-1.46	-4.43	-6.24	-2.43	-3.26
Mining					
Manufacturing sector	-6.39	10.64	-5.55	0.29	-5.81
Food and tobacco	1.09	-0.58	3.17	-1.23	0.34
Textile and leather	-0.01	-0.95	-11.00	-1.20	-0.90
Wood and furniture	0.27	-1.09	-0.71	0.18	0.24
Paper and printing	0.77	-0.16	0.12	0.69	0.30
Chemicals	0.34	-1.71	-0.61	3.69	-2.21
Stone, clay and glass	0.15	-0.29	0.25	0.13	-0.59
Basic metal	-0.17	-0.65	-0.34	-0.51	-2.03
Fabricted metal	-1.47	-1.26	-0.51	-3.72	-1.52
Non-electrical machinery	1.73	2.11	0.56	-0.77	1.65
Electrical machinery	-7.67	-0.44	2.74	2.25	0.29
Transport	-0.72	17.76	0.57	0.56	0.25
Instruments	-0.70	-2.10	0.22	0.22	-1.63
Service sector	8.64	-3.60	11.87	2.44	13.23
Electricity, gas and water	-1.57	-4.49	-0.42	-1.50	-5.24
Construction	-0.54	-4.80	0.34	-1.73	-1.15
Other services	11.23	-7.30	9.25	4.85	13.23
Transport and storage	-1.57	14.14	2.50	0.92	7.05
Communication	1.08	-1.15	0.20	-0.10	-0.66

