Abstract

The aim of the paper is to illustrate the challenges faced in the case study research. The research topic was turned upside down and unit of analysis changed several times. The paper includes also the evolution of the research. I tracked the diffusion of a revolutionary innovation, float glass, changing the flat glass industry globally. There is a need for deep longitudinal understanding of the nature of the international and globalizing industry and innovation. The case study provides tools for acquiring this understanding.

The purpose of my longitudinal case study was to understand the impacts of an innovation on the industry. Theoretically I aimed to apply management concepts. However, rich data allowed me to test and refine the well-cited cyclical model of technological change. Two of the industries applied in the original concept creation were the same I had in my study. The main contribution is to show how the focus on a phenomenon and case study research took me from cross-border acquisitions to a holistic analysis of the dynamically changed industry.

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Keywords: case study research, qualitative methods, innovative methodologies, industry change, global industry analysis

Changes in the unit of analysis in a case study research - my way to a holistic industry analysis

1 Introduction

The goal of the paper is to reflect my case study process during my Ph. D. studies. The case study research is not always straight forward. There may be immense changes. "Cases must be found because they cannot be specified beforehand...once cases have been found, they may be used to refine or even refute the theory that provided the initial guidance" (Ragin 1992). This was the situation with my case study. Another goal of the paper is to demonstrate how within case study research one can understand a contextualized phenomenon, which can be even dynamic and emergent. The case study research also provides an opportunity for a holistic approach on the industry study.

As an engineer having taken MBA I enrolled the doctoral program in international business (IB) in December 1990. From the beginning I was interested in foreign acquisitions made by Finnish companies. I also liked do a case study. The challenge with this combination (foreign acquisitions and the case study approach) was financing. Family and financial constraints prevented this for my doctoral studies.

After one and a half year night time studying of acquisitions and the related literature and of dreaming of money for travel I turned the topic upside down. I decided to study the Finnish manufacturing companies acquired by foreign companies. With this logic I found Lahti Glass Works. I thought that this is it. I had the literature and the case company to be visited. Again I became surprised. The acquisition literature could not explain me the reasons why Pilkington, a UK manufacturer had bought Lahti Glass Works in 1984. I faced the temporary events. The base for Pilkington's acquisition was laid already eight years earlier. The events related to the restructuring of the Scandinavian (Finland is included in this study in Scandinavia) flat glass industry (or exactly the sheet glass industry) and the introduction of float glass in Scandinavia had major impact on the acquisition of Lahti Glass Works. Thus my analysis of cross-border acquisition was enlarged to the analysis of an industry on a remote market.

Soon I found that the big companies who had come in the early 1970s with new technology to the national markets in Scandinavia, were European[1] multinational companies (MNCs) starting the competition on remote markets. To understand the Lahti Glass Works acquisition and the changes in Scandinavia I had to enlarge my research to the regional (Europe) and to the MNC level. I was lucky since this finding took me only a half of year.

In summer 1993 the study of the European market took the research to the 1950s and 1960 when Pilkington developed the float glass technology. The other sub-industry, the plate glass industry, of the flat glass industry was also identified. The European events in the plate glass industry in the 1960s were tightly linked to the events in the US flat glass industry. It seemed that my journey would never end. In autumn 1993 the impact of float glass on the flat glass industry were studied in Scandinavia and Europe. I found also the cyclical model of technological change (Anderson and Tushman, 1990) to be used in the analysis of the long term impacts of technological changes. Unfortunately the case study research was not that popular in the IB and the impacts of float glass innovation on the flat glass

[1] In this paper Europe means Western Europe.

industry were so complicated. In October 1993 my critical theory testing and theory refinement of Anderson and Tushman's model faced an enormous resistance in the doctoral seminar. After three hours meeting everybody in the audience said that I was doing story telling and not science. It was like the story from the movie "Twelve angry men". This was a total chock since everything for the licentiate thesis, one step to the dissertation, was ready.

In winter 1994 I switched to the safety glass industry which had grown a remarkable export industry in Finland. A little later I also changed unofficially my supervisor. In summer 1994 the topic was switched back to the analysis of the float glass. In autumn 1994 three more theoretical concepts were either tested or applied. In spring 1995 the licentiate thesis was done to the first supervisor and in autumn 1995 the doctoral thesis to the second one.

Here I demonstrated a situation where the case study research led me from would-be analyses of a cross border acquisitions outside Finland to a comprehensive industry analysis of one particular industry. The driving force within this journey was a phenomenon, a technological change, the impacts of which were followed starting from a small economy to the whole western world. I tracked the diffusion and impacts of float glass within the flat glass industry. In fact, this innovation converged two separate sub-industries, those of sheet glass (also called window glass) and the plate glass, to one industry. Float glass was introduced in the plate glass industry in 1959 and in 1970 it entered in the sheet glass industry.

However, the convergence of two sub-industries was difficult for the flat glass industry world wide to recognize as the quotation of the CEO of a U.S. flat glass manufacturer tells.

> "PPG's modernization program did not neglect existing facilities, and all the firm's other float and sheet glass plants have been upgraded in recent years for greater production capacity and more efficient operation. Attention to sheet as well as float glass facilities reflects our continued confidence in the efficiency of the vertical draw Pittsburgh process for sheet manufacture and the quality and economy of Pennvernon sheet glass. For the foreseeable future, PPG's sheet glass process will continue to be a more competitive production method for thin glass in residential construction and some other market. The company has a continuing research and development to improve the sheet process. (Barker, 1973:19).

The focus on the phenomenon, float glass, and a longitudinal case study research led me to understand the nature of the flat glass industry and the impact of float glass on it. After this knowledge a suitable theory was looked after. I found Anderson and Tushman's (1990) model. In the creation of this model Anderson and Tushman made longitudinal, quantitative studies on five U.S. industries. Two of them were the sheet glass and plate glass industries. This gave me an excellent opportunity to compare my empirical findings collected by different research method, the case study research. Their and my interpretations of the events in the industry were different. Thus, I was able to critically test and refine the cyclical model of technological change (Anderson and Tushman, 1990). I had serendipity here. One has to be exposed to luck.

