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PROBLEMS RELATED TO THE TRANSFER OF TECHNOLOGY IN THE MINING SECTOR WITH SPECIAL REFERENCE TO FINLAND

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ABSTRACT: Studies concerning the transfer of technology in the mining sector have been quite few traditionally as compared with studies on the development impact of the mining sector in general. In this study, the case of Finland is dealt with, with special reference to the period 1918-1939 when Finland was a kind of a newly industrializing country in Europe.

Finland was an experimental field for large-scale applications of electro-metallurgical technology in the copper, nickel, iron and steel industry. Both domestic companies and International Nickel Co., which operated in Finland in the late 1930s, applied this technology that was transferred from Norway. This transfer of technology was successful and, later on, the Finnish example was followed in Sweden and Canada.

Since domestic hydropower resources in Finland are quite limited from an international perspective, electro-metallurgical technology was not, however, appropriate taking into consideration the long-term structural constraints of the energy supply in the country. An acute shortage of energy characterized the postwar situation in Finland in the late 1940s. That is why new energy-saving smelting methods were developed. Later on, Finland has become an important manufacturer and exporter of mining machinery and equipment and metallurgical knowhow all over the world.

Finally, it is proposed that studies concerning the transfer of the Finnish mining technology and metallurgical knowhow to the contemporary NIC-countries, such as South Korea, India, Mexico and Brazil should be undertaken.

KEY WORDS: Mining sector, transfer of technology, NIC-countries, electro-metallurgical technology, Finland.

## Preface

This is the third paper related to the research project "The Rise of Autonomous Technological Capability in the Mining Sector in Finland with Special Reference to the Copper Sector" under the auspices of the Research Institute of the Finnish Economy (ETLA). The first paper "Kaivos - ja metallituotteiden maailmantalous" (The world economy and mining and metallurgical products) and the second one "The Role of Education in the Development of the Mining Sector in Finland" have been published as ETLA Discussion Papers No 211, 18.06.1986 40 p. and No 219, 04.12.1986 83 p.

# PROBLEMS RELATED TO THE TRANSFER OF TECHNOLOGY IN THE MINING SECTOR WITH SPECIAL REFERENCE TO FINLAND

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Contents



A study based on the paper presented in the symposium "Problems of Mineral-Based Industrialization with Special Reference to the Transfer of Technology" at the University of Helsinki Institute of Development Studies, June 10, 1987. Will be printed in the publication based on the papers of the symposium edited by Jussi Raumolin and Lauri Siitonen, Publications of the University Helsinki Institute of Development Studies: Report 16. Series B in autumn 1988.

## 1. Introduction

This study is related to my former studies on the development of domestic technological capability in Finland during the industrialization as seen from an international perspective. The main focus in these studies has been on the forest sector and the mining sector, which have been and still are important resource-based export sectors in the country (cf. Raumolin 1982, 1984a, 1984b, 1985, 1986b, 1988).

It is of course, hoped for that these studies would have some relevance as regards the international discussion on peripheral resource-based industrialization especially taking into consideration the specific and divergent development path in Finland.

In this context I shall concentrate on the Finnish case during the interwar period of 1918-1939. Finland was a kind of a newly industrializing country at that time. Since I have dealt with the development of geological research and education in the mining sector in another study the main emphasis in this study is in the development of the mining and metallurgical industries. Especially the introduction of electro-metallurgical technology in Finland in the 1930s will be dealt with (cf. Raumolin 1986b).

## 2. Theoretical Background

Such general models as diffusion or dependency models have been used in the studies of the transfer of technology. According to the diffusion model, the spread of technology on the globe is quite a natural process whereas the dependency model emphasizes many obstacles to the spread of technology (cf. Rosenberg 1976, 1982, Ray 1984, Madeuf 1981).

These studies have mainly dealt with the role of enterprises, especially multinational enterprises in the transfer of technology. Such issues as the role of the education system, the interaction between the universities and enterprises or the learning process among the workers have been only marginally touched upon.

After the efforts towards generalization on the global level, the focus in the development studies has been shifted to studies on national development paths in the 1980s. Only after the national development paths are better known will new fruitful generalizations be possible.

In this study, the key issues that will be dealt with are the role of the state the interaction between domestic and foreign factors, reasons for the success or failure of the transfer of technology, and the appropriateness of foreign technology. Similar questions are typical in the studies on the transfer of technology. A closer consideration of the key issues in question will be given in the next section dealing with some case studies on the transfer of technology in the mining sector.

## 3. Some Case Studies

Historical studies on economic development distinguish between three different development zones in the world according to conventional classifications based on the international division of labour: the industrialized centre, the peripheries of the industrialized West and the peripheral developing countries.

Turning to the centre, the historical studies on the spread of the mining and metallurgical technology have concentrated heavily on the study of the iron and steel industry because of the major importance of this industry for the industrialization. Instead marginal attention has been paid to the spread of technology in the non-ferrous metal industry. In the same manner as the existence of many lags has characterized the spread of the non-ferrous metallurgy there are several gaps in the research (cf. Fremdling 1982, OECD, Gaps ... 1969).