Source: WIFO

Figure 13

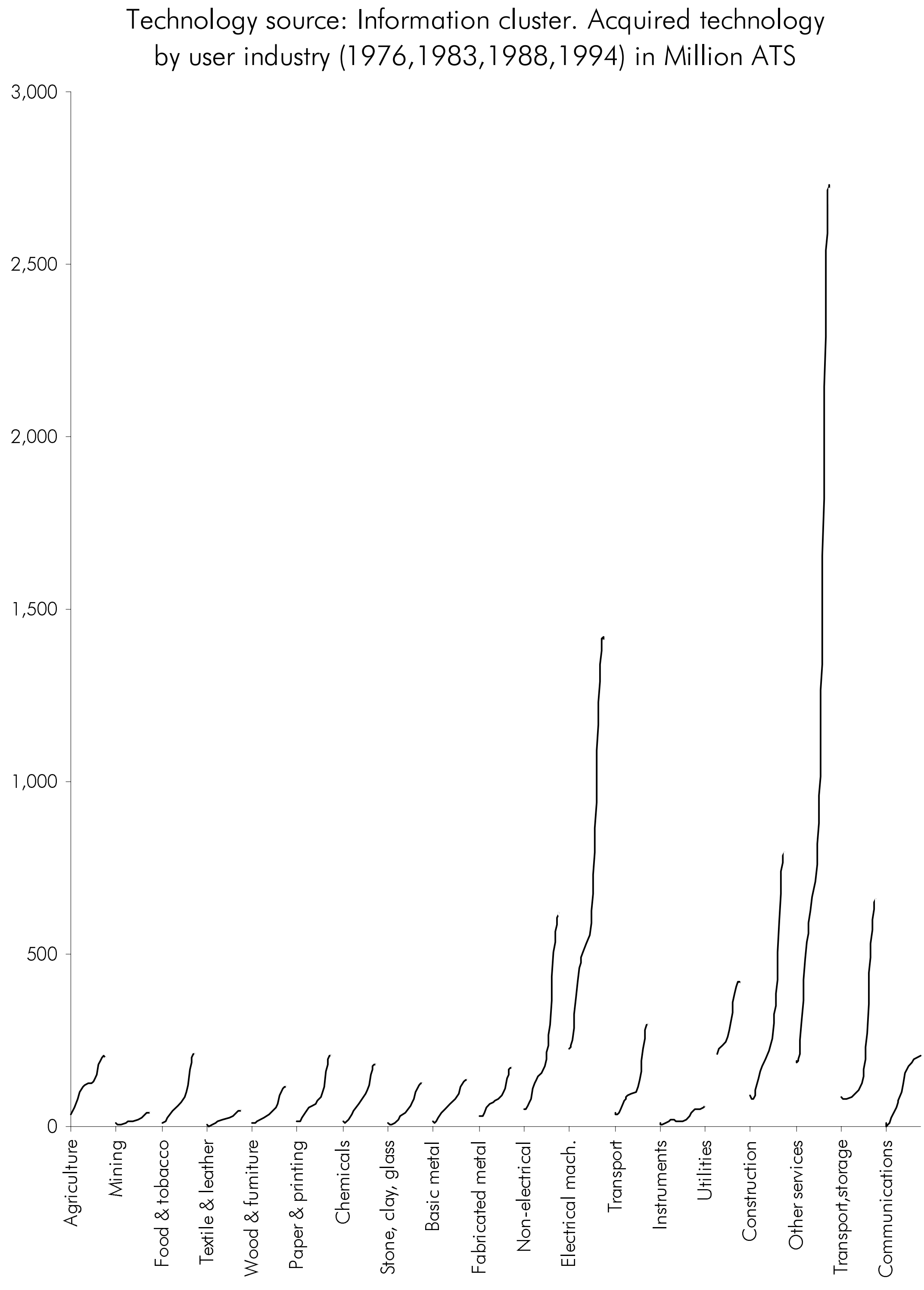

Technology source: Information cluster. Acquired technology by user industry (1976,1983,1988,1994) in Million ATS
3,000
2,500
2,000
1,500
1,000
500
0
Agriculture
Mining
Food & tobacco
Textile & leather
Wood & furniture
Paper & printing
Chemicals
Stone, clay, glass
Basic metal
Fabricated metal
Non-electrical
Electrical mach.
Transport
Instruments
Utilities
Construction
Other services
Transport,storage
Communications