The remaining of the paper has five parts. First, I briefly describe the evolution of the flat glass industry, including the impact of float glass innovation, in 1930-1980. Second, I illustrate the theory, the cyclical model of technological change, its testing and its refinements. Third, I report the evolution of my research and discuss the units of analysis. Fourth, I introduce the research

methodology, which is a longitudinal, historical and contextual case study research applying multiple sources of data. Fifth, I draw the conclusions and discuss the implications.

2 The evolution of the flat glass industry in 1930-1980: the context

This section provides an illustration of the evolution of the flat glass industry in Europe, in the US and Scandinavia. Float glass, the phenomenon of my study, was introduced by Pilkington in the UK in 1959. It was quickly adopted in the US. The Scandinavia gives an example of remote and national markets. First, the evolutions of sub-industries (sheet glass and plate glass) of the flat glass industry in general in 1930-1960 are described. Second, the development and impacts of float glass are illustrated. Third, since I discuss the evolution of the study process, the origin that is the Scandinavian (including Finnish) flat glass market is discussed.

2.1 Flat Glass Manufacturing in 1930-1960

As late as 1970 the flat glass industry had two separate industries, sheet glass (also known as window glass) and plate glass (see Figure 1). Sheet glass was thin, cheap and it had optical distortion while plate glass was thick, expensive and free of optical distortion. The production of plate glass was noisy and it provided a lot of dirty grinding powder. Plate glass was needed in more sophisticated applications such as mirrors and the large windows used for retail displays and architectural effects, where optical distortion were not acceptable. Plate glass was high quality and expensive.

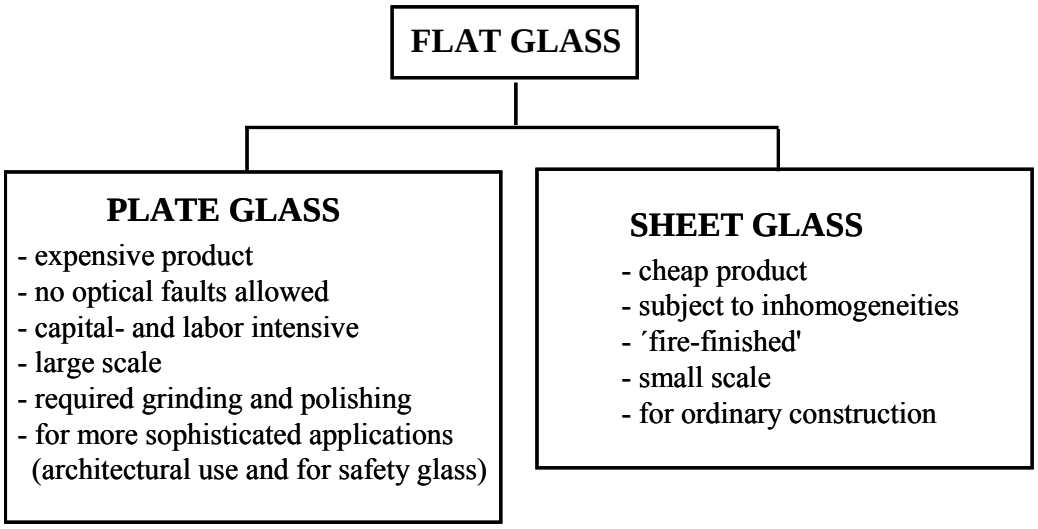

Figure 1. The Division of Flat Glass in the 1950s

Continuous sheet glass production started in the early 1900s (Doyle, 1979). Sheet glass was drawn vertically into a ribbon into a room where the cooled, hardened glass was cut and stacked. Sheet glass was cheap and subject to optical distortion. It was suitable for ordinary windows used in construction. The drawn sheet glass processes diffused rapidly in Germany and Belgium.

These industries had different customers. The plate glass industry was concentrated because of high investment requirements and large production capacities. Few large flat glass manufacturers produced both sheet and plate glass. Although they developed technologies in both industries, they kept the industries separate. These companies had entered safety glass manufacturing to serve the growing auto industry in the late 1920s.

In 1935 Pilkington introduced a `twin' grinding machine to grind both sides of a plate glass ribbon simultaneously, which lowered the cost of plate glass. The company licensed this technology to the plate glass producers (Barker, 1977). In the 1950s world demand for plate glass was satisfied by few large producers located in the main industrial countries. By 1960 Pilkington, BSN, St. Gobain and Glaverbel produced plate glass in Europe while PPG, LOF and Ford in the U.S.

2.2 The float glass innovation: Development and Impacts

The float glass innovation had its origins from both sub-industries. It aimed to have optical quality from the plate glass industry and "fire-finished" manufacturing method from the sheet glass industry. The R&D of float glass in Pilkington took seven years. The company decided to position float glass as a readymade product in the plate glass industry. Float glass was introduced in 1959 to replace the labor- and capital-intensive plate glass process (Salmans, 1980; Quinn, 1977). Float glass was a complete surprise to the industry. Furthermore, Pilkingon developed the process to make thinner float glass. This enabled float glass to enter the sheet glass industry, as well (see Figure 2.). This is why took the case of float glass innovation within the flat glass industry.

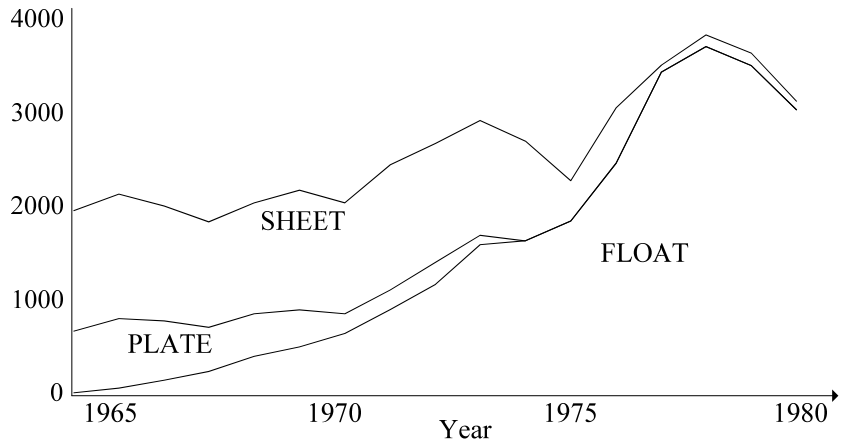

Figure 2. Flat Glass Production in the U.S., 1964-1980 (Millions of Sq. Ft.) (Edge, 1984).