As concerns the peripheries of the West, such as Canada, the Nordic countries and Japan, the state of research is quite uneven. One of the founders of the Canadian variant of the staple theory, Harold A. Innis created a good basis for studies on the development of the mining industry in Canada already in the 1930s. In his view, the rapid rise of the mining industry in a marginal country like Canada took place by means of a massive importation of foreign technology. Recent Canadian studies such as Robert Armstrong's study on the development of the asbestos industry in Quebec and Alexander Dow's study of the development of the non-ferrous metal industry in general have resulted in a more balanced view of the interaction between the foreign and the domestic factors (cf. Innis 1936, 1941, Armstrong 1985, Dow 1985).

It is surprising that in the Nordic countris, where studies on economic history are so advanced, almost nothing has been written about the role of the mining sector and the transfer of technology from the perspective of development studies. It is maybe so that a highly sophisticated treatment of economic history and an open study of development do not fit well together. In any case Sweden has strong traditions in the mining industry and the research and development in metallurgical processes: it has long been close to the European industrial centre. Furthermore active research and development of electro-metallurgical processes has taken place in Norway during this century. The Finnish case is dealt with in this study.

As far as the Japanese case is concerned, the historical development path is quite well known thanks to the project "Historical Background of Technology Transfer Transformation and Development of Japan" undertaken under the auspices of the Unites Nations University during the late 1970s. I shall have a closer look on the Japanese case a little later (cf. Hayashi 1979).

Following the example of the industrialized West, special attention has been paid to the transfer of technology in the iron and steel industry in the peripheral developing countries. For instance UNIDO and the scholars associated with Le Centre de Recherche sur l'Industrialisation et le Développement de l'Université de Grenoble (I.R.E.P.) have dealt with these issues (cf. Roberts & Perrin 1975, Judet 1980).

Instead, the transfer of technology in the non-ferrous mining and metal industry is largely unknown. Concerning Latin America, such organizations as the Andean Group, Junta del Acuerdo de Cartagena and the International Development Research Centre in Ottawa have promoted studies on the technology transfer in the copper industry, for example. The British scholar John T. Thoburn has dealt with these problems in the case of the tin industry in Malaysia (cf. Mytelka 1978, Warhulst 1985, Thoburn 1973).

In Africa, Robert E. Baldwin touched upon these problems in his classic study on the copper industry in Rhodesia (cf. Baldwin 1963). Recently the Belgian scholar Jean-Claude Willame has published an impressive study on the problem associated with the transfer of Western industrial technology to Zaire, which has included the building of many "cathedrales de désert" (cf. Willame 1986).

Generally seen there is no synthetical study on the transfer of technology in the mining sector in the developing countries. This question is only marginally dealt with in most of the general, regional or sectoral studies mining-based development in the developing countries (cf. Metzer 1980, o'Faircheallaigh 1984, Yachir 1987).

In the following, I shall take a closer look at two cases: the results of the Japanese project "Historical Background of Technology Transfer, Transformation and Development of Japan" with special reference to the mining sector and the views of the scholary associated with Le Centre de Recherche, sur l'Industrialisation et le Développement de l'Université de Grenoble (I.R.E.P.).

The Japanese study clearly points out that there were strong national traditions in the copper industry and in the iron production in Japan. When industrialization started, these traditions were both an advantage and an obstacle. For instance the traditional organization of labour was a great obstacle (cf. Hoshino 1982, Iida 1979, Murakushi 1979, Yoshiki 1979).

The role of the Japanese state has been very active in the development of the mining and metal industries since the beginning of the industrialization of the country. Military interests were heavily involved, the state sent students abroad to have well educated experts at its disposal in the future, domestic education was promoted as well and several industrial expositions were organized to spread the information on Western technology. Japanise scholars were, however, looking for appropriate solutions to the national conditions instead of slavishly imitating the technology developed in the West.

The role of cultural factors, such as nationalism and national self-respect, played an important role in the transfer of technology. Japan followed a kind of intelligent followers' strategy by selectively opening itself to Western influences while integrating foreign acquistions with national development aims.

The scholars associated with Le Centre de Recherche sur l'Industrialisation et le Développement de l'Université de

Grenoble (I.R.E.P.) have undertaken pioneering studies on the role of the consulting engineering in the industrialization process. They have made an effort to relate the history of the European industrialization to the industrialization of the developing countries. As far as the mining sector is concerned they have paid special attention to the role of the steel industry (cf. Perrin 1977).

The stress the key role of consulting engineering in their studies. Creative development often takes place by dialectics of internal and external factors. The role of the state is always important in the successful cases of the transfer of technology and learning by doing is important in the spread of technology. They have paid special attention to the industrialization of the so-called newly industrializing countries (NIC), such as South Korea, Taiwan, India, Brazil and Mexico. Ultimately, their studies have led to a re-evaluation of industrialization process on the globe (cf. Judet 1981 Perrin, 1983, Courlet & Judet 1986).

This selection of examples perhaps reflects my bias toward development studies. It is clear that the Japanese case and the studies by Judet and Perrin are more relevant for the Finnish case than for the African case, for instance.

## 4. The Finnish Case

### 4.1. The Background

After Finland gained independence in 1917, an active policy of promoting economic development started in the country. Special attention was paid to the mobilization of domestic natural resources to economic expansion. An advance of industrialization was evident during the interwar years 1918-1939. Finland belonged to the group of countries which were called the newly industrializing countries by eminent German experts on the world economy.