Figure 14

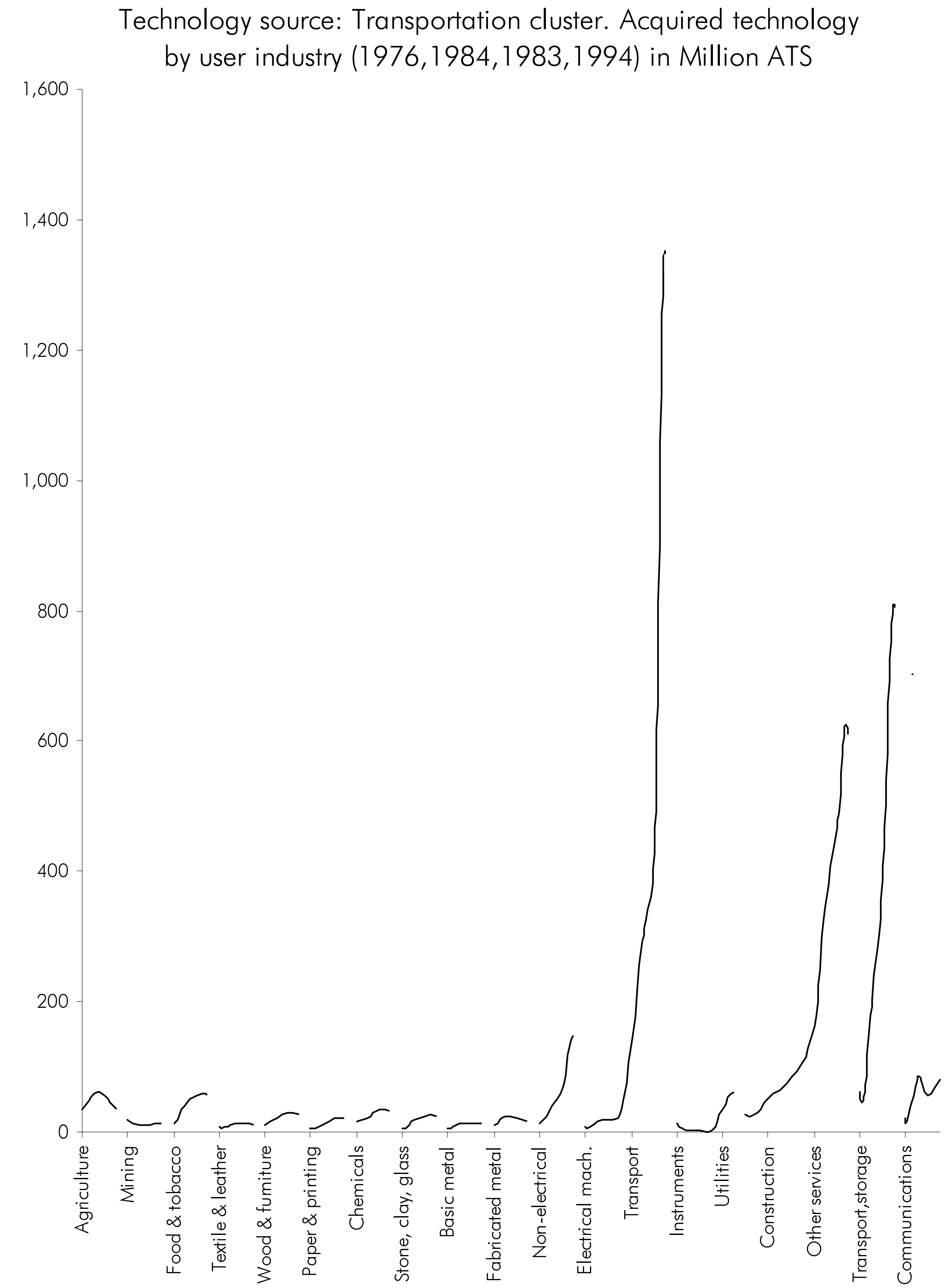

Technology source: Transportation cluster. Acquired technology by user industry (1976,1984,1983,1994) in Million ATS
1,600
1,400
1,200
1,000
800
600
400
200
0
Agriculture
Mining
Food & tobacco
Textile & leather
Wood & furniture
Paper & printing
Chemicals
Stone, clay, glass
Basic metal
Fabricated metal
Non-electrical
Electrical mach.
Transport
Instruments
Utilities
Construction
Other services
Transport,storage
Communications