The threat from the improving quality and low price of sheet glass was obvious for the plate glass plants. Here float glass came to the rescue (Barker, 1977). Pilkington licensed float glass technology inside the plate glass industry and not to the sheet glass industry (Spoerer et al., 1987). In the 1960s it was not evident that float glass would also replace sheet glass. In 1970 Pilkington produced 2 mm

thick float glass. Float glass started to compete with sheet glass. Float glass advanced the plate glass industry a huge step towards a real automated process industry. Ultimately in the mid 1970s float glass took over sheet glass (see Figure 2 for the US).

2.3 The Scandinavian Flat Glass Industry in 1960-1990

In 1960 there were seven independent sheet glass manufacturers in Scandinavia which invested heavily in new sheet glass plants. The emerging Scandinavian safety glass industry used imported high quality sheet glass as its raw material. In the late 1960s plate glass (float glass) producers followed the safety glass industry. Pilkington acquired three safety glass manufacturers in 1968-1975. In 1976 Pilkington started float glass production in Sweden and St. Gobain acquired the Swedish, Norwegian and Danish flat glass producers. In 1978 sheet glass production was terminated in Norway and Sweden. In 1978 Pilkington acquired a 50% of the only Finnish operating sheet glass manufacturer, Lahti Glass Works. In 1987 Pilkington and the Finnish Government started float glass manufacturing in Lahti Glass Works. (Uusitalo, 1995).

3 The model and its refinements

Only the cyclical model of technological change is discussed here. The dissertation applies three additional concepts: 1) toward a sociology of technology (Tushman & Rosenkopf, 1992), a design envelope model (McGrath et. al., 1992) and S-curves (Foster, 1986).

3.1 The cyclical model technological change

The normal process of technical progress in an industry consists of long periods of incremental change. A technological discontinuity inaugurates an era of ferment in which competition among variations of the original breakthrough culminates in the selection of a single dominant configuration of the new technology. The era of ferment has two processes: technological substitution and design competition. Successful variations were preserved by the incremental evolution of this standard design until a new discontinuous technological change initiated a new cycle of variation, selection, and retention. The model is illustrated in Figure 3. Anderson and Tushman's (1990) model provides a base for understand different types of innovation in different industries during different periods.

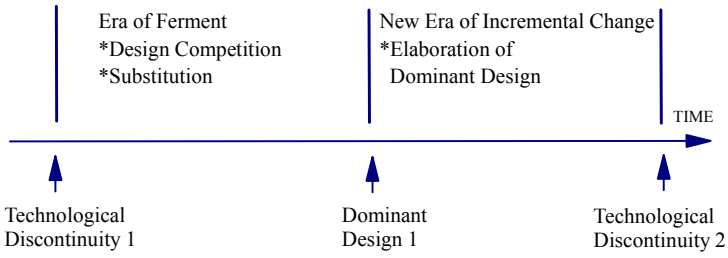

Figure 3. Cyclical model of technological change (Anderson and Tushman, 1990).

Technological innovation is defined as the first commercial introduction of a product or a process in an industry when that introduction constitutes a technological change (Anderson, 1988). To identify a technological discontinuity one must be able to track progress in key performance parameters over time. For plate and sheet glass it is the capacity of a flat glass forming machine (Anderson and Tushman, 1990). Tushman and Anderson (1986) characterized technological discontinuities as competence-enhancing (that is significantly advancing the state of the art, or permitting the transfer of, existing know-how and knowledge) or competence-destroying (that is significantly advancing the technological frontier, but with a knowledge, skill and competence base that is inconsistent with prior know-how).

3.2 The model refinements

Based on my empirical case study results and the analysis of the Anderson and Tushman's (1990) empirical interpretations (based on quantitative research) I redefined three pertinent concepts of the model. They are performance parameter, technological change and dominant design (see Uusitalo, 1995).

Performance parameter. Anderson and Tushman (1990 and 1991) used production capacity (square feet of flat glass produced) as the performance parameter. However, production capacity measures the efficiency and not the effectiveness of an organisation (Pfeffer and Salancik, 1978). Their definition seems to presume that efficiency is equal to effectiveness. According to it both sheet glass and plate glass production technologies have equal product attributes (one thickness and one quality class) and equal and constant cost structure. However, thickness of flat glass has an effect on the capacity (that is square feet of flat glass) of a manufacturing process. The thickness and the price of float glass were two major variables affecting the entrance of float glass into the sheet glass industry (Perry, 1984). I operationalise the performance parameter as the price (derived from the cost) of one square meter of flat glass of assumed quality and thickness.

Technological discontinuity. My definition of technological discontinuity means that a technological change exists only if technology moves clearly from one base technology to another more effective one. I strictly apply the definition of Foster (1986) which does not accept economies of scale (a jump on a higher level within the same S-curve) as a technological discontinuity.

Dominant Design. Anderson and Tushman (1990, 1991) did not regard Pilkington's float glass as the dominant design in the US market (see Figure 2). Contrary to Anderson and Tushman, first, while analyzing the impacts of float glass I kept the potential sub-industries, the plate glass and sheet glass industries, separate, second, I included patent considerations in the model2, and, third, I redefined a narrow range of configuration.

[2] This is also suggested by Pavitt (1987).

First, the flat glass industry had, up until the mid 1970s, two sub-industries. Float glass was invented in the plate glass sub-industry (Barker, 1994). Second, Pilkington realised that lower fixed capital costs attract newcomers into the plate glass industry, the high capital costs of which had previously deterred new entrants. Pilkington's policy was, therefore, to license only the existing plate glass producers (Barker, 1994, Kinkead, 1982). By the end of 1960s sheet glass manufacturers began to deluge the company with license applications. Third, the operational definition of a dominant design was a single configuration or a narrow range of configurations that accounted for at least fifty per cent of the new process installations in at least three (Anderson, 1988) consecutive years following a discontinuity. Contrary to Anderson (1988) I regarded technology within a narrow range of configuration if it was licensed by the inventor. Thus, I followed Suárez and Utterback (1995) and regarded float glass as being within a narrow range of configuration. The evolution of the float glass in three markets is analyzed with the help of Anderson and Tushman's (1990) redefined (Uusitalo, 1995) model in Appendix 1.