The international environment for the mining and metal industries included both positive and negative trends vis-à-vis development prospects in a small peripheral economy. The strong upward cycle in the international markets in the late 1920s was soon followed by a long depression. New cores of the heavy steel industry started to develop in the Soviet Union and Japan, which challenged the dominating position of the West European and North American cores in the world economy, by and by (cf. Predöhl 1949).

After the Great European War, 1914-1918, large Western mining companies began to expand towards the South, to the African colonies and to Latin America in order to gain control of large deposits of non-ferrous metals in view of the expanding demand for metals in the industrialized West. Especially the large Anglo-American companies succeeded in gaining control of most of the available resources in the world. Instead a relative shortage situation prevailed in Germany, where the traditional mines were being exhausted, by and by and because Germany had lost its colonies. In the East, the Soviet Union started a centralized mobilization of considerable domestic non-ferrous metal deposits for an autarkic industrialization of the country (cf. Elliot et al. 1937, Avieny 1941).

The limited number of good deposits, the continuous increase in capital intensity of the production, the internationalization of the operations and strong fluctuations in the markets led to a movement of concentration and mergers in the copper and nickel industry in the West especially after the turn of the century. The most striking was the case of the nickel industry where the American-Canadian International Nickel company gained a quasi-monopoly in the market (cf. Schmitz 1986).

As far as technological trends are concerned, new furnace technology such as electrical furnaces facilitated the use of scrap as raw material in the iron and steel industry which made it possible to decentralize these industries from the dominance of the iron and coal fields. In the non-ferrous metal industry new mechanized machinery facilitated the extraction of metals. New flotation methods in concentration made possible a better utilization of various elements in ore bodies. New furnace technology made it possible to substitute electricity for coal. In addition, the erection of related chemical industry plants became profitable (cf. Parsons (ed.) 1947).

These new technologies were well accessible inside the industrialized West. It was always possible to practice studies abroad, scientific and technical publications circulated quite freely, the leading supplier industries were competing for the orders, consulting services and experise were available, and the transfer of the new technology could take place by means of direct investment as well.

The leading theorists of the world economy and the theorists of the space economy did not, however, see much chance of the peripheral countries building integrated iron and steel or non-ferrous metal industries. This restrictive theoretical environment and creative development opportunities seem to have been in a certain conflict with each other (cf. Raumolin 1984c, 1986a).

Turning to the Finnish responses to these development challenges, the principal political formations in the country such as the Peasant Party, the Social Democratic Party, the Progressive Party and the Conservative Party which all represented more or less Finnish-nationalist interests adopted economic nationalism as a principle for using domestic natural resources. The new Finnish state created state-owned companies in the hydropower, chemical and fertilizer industry armament industry, forest products industry and mining industry (cf. Raumolin 1984b, 1986b).

Reasons for the formation of the state-owned companies included domestic control of resource use, strategic importance of key industries and the capital-intensive character of these industries in a country poor in capital resources. In addition, the state-owned companies permitted an access to responsible jobs for the Finnish-language engineers and managers as most of the private manufacturing industry was controlled by the traditional Swedish-language economic elite which kept on defending the free enterprise system.

The Finnish economic nationalism was anyway more pragmatic and selective than dogmatic. In the case of the mining industry the largest copper deposit in Western Europe at Outokumpu, was exploited by a state-owned company, Outokumpu Oy especially because of its large potential linkages with national economy. Except for the building of a copper industry it provided raw material for the creation of a chemical and fertilizer industry, the building of an iron and steel industry, and supplies of sulphur for the leading export industry, the pulp and paper industry.

On the other hand, the discovery of a large nickel deposit at Kaulitunturi in the Petsamo District resulted in a concession to the International Nickel company. There were few possibilities to build an extensive domestic nickel industry because of the market control by this company and, in general, the potential linkages with the national economy were limited in this case. The exploitation of the old Orijärvi copper-zinc-lead mine was leased to a Swedish company because this company had a special expertise in the exploitation of poor deposits of ore (cf. Killinen 1935).

The management of the state-owned companies was ready to accept new Western technologies: the chemical industry plants, for instance, were built on a turn-key basis. The domestic component in the development of new capital-intensive industries included the building of infrastructures, such as electricy supplies, transportation networks and education facilities. Most of the labour force, a major part of administrative and technical personnel and the management were domestic. A part of the machinery and equipment was supplied by the Finnish engineering industry. The strategic development idea of these companies included the upgrading of the domestic component, by and by.

## 4.2. The Building of a Pioneer Electro-Metallurgical Capacity

After the possibilities of electro-metallurgy were discovered in France, USA and Germany toward the end of the last century, this new technology was first applied to the aluminium, chemical and steel industries. The new electro-metallurgical technology rapidly spread to the countries provided with ample hydropower resources, such as Sweden, Norway and Switzerland in Europe and Canada in North America.

Norway started to become an important centre for the research and development in the electro-metallurgical technology in the 1910s. Although the country lacked coal, there were ample hydropower resources and the traditions of the mining industry and higher education in mining and metallurgy were long. After the Great European War 1914-1918, the names of such Norwegian inventors and engineers as Söderberg, Westly and Hole became world-famous (cf. Sem 1950).