Figure 15

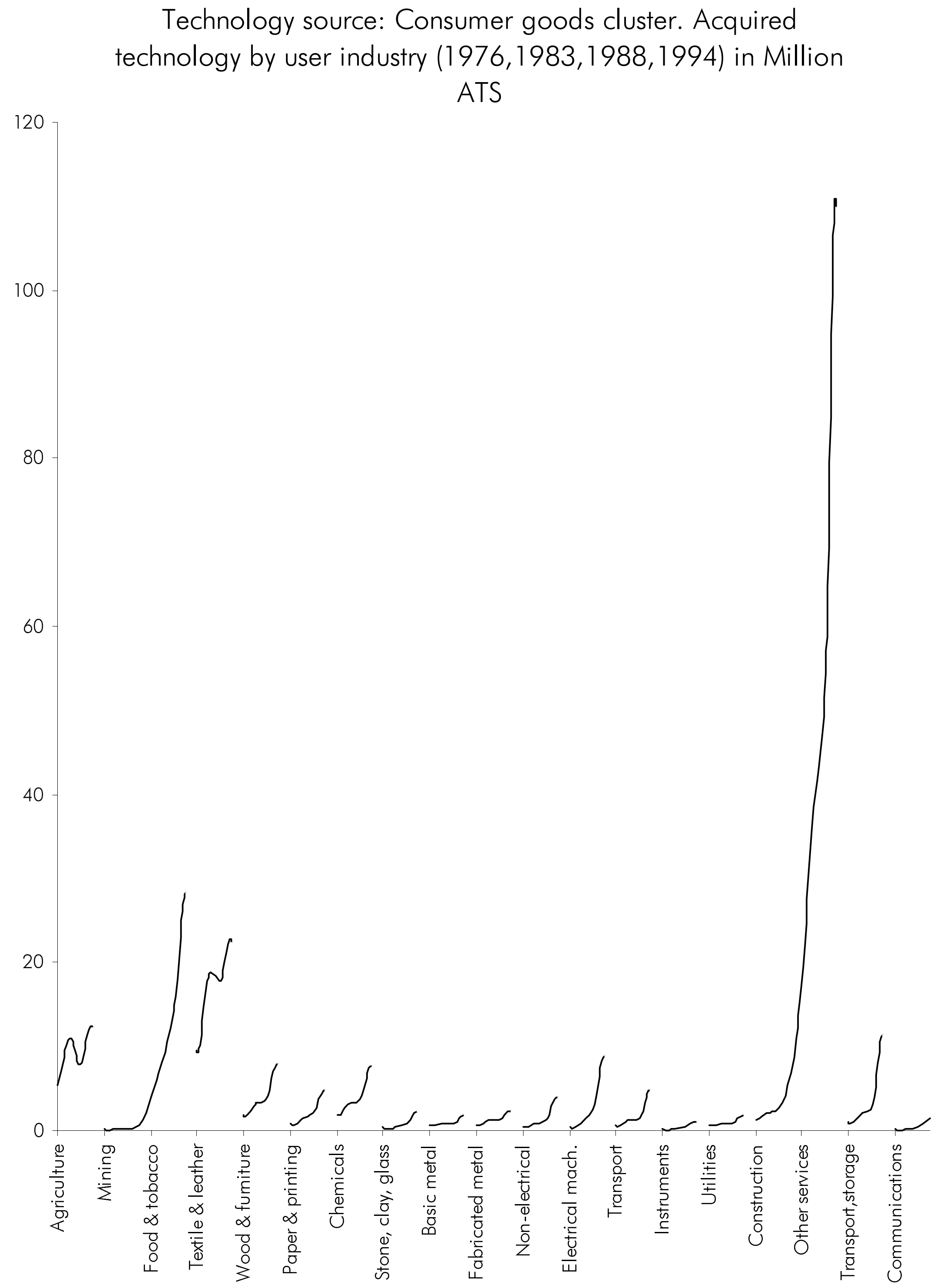

Technology source: Consumer goods cluster. Acquired technology by user industry (1976,1983,1988,1994) in Million ATS
120
100
80
60
40
20
0
Agriculture
Mining
Food & tobacco
Textile & leather
Wood & furniture
Paper & printing
Chemicals
Stone, clay, glass
Basic metal
Fabricated metal
Non-electrical
Electrical mach.
Transport
Instruments
Utilities
Construction
Other services
Transport,storage
Communications