4 The evolution of the research process and the units of analysis

This part has two sections. First, the phases of the research process are illustrated. Second, the units of analysis within the research are summarized.

4.1 The evolution of the research

I) The starting point for the research was my interest in foreign acquisitions of manufacturing firms made by Finnish companies. In the late 1980s there was a boom of foreign acquisitions among Finnish companies (Uusitalo, 1992). Nokia had acquired several television manufacturers. I also liked to do an exploratory type case study. Why foreign firms had been acquired and how they had been integrated in the parent company? As was mentioned the bottle neck for this kind of research is financial constraints. For me it was extremely challenging because 1) I had four young children, 2) lived 100 km from the university, 3) did not belong to any research group and 4) outside financing was almost impossible. I studied for one and a half year in night-time acquisitions and related literature not so effectively. I participate doctoral courses, found out that all students had their empirical targets to study and tried without success to join the centre of IB research. My empirical study consisted of second hand material, only. Then I realized to turn my topic upside-down. I decided to study manufacturing companies in Finland acquired by foreign companies.

This lead me to the would-be analysis of a cross-border acquisition of Lahti Glass Works (see Figure 4). According to Yin (1984) my unit of analysis was a Finnish company, neat. However, the case study research forced me to enlarge the scope. Quickly the impact of float glass on the Finnish flat glass industry was recognized. The five next empirical phases were the analyses of II) the Finnish and III) the Scandinavian (including the writing of a teaching case), IV) the European and V) the North American flat glass industries. During phase V the proper theory, the cyclical model of technological change (Anderson and Tushman, 1990), for analyzing discrete technological changes was recognized. After identifying the theory I had difficulties to persuade my supervisor that my study was scientific. Because of this I switched to the Finnish safety glass industry. In spring 1994 I studied that industry (phase VI) until I switched back to the float glass innovation and its impact on the flat glass industry (phase VII).

Since phase II I did case study research. First the unit of analysis was Lahti Glass Works. Soon the unit of analysis changed to the Finnish flat glass industry. Then other markets where taken and thus my research design changed to the multi-case analysis. The markets and the float glass innovation were studied both separately and jointly. Finally I employed multi-case analysis of three markets for analysing the impact of float glass on the flat glass industry.

II) Finland. The research on the flat glass industry began as an analysis of the cross border acquisition of Lahti Glass Works in autumn 1992. Several histories (Ahtokari, 1981, Aro et. al., 1977, Berg, 1984, and Löfberg, 1973) and book n technology (Doyle, 1969 and Persson, 1969) of the flat glass industry were read. Few interviews of managers were done. It was soon apparent that a technological innovation, float glass, had had an enormous impact on the Finnish flat glass (in fact the sheet glass industry since there were no plate glass manufacturers in Scandinavian) industry. The Finnish flat glass industry also seemed to be connected to the Scandinavian one. The major link to the acquisition of Lahti Glass Works had been float glass. It became the phenomenon to track.

III) Scandinavia. In winter 1993 the Scandinavian industry was analyzed. One important source for that was Berg (1984). That time a teaching case (Uusitalo, 1993) together with industry participants was written. Prof. Heather Hazard suggested me to write a case study. Two big European flat glass manufacturers, Pilkington from the UK and St. Gobain from France, had played a major role especially when float glass had diffused to Scandinavia. Thus, Europe could not be excluded from the analysis of the Scandinavian market. Float glass became stronger as the phenomenon to be followed. I also found that float glass was well researched topic. However, I deliberatively took the risk to find something new from it and thus to contribute to the science, as well. This was crucial for a doctoral student.

VI) Europe. In spring 1993 the European industry was analyzed. Here both plate glass and sheet glass was manufactured. The float glass innovation was tracked in detail. During this phase it was noticed how international the flat glass industry had been already from the beginning of the 20th century. Large European and U.S. plate glass manufacturers had shared the markets (they had had a cartel). Float glass was diffused to the U.S. more quickly than to Europe. All U.S. plate glass manufacturers licensed the Pilkington technology by the mid 1960s. St. Gobain also entered to the U.S. plate glass industry in 1962 by building a new plate glass plant. Thus, North America had to be included in the analysis of the European flat glass industry.

V) North America. The previous analysis led me to track this area. Also here both sheet glass and plate glass was made, thus, the analysis of the diffusion of float glass would be interesting. Canada is included since Pilkington had manufactured sheet glass in Canadian from the early 1950s. It also built float glass plant in Canada in 1967. As was mentioned the U.S. plate glass manufacturers licensed quickly float glass. Pilkington only licensed to them and neither to sheet glass manufacturers nor other outsiders. After having studied North American market for a while I just happen to find a suitable theory for my research.

Theory; the cyclical model of technological change. Having obtained a reasonably good empirical knowledge of the flat glass industry and the underlining phenomenon, float glass, I looked for a theory to understand this specific technological change. This led me to Anderson and Tushman's (1990) model. However, I found inconsistencies between their and my own interpretations of events in the flat glass industry. This started an inductive theory testing and a deeper analysis of the North American flat glass industry. Unfortunately I was not able to present these findings to my supervisor and the research group.