In particular, these Norwegian engineers developed electrodes and electrical furnaces. For the commercial exploitation of their inventions, they founded a consulting engineering company, Det Norske Aktieselskab for Elektrokemisk Industri. They paid considerable attention to the application of new technology to the iron and non-ferrous metal industries. For instance, Jens Westly built a small efficient copper furnace for the Sulitjelma smelter in Norway in 1928. This was the first electrical copper smelter in the world.

As there was no domestic coal available in Finland, the Finnish managers of the Outokumpu copper mine were interested in the new Norwegian smelting technology from the beginning. During the first phase of the development of the Outokumpu mine in the 1910s, the small copper manufacturing unit in Outokumpu acted as an experimental unit for a new Norwegian hydro-metallurgical manufacturing technology. Because this technology was still at an very experimental stage, the copper production was neither a technical nor commercial success.

After the state-owned hydropower company Imatran Voima Oy had harnessed the largest rapids in southern Finland at Imatra for electricity generation in 1929, which provided large amount of cheap electricity for industrial purposes, great visions were presented about the building of "a Finnish Ruhr area" on the basis of white coal in southeastern Finland. The building of other hydroelectrical power stations was planned in the Vuoksi River valley as well.

The onset of the Great Depression soon put a clamper on these visions for a while. Nevertheless, since the exports of the Finnish pulp and paper industry fared well during the depression, the Finnish economy did not experience such major difficulties as was the case in most of the countries during the period 1929-1934. An export-led industrialization supported by an import-substituting industrialization characterized the economic development in Finland during the entire interwar period (cf. Raumolin 1985).

Outokumpu Oy concentrated on the expansion of its mining and concentrating facilities at Outokumpu and on the opening of railway connections in the 1920s. For instance the new flotation methods were introduced. The expanding production of copper and pyrite concentrates was exported to the copper-hungry Germany. After the first expansion of mining activities was completed in 1928, the management of the company started to plant to integrate the production forwards. The situation soon became, however, economically critical as the price of copper fell drastically during the depression.

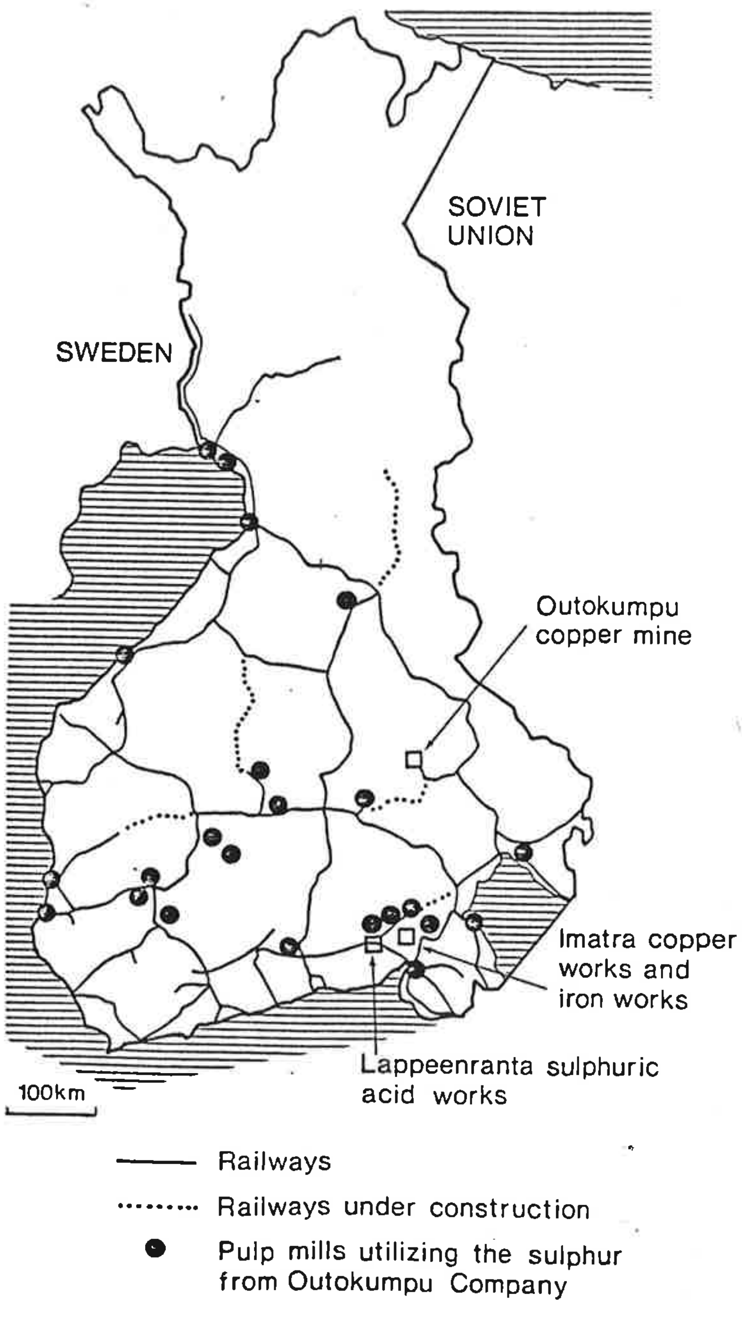
The policy of the international sulphur cartel which succeeded in keeping prices high and the continuous expansion of the Finnish pulp and paper industry sustained the development prospects of Outokumpu Oy. The company was able to sell an increasing amount of pyrite concentrates to domestic sulphite pulp mills. This was a decisive step which made the building of a copper smelter technically and economically feasible (cf. Mäkinen 1935) (see Map 1.).