Figure 16

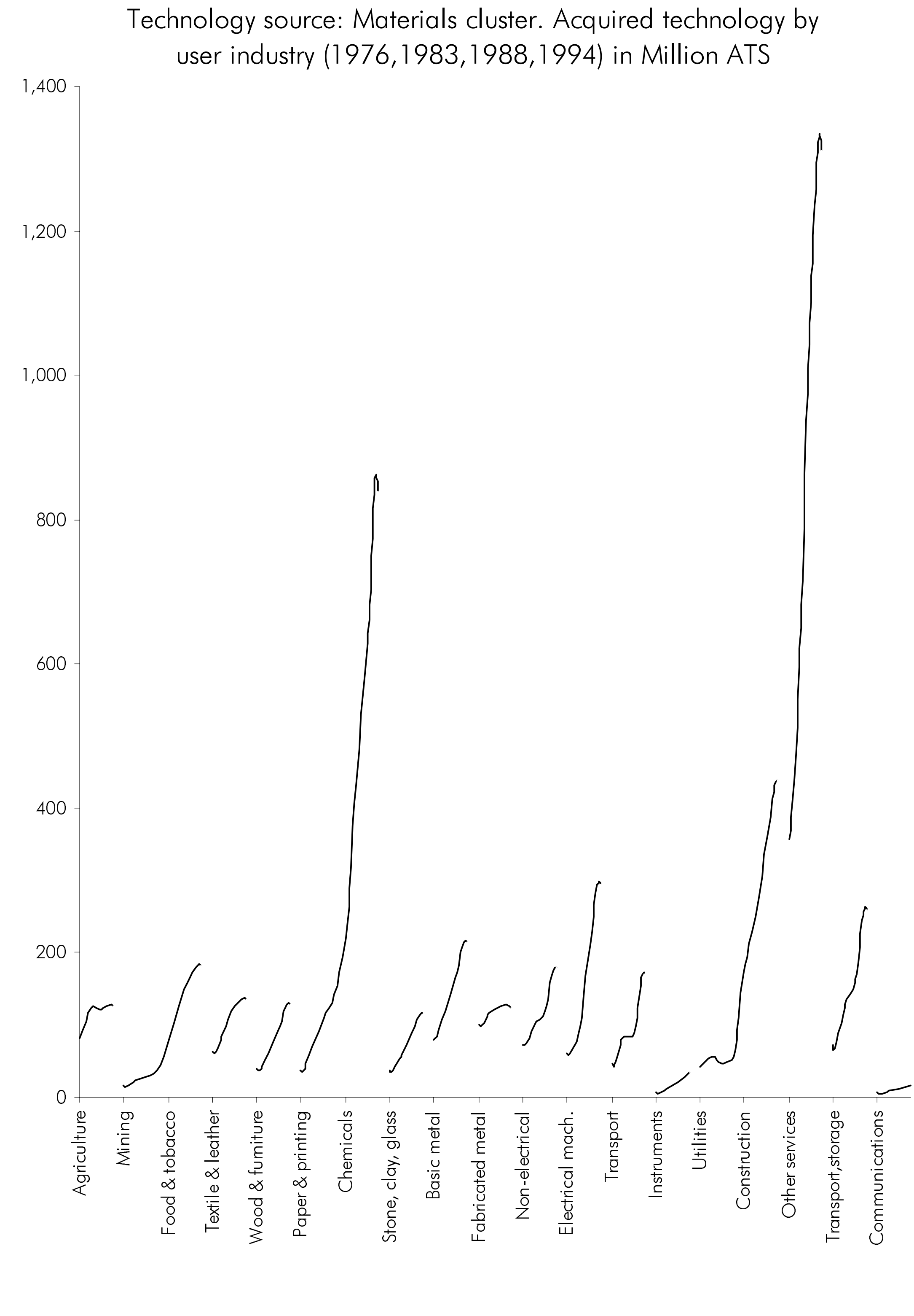
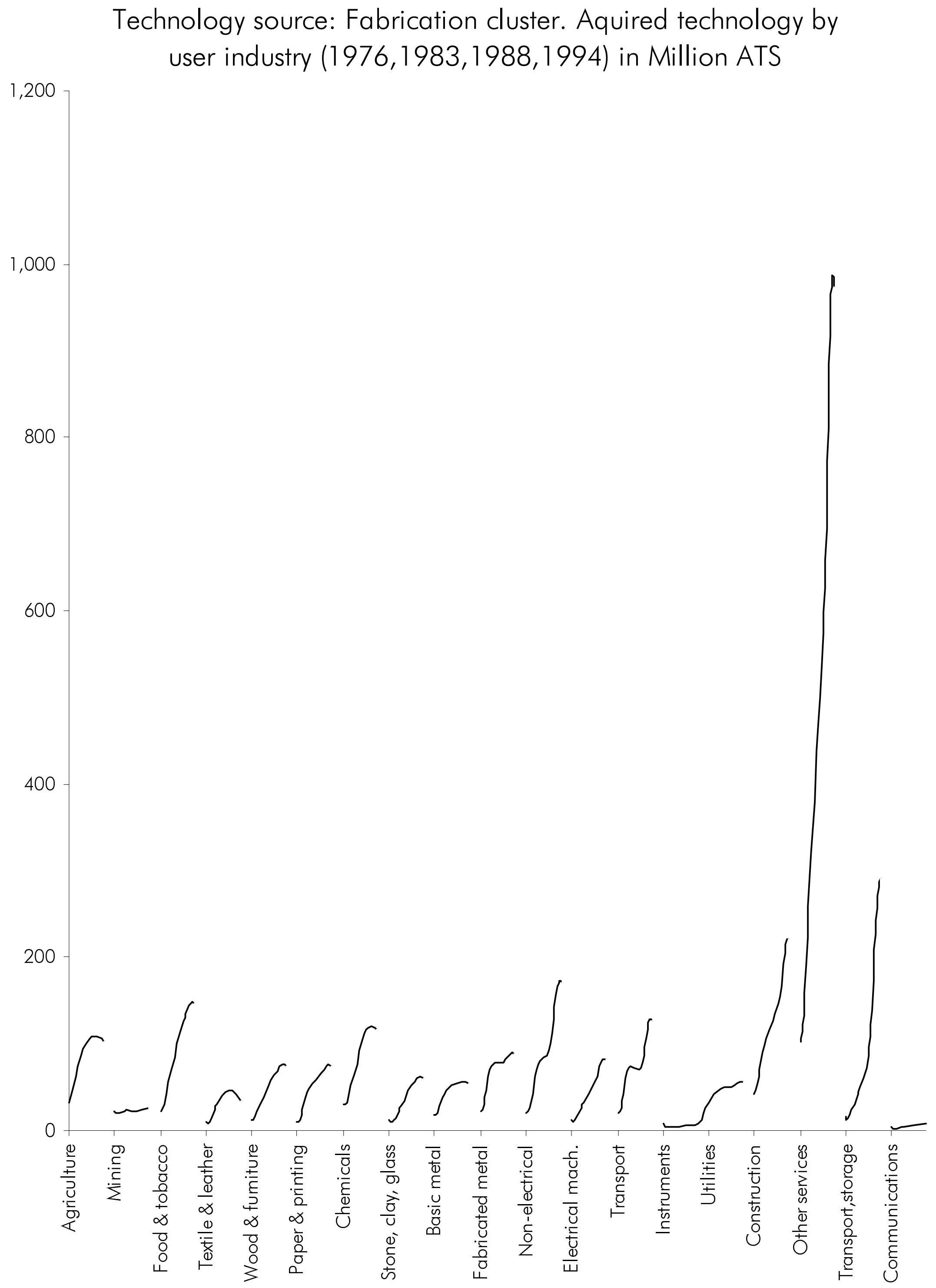