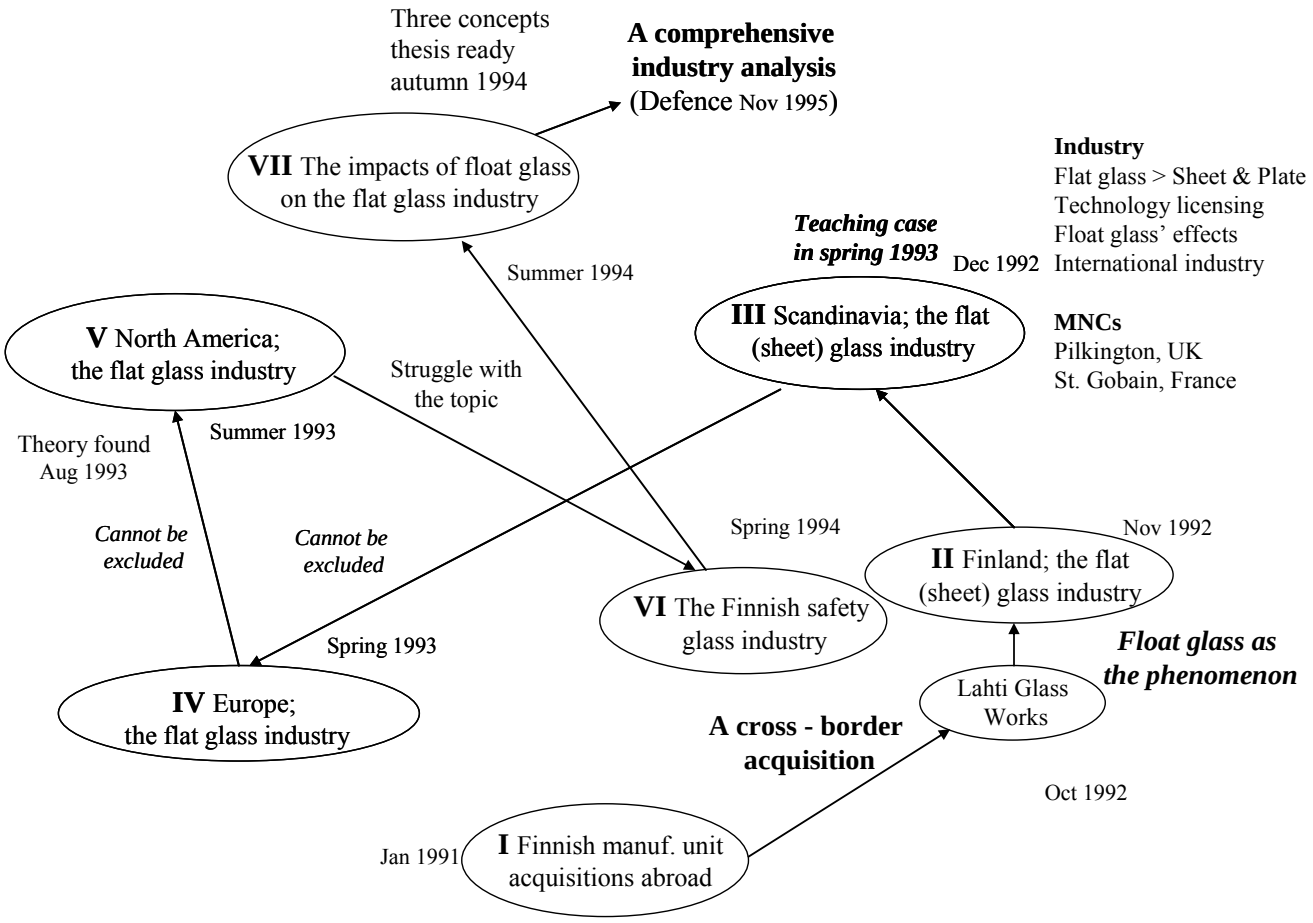

Figure 4. The phases in the research process

VI) The Finnish safety glass industry. Since the feedback for float glass innovation was so bad I switched the topic to the Finnish flat glass industry. There was a new unit of analysis, again. At the same time I realized to change the supervisor. The only way to change a supervisor is writing. I you write interestingly people become interested on you. Another professor in the same university had promised half a year ago to read one of my paper (Uusitalo, 1992). In March 1994 I asked him to read my paper on float glass and the cyclical model of technological change instead. He became interested and became my unofficial supervisor.

For more than one year I communicated with my unofficial supervisor but not with my official one. This situation hit me badly since neither the official nor the unofficial supervisor wrote me recommendations for scholarships. The study of the Finnish safety glass industry gave me deeper understanding of the links between flat glass, safety glass manufacturing and the auto industry. As was mentioned Pilkington, the inventor of float glass, had acquired three safety glass manufacturers in Scandinavia in 1968, 1970 and 1975. The flat glass and safety glass industries are closely linked and many flat glass manufacturers have also moved into the safety glass business. Safety glass has been an important raw material for automobiles for decades and car sales as well as the content of glass in a car grew in the 1960s. That is

why the processed flat glass products became important for the diffusion of the float glass. Uusitalo (1995). This knowledge was crucial in the next phase (VII)

VII) The analysis of the impact of float glass on the flat glass industry in the Western World. In spring 1994 I switched back to the analysis of the float glass under my new unofficial supervisor. Now I had the final set of units of analysis. They were float glass on three markets, Scandinavia, Europe and North America. In autumn I enrolled the doctoral course on thesis writing. In summer and autumn 1994 the European and the North American flat glass industries were analysed again in detail. In autumn accidentally I realised to look whether something had been written on the base of cyclical model of technological change (Anderson and Tushman, 1990). I found two other concepts, design envelope (McGrath, et. al., 1992) and organizational determinants of technological change (Tushman and Rosenkopf, 1992 and Rosenkopf and Tushman, 1994) which I could discuss with my empirical material. Moreover, I included also the applications of Foster's (1986) S-curves in my dissertation. In spring 1995 I did my licentiate degree and finalised my doctoral studies in autumn 1995.

V) North America. The previous analysis led me to track this area. Also here both sheet glass and plate glass was made, thus, the analysis of the diffusion of float glass would be interesting. Canada is included since Pilkington had manufactured sheet glass in Canadian from the early 1950s. It also built float glass plant in Canada in 1967. As was mentioned the U.S. plate glass manufacturers licensed quickly float glass. Pilkington only licensed to them neither to sheet glass manufacturers nor other outsiders. After having studied North American market for a while I just happen to find a suitable theory for my research.

Theory; the cyclical model of technological change. Having obtained a reasonably good empirical knowledge of the sheet glass, plate glass and safety glass industries and the underlining phenomenon, float glass, in the Scandinavia, Europe and North America I looked for suitable theory by which to understand a specific technological change, float glass. The search led me to Anderson and Tushman's (1990) cyclical model of technological change, which suited my case perfectly. However, I found inconsistencies between their and my own interpretations of events in the flat glass industry. This started the process of the inductive theory testing and a deeper analysis of the North American flat glass industry. Unfortunately I was not able to present these findings to my supervisor and the research group.