The copper smelter was located at Imatra because of cheap electricity available, favourable transportation costs for concentrates and opportunities to find outlets for the planned liquid sulphur dioxide production in the large sulphite pulp mills in the vicinity. As the management of Outokumpu Oy had already considered the developments at Sulitejlma in Norway as a good example to follow, Det Norske Aktieselskab for Elektrokemisk Industri and Jens Westly were invited to construct and electrical furnace for the Imatra smelter in 1933. The other alternative, the erection of a traditional coal-fired furnace would have necessitated, among other things, the imports of large amounts of coal.

When the furnace started production in 1936, it was the largest electrical furnace ever built in the world. For its part, the copper smelter with its yearly production capacity of 12.000 tns of blister copper was one of the largest in Europe. The installations did not include any roasting facilities as the roasting of pyrites took place in the pulp mills in the vicinity. The smelting gases were utilized for the production of liquid sulphur dioxide. For this purpose, the British multinational company Imperial Chemical Industries Ltd. planned and constructed the largest sulphur dioxide mill ever built in the world (cf. Mäkinen 1938).

Map 1.

The Outokumpu Copper Mine and Related Production in Finland in 1938.




Source: J. Raumolin: The Impact of Forest Sector on Economic Development in Finland and Eastern Canada: in J. Raumolin (ed.): Natural Resources Exploitation and Problems of Staples - Based Industrialization in Finland and Canada. Fennia 163:2, 1985, p. 417.

In addition to Norwegian and British expertise and technology, German expertise and technology were utilized for the construction of the Imatra copper smelter. Although the management of Outokumpu Oy aimed at keeping the planning of the smelter in domestic hands, the company hd to resort to German expertise, for instance, G.A. Friedrich Krupps Grusonwerk AG., during the planning phase (cf. Kuisma 1985).

The main idea behind the construction of the smelter was to utilize the economies of scale offered by the rich copper deposit at Outokumpu and to look for new technical solutions. As the building activities of new facilities were depressed in the international markets, foreign suppliers were ready to work for the aims of the Outokumpu company. The operation of the smelter was faced with some technical problems at the beginning, which necessitated calling on the aid of German expertise. An experienced German engineer was appointed as the Technical Director of the smelter. After the difficulties in the start were overcome, the smelter worked well.

On the other hand, the sulphur dioxide plant ran into continuous technical difficulties. It seemed to be so that the supplier did not master the large size and the new production process in question. The planned production targets were never attained.

After the building of the copper smelter had started, an agreement was made between the Outokumpu company and the private Oy Vuoksenniska Ab about the building of an iron and steel works at Imatra in 1935. The cinders of pyrite concentrates containing 60 % iron were used as raw material for this works. The domestic production of iron are was insignicant before the opening of the Outokumpu mine. The Imatra iron and steel works started its operations in 1937.

The Imatra works applied electro-metallurgical production methods. The electrical furnace used in the iron production was a Norwegian type of Tysland-Hole furnace provided with Söderberg electrodes. It was the largest electrical furnace of its kind in the world. The German supplier Demag AG provided the electrical steel furnace and the rolling mill. Norwegian and Swedish experts assisted with the start-up of the works and it acquired an efficient operating rate from the beginning (cf. Grönblom 1938).

The Imatra iron and steel works was the first modern iron and steel works in Finland. The management of Oy Vuoksenniska Ab was clearly conscious about new technological possibilities for peripheral production and aimed at high-quality production following the Swedish example. The company started large scale production of rails for the State Railways, which were then substituted for the traditional imports (cf. Grönblom 1935).

As far as the activities of International Nickel Company in Finland are concerned, it established a Finnish subsidiary Petsamon Nikkeli Oy in 1936. A strategic decision was soon taken about the construction of electrical furnaces for nickel smelting in Finland. Electro-metallurgical technology had never been used before in nickel smelting but the good example of the Outokumpu copper smelter in Imatra, the potential availability of cheap hydroelectricity in northern Finland and the difficult transportation problems in the unsettled wilderness area in Petsamo contributed to this decision. In addition, this mine was peripheral in the global strategy of International Nickel Company: it could be well used as a laboratory for new experiments (cf. Petsamon Nikkeli 1945).

British, American and Canadian experts associated with the company and Norwegian consulting engineers collaborated in the planning of the project. Two large electrical nickel furnaces were provided with Söderberg electrodes and constructed by Birmingham Electrical Furnace Co. The furnace type was different from the Norwegian ones in accordance with the requirements of American experts. These furnaces were even larger than used in Imatra. The converters, which were imported from the USA were the largest in Europe.

The mining methods were planned in view of the needs of electrical furnaces. The planned methods were more mechanized than used in the existing Finnish mines. The management of the company, technical experts and foremen came from Anglo-Saxon countries, which was unusual in Finland at that time.