Technology source: Materials cluster. Acquired technology by user industry (1976,1983,1988,1994) in Million ATS
1,400
1,200
1,000
800
600
400
200
0
Agriculture
Mining
Food & tobacco
Textile & leather
Wood & furniture
Paper & printing
Chemicals
Stone, clay, glass
Basic metal
Fabricated metal
Non-electrical
Electrical mach.
Transport
Instruments
Utilities
Construction
Other services
Transport,storage
Communications

Figure 17


Technology source: Fabrication cluster. Aquired technology by user industry (1976,1983,1988,1994) in Million ATS
1,200
1,000
800
600
400
200
0
Agriculture
Mining
Food & tobacco
Textile & leather
Wood & furniture
Paper & printing
Chemicals
Stone, clay, glass
Basic metal
Fabricated metal
Non-electrical
Electrical mach.
Transport
Instruments
Utilities
Construction
Other services
Transport,storage
Communications

Medieninhaber (Verleger), Herausgeber: Österreichisches Institut für Wirtschaftsforschung • Hersteller: Österreichisches Forschungszentrum Seibersdorf Ges.m.b.H., A-2444 Seibersdorf, Tel. +43 2254 780-0, Fax +43 2254 780/3888, http://www.arcs.at, E-Mail: seibersdorf@arcs.ac.at • Verlags- und Herstellungsort: Seibersdorf

Satz und Druck: Österreichisches Forschungszentrum Seibersdorf

Verkaufspreis: ATS 500,00 bzw. EUR 36,34