VI) The Finnish safety glass industry. Since the feedback for float glass innovation was so bad I switched the topic to the Finnish flat glass industry. There was a new unit of analysis, again. At the same time I realized that I had to change the supervisor. I found that the only way to change a supervisor is writing. I you write interestingly people become interested on you. In March 1994 I managed to persuade another professor to ready my work. He became my unofficial supervisor. For one year I communicated with my unofficial supervisor but not with my official one. This situation hit me badly since neither of professors wrote me recommendations for scholarships. The study of the Finnish safety glass industry gave me deeper understanding of the links between the flat glass, safety glass and auto industries. As was mentioned Pilkington had acquired three safety glass manufacturers in Scandinavia in 1968, 1970 and 1975. The flat glass and safety glass industries are closely linked and many flat glass manufacturers also produce safety glass. Safety glass has been an important raw material for automobiles for decades and car sales as well as the content of glass in a car grew in the 1960s. That is why the processed flat glass products became important for the diffusion of the float glass. Uusitalo (1995). This knowledge was crucial in the next phase (VII)

VII) The analysis of the impact of float glass on the flat glass industry in the Western World.
In spring 1994 I switched back to the analysis of the float glass under my unofficial supervisor. I had the final set of units of analysis: float glass on Scandinavia, Europe and North America. Next the flat glass industry was analysed again in detail (Appendix 1). In autumn 1994 accidentally I found two concepts, design envelope (McGrath, et. al., 1992) and organizational determinants of technological change (Tushman and Rosenkopf, 1992) based on Anderson and Tushman (1990)'s model which I could discuss with my empirical material. Moreover, I applied also Foster's (1986) S-curves. In spring 1995 I did my licentiate degree and finalised my doctoral studies in autumn 1995.

4.2 The units of analysis

The illustration of the changes in the unit of analysis was one of the main goals of this paper. My study applied the case study method proposed by Yin (1984) and Eisenhardt (1989). Table 1 has a collection of units of analysis. I used multiple-cases rather than a single case. According to Eisenhardt (1991) the multiple-case approach encourages researchers to study patterns common to cases and theory and to avoid chance associations. Eisenhardt (1989) recommends that the number of cases should be between four and 10 cases.

I had as a unit of analysis 1) four industries (the flat glass, plate glass, sheet glass and safety glass), 2) three flat glass technologies (plate glass, sheet glass and float glass), 3) several companies and 4) four markets (Finland, Scandinavia, Europe and North America). Thus, the number of cases is more than 10 although they are interlinked (Table 1). In phase I had neither an industry nor a firm as the case. Since in Finland and Scandinavia there were no plate glass manufacturing the industry in these markets was limited to the sheet glass industry. In Europe and North America there were both sheet glass and plate glass manufacturers, thus there the unit of analysis was the flat glass industry. The safety glass industry was studied in Finland (phase VI). Table 1 lists the latest production lines or modification of existing technologies (plate glass and sheet glass) before the introduction of float glass. The last plate glass line was opened in 1962 by St. Gobain in the US. In the 1960s and 1970s several sheet glass manufacturers invested in sheet glass plants.

The year when each company started to manufacture float glass under Pilkington's license is included. Guardian, a US safety glass manufacturer, was the only exception for this rule. In 1969 the company started float glass production without a license. This indicates the importance of float glass to the safety glass industry. In 1970 Guardian made the licensing agreement with Pilkington. The industry impact of float glass is also included. Higher the research phase number is greater the impact of float is. In Table 1 the style of the yes-word tells this.

On the company level it is interesting to see that West German companies, Delog and Detag were not able to license float glass. Bossois, St. Gobain and Pilkigton acquired the German manufacturers and started float glass manufacturing there. In Scandinavia only Lahti Glass Works under the ownership of Pilkington could switch to float glass process. All other producers were acquired by St Gobain and they ceased their flat glass production by 1980. In the US Pilkington did not license float glass to its European rivalry St. Gobain. The new but old-fashioned plate glass line was burden for St. Gobain during the whole 1960s.

Table 1. The unit(s) of analysis in different research phases

Research phase	Unit(s) of analysis: Industry	Flat glass manuf. Technologies: Float glass Industry impact	Start-ups: Float	Plate	Sheet	Firm	Geographic area
I	none					none	General
II	sheet glass	yes				*Lahti Glass Works*	Finland
III	sheet glass (national)	Yes	1976			Pilkington, UK	Scandinavia
						St. Gobain, France	
			1987		*1974*	*Lahti Glass Works*	
			-		*1969*	*Korsör (JV)*	
	outside the		-		*1968*	*Emmaboda*	
	plate glass		-		*1966*	*Drammen*	
	industry		-		*1974*	*Riihimäki*	
			-			*Valke*	
IV	flat glass (regional)	YEs	1959			Pilkington	Western Europe
			1965			St. Gobain,	
			1966	1956		Boussois, France	
			1965			Glaverbel, Belgium	
			none			*Detag, Delog, W-G*	
V	flat glass (regional)	YES	1967			Pilkington, Canada	North America
			1964	1957	1971	PPG	
			1964			LOF	
			1966	1961		Ford Motor Co.	
	outside US		no	1962		St. Gobain (French)	
	outside the		*1969*			*Guardian (no license)*	
	plate glass		*1971*			*Combustion-Engineering*	
	industry		*1973*			*American St. Gobain*	
			1974			*Fourco Glass*	
VI	safety glass (regional)	no				Lamino	Finland
VII	flat glass safety glass	**YES**				all firms	Western World

5 Case study method

Both main objectives, to test the model (Anderson and Tushman, 1990) and to track the impacts of float glass innovation on the flat glass industry, required a processual research approach (Pettigrew and Whipp, 1991). Based on Pettigrew (1985) I adopted a contextual and historical perspective on processes of change. Since the research on the impacts of a technological change on the industry structures required the recognition of an innovation within the industry and the calculation of the new manufacturing installations and withdrawals from the industry, it is extremely important to know the

industry concerned and the reasons for withdrawing from it. Since industries and reasons for withdrawals change all the time the competition (or internal and external contexts) is (are) best appreciated in a two dimensional way (Pettigrew and Whipp, 1991). The dimensions are the levels at which competition operates and the element of time. The competitive performance of a firm is based on the recognition that firms compete not merely against one another but at the same time within the sectoral (industrial) and national / international structures and relationships. Pettigrew & Whipp (1991) further state that the sectoral and national conditions are usually unstable. They also mention that firms have different abilities to perceive those changes and to react to them.

After one and a half year in phase I (see Figure 4) I found a phenomenon, float glass. I focused on the phenomenon all the time as Birkinshaw (2004) suggests. In teaching case writing (phase III) I applied the ideas of Porter (1980) and Quinn (1980). Porter (1980) says that in an industry analysis is important to gain an overview first, and only then to focus on the specifics. Quinn (1980) developed teaching cases as a foundation for his theoretical work. Descriptions are central to the generation of insight (Pettigrew, 1990).