An interesting episode in this context was the return of "Amerikan mainarit" (American miners) to Finland. The main part of the Finnish emigration abroad at the beginning of the century and in the 1920s had been directed toward the USA and Canada. Many Finnish emigrants became miners in Minnesota and Ontario. As they knew English and were accustomed to the American mining methods, Petsamon Nikkeli Oy tried to lure them back to Finland. In fact, a few of them were working in the Kaulitunturi nickel mine in the late 1930s. They gained a legendary reputation among the Finnish miners (cf. Laaksonen et al. 1982).

The construction of the smelter was not yet finished when the so-called Winter War broke out between Finland and the Soviet Union at the end of 1939 in conjunction with the World War 1939-1945. All the Anglo-American experts left Petsamo as this part of Finland became a part of the battlefield along the Eastern border. The installations were not, however, severly damaged and the control of this largest nickel deposit in Europe became an object of heavy competition by the British, German and Soviet Government in 1940-1941. The Finnish Government continued the construction with the help of Swedish expertise and suppliers.

After the so-called Continuation War broke out between Finland and Soviet Union in conjuction with the German offensive towards the East in the summer 1941, German suppliers and consulting engineers provided support but Finnish engineers had to bear the main responsibility for the completion of the works. Due to these difficult circumstances, the production of the smelter started only at the beginning of 1943 and it functioned without major problems until 1944. Finland then had to cede the Petsamo District and the nickel mine and smelter to the Soviet Union according to the peace treaty between the countries in September 1944.

The success of the application of electro-metallurgical technology on a large scale in copper and nickel smelting and iron manufacturing in Finland in the late 1930s and during the early 1940s resulted, however, in an international spread of this technology after the War. The Swedish mining company Bolinden AB built a large electrical copper smelter according the example of the Imatra smelter in Rönnskär, Sweden and International Nickel Company built a large electrical nickel smelter according to th example of the Kaulitunturi smelter in Thompson, Canada (cf. Honkasalo 1982).

Another project the realization of which ran into difficulties due to the War was the building of a electrolytical copper refinery and a copper plant by Outokumpu Oy. As the blister copper from the Imatra copper smelter was sent to Germany for further refining and processing the management of the company decided in 1938 to build an integrated production capacity in Finland due to the need for increasing national self-sufficiency in the situation where war preparations by the major power were well under way. The domestic private metal and engineering industry, and both the Swedish and the German copper industry opposed this decison but the management of Outokumpu Oy gained enough support in the Government in order to carry out its aims.

These new plants were located on the West coast at Pori due to defence reasons. There were also energy supplies and labour force available in the Pori region. The American consulting engineering company Archer Wheeler Co. was invited to plan the construction of the electrolytical refinery whereas the American Scomet Engineering Company delivered the electrical furnace for the copper plant. For the reasons of trade policy one third of the machinery needed was ordered in principle from England whereas two thirds were imported from Germany. After the war started foreign deliveries were interrupted and substitutes had to be looked for from Sweden and domestic engineering companies. Both of the plants did not start production until 1941 but they worked well (cf. Levanto 1941).

## 4.3. Some Factors for the Success of the Transfer of Technology

Finland acted as an experimental field for the application of the new electro-metallurgical technology developed abroad during the 1930s. Since there were no significant traditions in non-ferrous metallurgy in the country, the good results allowed may seem surprising. Many reasons, however, contributed to the success of this transfer of technology.

Firstly, the traditions in iron manufacturing were quite long in Finland and the introduction of electro-metallurgical technology on a small scale took place as early as in the 1910s. In fact, Oy Vuoksenniska Ab was a descendant of these former experimental companies (cf. Myllyntaus et al. 1986).

On the other hand, the lack of traditions in the non-ferrous metallurgy may have been a positive factor. The propensity to accept and adapt new technology was greater without restrictive traditions. Typical of the non-ferrous metal industry was an audacious pioneering spirit and a propensity to follow technological frontiers.

The creation of a state-owned in the copper industry made it possible the creation of an integrated production chain and the development of many linkages with other sectors of the national economy. In presented young Finnish-language engineers with challenging tasks. The successful establishment of one of the largest copper smelters in Europe provided with pioneering technological applications was considered in the Finnish nationalist circles as a great national and heroic feat.

The Norwegian consulting engineers who planned the transfer of technology from Norway to Finland were evidently competent experts and the German and Swedish experts who aided at the start-up of the new plants were experienced and competent as well. Similarities in natural environment and historical and cultural traditions facilitated the transfer of the Norwegian and Swedish technology and expertise to Finland.

When the building of new plants started in the 1930s there were available Finnish experts who had gained a considerable experience in the service of the mining and metallurgical companies abroad and returned back to assume managerial and expert positions in the new plants. Some experienced workers returned back from abroad as well (cf. Raumolin 1986b).

The management of Outokumpu Oy practised a consistent education policy whereby, for instance, promising young Finnish engineers were sent to study abroad in reputable foreign universities in order to assume expert tasks in the planned new plants in the future. The formally organized higher education in mining and metallurgy started as late as in 1937 when a section of mining engineering was set up in the Department of Chemisty at the Helsinki University of Technology.

As a newly industrializing country, the relative advantages of the periphery were exploited in the Finnish mining and metallurgical industry. The first theorist of the success of NIC-countries, Thorstein Veblen who dealt with the cases of Germany and Japan at the beginning of this century enumerated some basic advantages, such as the active role of the state, the possibility to adopt the newest technology in the building of plants, and good opportunities to use the economies of scale in the production (cf. Veblen 1915).

The successful construction of some of the largest manufacturing equipment in Europe or the world and the capability to solve the problems caused by the war in the construction and running of the Kaulatunturi nickel mine and smelters and the Pori copper plants, of course, raised self-confidence among the Finnish engineers and increased the courage to accept new challenges.

To put this success story back into proportion a little, it may be appropriate to relate an unsuccessful example of the transfer of foreign technology to Finland. Finnish emigrant businessmen in the USA established the Finnish-American Mining Company in 1906 in order to exploit the old Orijärvi copper-zinc-lead deposit in Finland. The most advanced American and British technology was transferred, such as power machinery and equipment made by Allis Chalmers Co, drilling machinery made by Ingersoll Rand Co., concentration equipment produced by Wifley Mining Machinery Co. and flotation technology developed by Minerals Separation Co.. British consulting engineers assisted with the start-up of new machinery and equipment. The company soon ran into difficulties, however, and was obliged to shut down its activities. It seems to be so that a small enterprise backed with limited capital resources and marketing experience had few chances to survive (cf. Aaltonen 1911).

The next major transfer of Anglo-American mining technology to Finland by the multinational International Nickel Company was not carried out until the late 1930s. As far as the interwar period is concerned, the building of the sulphur dioxide plant in comection with the Imatra copper smelter was an evident failure.

4.4. The Paradox of Electro-Metallurgical Methods in Finland

An advance in electro-metallurgical technology took place in the countries provided with large hydropower resources while lacking coal such as Norway and Sweden, since the beginning of this century. This was an appropriate adaptation to the relative proportions of production factors in these countries.

On the other hand, Finland is provided with by far the poorest hydropower resources among the countries situated the northern coniferous forest zone, i.e. the Soviet Union, Finland, Sweden, Norway, Iceland and Canada. The Soviet Union has considerable hydropower resources, and hydropower is important in Sweden and Iceland. Norway still obtains about 99 percent of its electricity from this source whereas the equivalent percentage is close to 70 in Canada (cf. Deudney 1981).

Finland, on the other hand, is quite a flat country provided with limited hydropower resources. The theoretical resources have been estimated at only 4.100 megawatts. Nowadays, electricity produced by domestic hydropower only accounts a small part of the total electricity production in Finland (cf. Massa 1985).

The harnessing of the biggest falls in Finland afforded by the Vuoksi River at Imatra and other rapids close to it created a situation of a relative abundance of hydroelectricity in the 1930s. Since most of the pulp and paper mills were located close to smaller rapids, the companies were able to produce the electricity needed by their own means. The adoption of electro-metallurgical technology seemed to be appropriate to the Finnish conditions in this specific context.

In fact, an industrial complex based on hydropower resources took shape along the Vuoksi River Valley in southeastern Finland during the 1930s. This complex consisted of the large copper smelter, the iron and steel works, a couple of chemical industry plants and many large pulp and paper mills. All these works, plants and mills were connected with each other by means of interindustry linkages. The enthusiasts called this combination a "Finnish Ruhr area".

As a result of World War, 1939-1945 Finland lost a third of its hydropower capacity to the Soviet Union. The new frontier split the industrial complex along the Vuoksi River Valley and, for security reasons, the copper smelter was shifted from Imatra where the new frontier was very close, to Harjavalta in the vicinity of the Pori copper plants on the West Coast.

As the imports of fossil fuels were curtailed, since it was difficult to hire enough manpower for fuelwood cuttings and due to the rapid industrialization which was taking place, an acute shortage of energy characterized the postwar years in Finland. Because Outokumpu Oy wanted to avoid a shift to the methods necessitating imports of fossil fuels, it started to develop new energy-saving smelting methods. The metallurgists of the company were able to build an experimental furnace in 1947 which used a new autogenous flash smelting method (cf. Bryk 1951).

The Harjavalta copper smelter adopted this new technology in 1949 and it worked well. The basic idea of flash smelting was that roasting and smelting could simultaneously carried out in a single unit which led to a considerable saving of fuel. Because it produced a steady flow of furnace gases with unusually high sulphur dioxide content, it was also easy and profitable to build in conjuction a sulphuric acid plant.

The invention and the application of the flash smelting technology which replaced the former electro-metallurgical technology was an appropriate solution to the long-term structural constraints with respect to the energy supply in Finland. The promotion of energy-intensive production could be called rational in the Finnish conditions provided that new and efficient energy-saving production methods were developed.

The inventive capacity among Finnish metallurgists stemmed from the experience gained in the application of new solutions in the 1930s and at the early 1940s, the expansion of the higher education in mining and metallurgy and the pioneering attitude with regard to new challenges (cf. Raumolin 1986b).

Concerning the international diffusion of the smelting technology based on the Finnish experience in the postwar world, an interesting contrast can be observed. The prewar electro-metallurgical knowhow spread to Sweden and Canada, which are rich in hydropower resources, whereas the Furukawa Mining Company in Japan decided to modernize its copper smelter in Ashio by adopting the flash smelting system in 1954. The domestic energy resources in Japan are quite limited (cf. Bryk et al. 1958).