After finding inconsistent evidence I attempted to reconstruct the evolution through deeper probing of the meaning of differences (Eisenhardt, 1989). I collected both theoretical and empirical material. I went through the data thoroughly on the industries and companies on three markets on several occasions to create a waterproof chronology (Mintzberg, 1979). I tracked down patterns and inconsistencies in the empirical data. My work was followed by creative leaps (in relevant directions; Mintzberg, 1979) in understanding the reasons for the inconsistencies between the events and their interpretations in Anderson's (1988) and Anderson and Tushman's (1990 and 1991) studies. It seemed that my engineering background, several years of work experience in industrial marketing and a good knowledge of the sheet glass and plate glass industries provided me with the "touch" required for intuition to emerge (Mintzberg, 1979). The importance of a good knowledge of the industry was also emphasized by Porter (1980), who stressed the value of in-depth industry histories in understanding industry environments and identifying firms' strategic interactions on a longitudinal basis. This phase was also characterized by both inductive and deductive phases. According to Eisenhardt (1979) and Cipolla (1991), the accumulation of knowledge involves cycling between theory and data.

5.1. Data Sources

To improve the validity of the model testing I used the triangulation methods (Jick, 1979 and Pettigrew, 1990) to construct case studies from a variety of information sources: interviews, company and industry histories, industry studies, business periodicals, books written by businessmen, trade journals, company correspondence, academic journals, and news clippings from the mass media.

Interviews. The role of the interviews at the beginning was to guarantee an accurate and truthful understanding of the sheet glass and plate glass industries (see Uusitalo, 1995). Thanks to these interviews (Table 2), a few fundamental facts (the existence of two independent sub-industries, the invention of float glass in the plate glass industry, Pilkington's licensing policy and the role of the safety glass industry in the diffusion of float glass) were grasped already at the beginning of the case writing process. Further interviews were carried out in phase VII. Sir Antony Pilkington, Chairman of Pilkington, Professor Barker, the author of three histories of Pilkington, and Professor Pearson, a former Pilkington researcher, were interviewed in summer 1995.

Table 2. Key interviews at phases II to IV (see Figure 4) of the study.

Jonas Borup	Managing Director 1993-2003	Sandomier Glass (Pilkington) / Poland
	Managing Director 1988-93	Lahti Glass Works (Pilkington)
	Administrative Director 1971-88	
	Department Manager 1967-71	
Kurt Lindqvist	Managing Director 1982-88	Lahti Glass Works
	Production Director 1975-82	
	R&D Director 1972-75	
	Production Engineer 1959-72	
Bo Sandberg	Managing Director 1976-82	Lahti Glass Works
Erkki Artama	Managing Director 1993-99	Lamino Group (Pilkington)
	Managing Director 1975-93	Lamino Windscreen Factory (Pilkington)
	Technical Director 1965-75	Lamino Windscreen Factory
Antti Kolehmainen	Managing Director 1965-76	Riihimäki Glass Works
	Deputy Managing Dir. 1959-65	
Bror Wahlroos	Secretary General 1969-92	Ministry of Trade and Industry

Histories and technology books. Professor Barker has written three histories of Pilkington and the flat glass industry (1960, 1977 and 1994). Other important histories were Ahtokari (1981), Amdam & al. (1985), Daviet (1989), Hamon (1990), Löfberg (1973) and Spoerer & al. (1987). Four books, Doyle (1979), Persson (1969), Pincus (1983), and Tooley (1984), on the sheet glass and plate glass technology were also used.

Trade journals etc. The accounts of the development of the U.S. flat glass industry in 1950-1984, is based on an extensive review The Glass Industry and Ceramic Industry Magazine. Both trade journals have been published since the 1920s or earlier. The American Glass Review, European Glass Review, and Chemistry and Industry were also consulted. Several articles from business periodicals (The Economist, Fortune, International Management, and Management Today) provided the view of management on the development of the flat glass industry. Bo Berg (Berg, 1984), a former MD in a Swedish sheet glass manufacturer, illustrates the events in Scandinavia in the 1960s and 1970s. Robert Skeddle (Skeddle 1980) worked for a long time in the U.S. flat glass industry. Tom Grundy (Grundy, 1990) worked as a foreman in Pilkington and especially in licensing projects.

Archival Records. Archival records (i.e. industry statistics, production volumes, import and export) were also used (Uusitalo, 1995). Qualitative data were supplemented by quantitative data.

5.2. Data Analysis

The analysis of the data is important in the case of explanatory and causal studies. The concept of internal validity deals with establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from false relationships. Internal validity can be enhanced by doing pattern recognition (Mintzberg, 1979) or seeing evidence through multiple lenses (Eisenhardt, 1989). Yin's (1984) pattern matching and explanation-building was used in the analysis, as well. High level of internal validity in this study was assured by subanalyses which approached the research phenomenon

(i.e. the evolution of sheet glass and plate glass industries) from many different perspectives. These subanalyses were combined at the end of the analysis in a way which resembled pattern recognition and seeing evidence through multiple lenses (See Table 3).

As far as reliability is concerned, a critical point in a case study is that the operations of the study (data collection and analysis) can be repeated and still the same results are achieved. According to Yin (1984), this is done by developing the case study protocol and case study data base. During the research process (see Figure 4) the empirical data were filed to form a proper data base. The reliability of the empirical study is assumed to be high because the data were collected from many historical independent documents. Furthermore, the study protocol (i.e. first grasping the nature of the industry and then doing research) in a sense repeats the data collection since the new markets (North America and Europe) were added with new empirical material from different, independent sources. Since the data consist of historical material, the research can be repeated quite easily and with the same results.