Because the expansion of the leading export industry, the pulp and paper industry, was continuous and founded on energy-intensive production methods and new energy-intensive process industries were established in Finland, the government decided to resort to electricity generated by nuclear power plants in the 1950s. The large share of the industries using energy-intensive production methods in the national production structure, the restricted possibilities of energy production by domestic sources and a strong dependence on nuclear power in electricity generation later resulted in schizophrenic discussions and conflicts on energy policy in Finland.

## 5. Final Reflections

A successful development took place in the mining sector in Finland from the 1950s up to the 1980s. The intensification of exploration after the war resulted in several discoveries of metal deposits in Finland. The rising prices of non-ferrous metals in the international markets in the 1960s favoured the diversification of the production structure of Outokumpu Oy. Nickel production started at the beginning of the 1960s, the company erected a large zinc plant in the late 1960s and the production of stainless steel started in the middle of the 1970s.

Domestic technological capability in the mining machinery and equipment and metallurgical process technology and equipment grew in strength. New processes, machinery and equipment developed and manufactured by Outokumpu Oy and the supplier industries were appropriate in the Finnish conditions, such as hardrock mining machinery capable of withstanding harsh winter conditions or metallurgical knowhow adapted to the exploitation of poor polymetallic deposits.

After some iron ore deposits were discovered, the expansion of the Finnish steel industry was rapid in the 1960s. Vuoksenniska Oy built another works and the state-owned Rautaruukki Oy erected a new steel works. This building of the steel industry capacity lent heavily on foreign technology and equipment.

The Raahe steel works of Rautaruukki Oy combined both Soviet and Western technology. This combination has proven successful. It seems to be so that Finnish engineers have gained a certain ability in this respect as the Loviisa nuclear power plant based on a combination of Soviet and Western technology is also operating well.

Both the private and the state-owned steel industry were not merely passively adapting foreign technology. On the contrary, they were actively developing new process control technology and new steel grades. After rationalization of the private steel industry in Finland in 1979 Vuoksenniska Oy was merged into the new company Ovako Oy. After the recent merger with the Swedish SKF Steel AB the name of the company is Ovako Steel Ab.

The stregthening of domestic technological capability and the rise of the supplier industries has resulted in considerable exports of mining machinery and equipment, metallurgical knowhow and machinery and equipment for metal industry plants. Outokumpu Oy was a pioneer in these export activities. During the 1970s, it was able to export integral nonferrous metal industry plants on a turn-key basis in collaboration with other Finnish companies. Both Ovako Oy and Rautaruukki Oy established engineering departments in the 1980s for the promotion of exports of steel mill knowhow.

As a result of these developments, a shift of perspectives from studies of the transfer of foreign technology to Finland to that of the transfer of the Finnish technology to the developing countries becomes more and more pertinent. I shall briefly deal with some examples from the NIC-countries which are actively building a metal industry capacity of their own, such as South Korea, India, Mexico and Brazil (cf. Raumolin 1986a).

As far as South Korea is concerned, Outokumpu Oy has delivered a large flash smelting copper smelter to the Onsan Copper Refinery on a turn-key basis. The company has exported flash smelting technology to India as well and erected a ferro-chromium plant on a turn-key basis there. For its part, Rautaruukki Oy has delivered steel manufacturing equipment to the Bhilai steel works in India in collaboration with the Soviet export house Tyazhpromexport. Because of the success of the transfer of the Soviet technology to Finland, Soviet export houses and engineering industry manufacturers are interested in collaboration with Finnish partners in the international export markets.

A comparative study on the impact of the transfer of the Soviet steel industry technology to Finland and to India would be quite interesting. The building of plants took place during the same period and state-owned companies were involved in both of the cases. In the Finnish case, the result was an efficient industry whereas the Indian industry has suffered from many problems. The social and cultural setting is, of course, very different.

Turning to Mexico, this country has advanced steel industry traditions. Rautaruukki, in collaboration with the British multinational Davy McKee Ltd, has exported rolling mill technology to the Sicartsa steel works in Lazaro Cardenas. The collaboration of Rautaruukki and Davy McKee started after the British company delivered machinery and equipment for the Rautaruukki steel works in Finland. Outokumpu Oy has delivered a couple of flash smelting installations to Mexico (cf. Mäntymäki 1985).

Concerning the Brazilian case, Outokumpu Oy has been active in the Brazilian market. Among other things, it established together with the Finnish manufacturer of drilling machinery and equipment Tamrock Oy a subsidiary engineering shop Brasmecanina there in 1981. Outokumpu sold its shares in Brasmecanica to Tamrock in 1987. Manufacturing of large Outokumpu floatation cells is taking place under licence in Brazil. As Rautaruukki Oy has developed a special expertise in the vanadium industry, it sold knowhow regarding the process chain of vanadium in collaboration with Jaakko Pöyry Engenharia to the Brazilian company Odebrecht last year (cf. Raumolin 1988).

Consequently, there is an evident need to broaden the scope of the Finnish development studies to Asia and Latin America. The structure and the attitudes in the organizations responsible for research funding make, however, the realization of such aims quite improbable (cf. Raumolin 1986d, 1987).

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