Table 3. Viewing the research phenomenon from different perspectives

Perspective	**Focus of analysis**
Technology	Plate, sheet and float glass manufacturing processes
Technology transfer	Wholly-owned subsidiary, licensing or joint venture
Industry	The plate glass, sheet glass and safety glass industries
Economy	
large	The U.S.
small	Finland
Regional	
concentrated	Plate glass industry
fragmented	Sheet glass industry in Scandinavia
Global	Licensing of float glass
Company	
large (MNC)	Pilkington, St. Gobain, PPG
small	Lahden Lasitehdas, Scanglas
Vertical integration	The safety glass
Network	Network of plate glass manufacturers
	Network of technologies
	Competing networks (Pilkington & St. Gobain in Scandinavia)

6 Conclusion

As was seen the case study research is not always strait forward as the research process above illustrated. There may several constraints such as financial, access to the data etc. to prevent the implementation of planned study. In my case the financial constraints forced me to switch the topic upside down.

After the topic was turn upside-down my situation was like pulling a rope. More I pull more interesting the situation became. There was no way to stop pulling. The same way my unit of analysis emerged. I started from the cross-border analysis of Lahti Glass Works, emerged to the Finnish flat glass industry, etc., ending up the float glass innovation with a holistic view of its impact on the flat

glass innovation. Figure 4 and Table 1 summarize my struggle. Table 1 also illustrates the strengths of case study research of holistic analyses of complex and dynamic phenomena.

According to Piekkari & al. (2010) a case study research is "a research strategy that investigates a phenomenon in its real-life context, relating it to theory and seeking to understand what the empirical phenomenon is a case of in theoretical terms". I did exactly this with the float glass innovation. My units of analysis can be regarded as social (companies and industries), geographical (markets) and temporal (flat glass technologies) (Plakoyiannaki, 2010) and they were not clear cuts (Alajoutsijärvi & al., 1999).

The study like this requires the commitment to the case study. You have to collect information and to link the events to each other. My information search had some incidents. August 1994 I was lucky to borrow for a month from a library summer trainee of Helsinki University of Technology monthly issues of two trade journals. Afterwards in a phone call the manager asked to bring the issues immediately back. After telling her that there could be a car accident on the way back to the library I got the permission to keep them. In summer 1995 in Sydney I went on Friday evening to the library to look the impact of float glass on the Australian market. Only a sick Finn age of 41 goes to library on Friday evening.

At the beginning of my process I was not fully committed to the studies. The weekly seminars within the IB at HSE were good and well-organized. However, if you write you paper just one week before your presentation and without any empirical data everybody in the seminar sees that there is no progress. I worked this was for almost two years until I found the flat glass industry. When one starts showing something after a long period of silence it may be difficult for the audience to believe him/her. In my case the background as an engineer combined with a technology oriented topic might have confused the audience. Table 3 collects the lessons.

Table 3. Lessons learnt for doctoral students.

1: The research process may not be straight forward, let your creativity work.
2: Look the best suitable research method for your study.
3: One must have drive, stamina
4: Be committed and thus, exposed to luck.
5: Be serious already from the beginning of your research.

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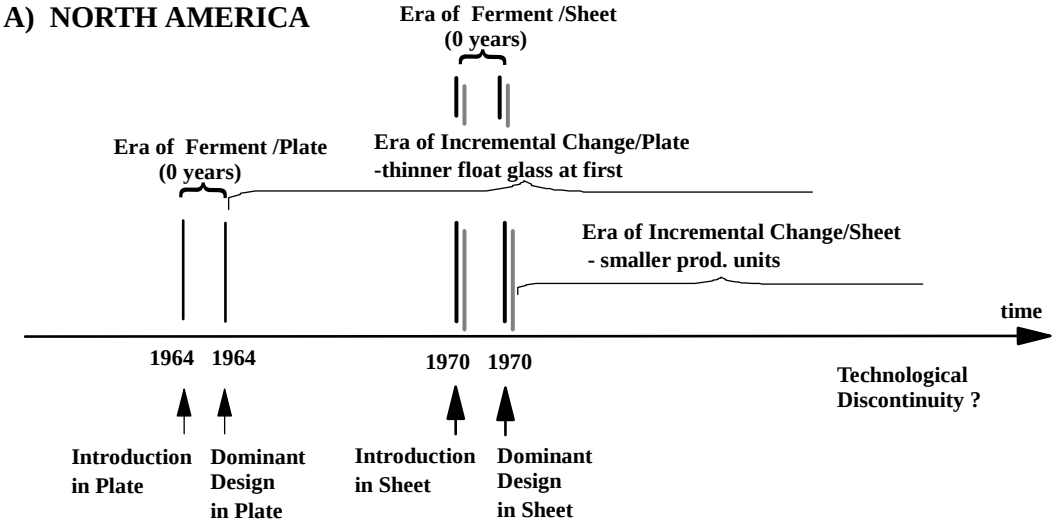
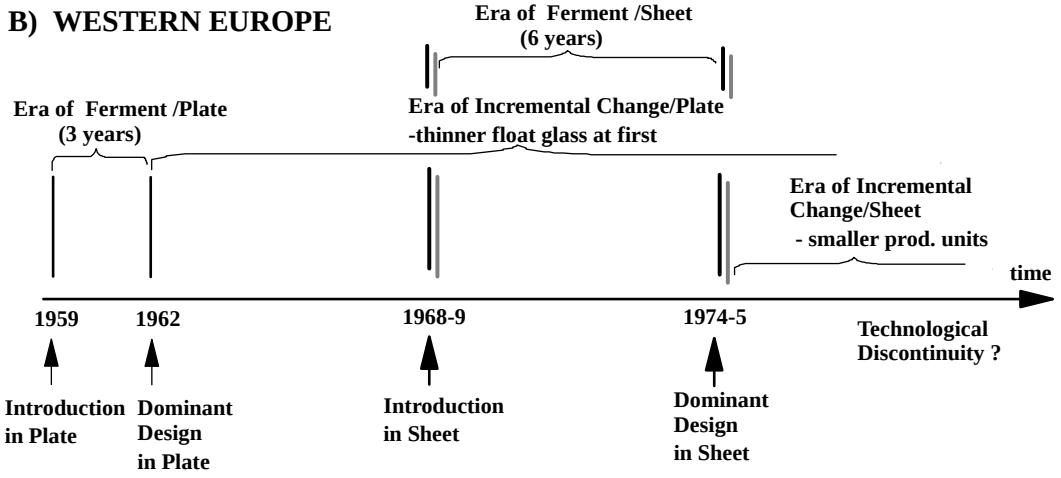
APPENDIX 1. Analyses of three markets with the redefined model.

A) NORTH AMERICA



B) WESTERN EUROPE



C) SCANDINAVIA