Fleischer, Manfred

Doctoral Thesis

The inefficiency trap: strategy failure in the German machine tool industry

Fleischer: The Inefficiency Trap

Herausgegeben vom
Wissenschaftszentrum Berlin für Sozialforschung

Abteilung: Market Dynamics
Direktor: Professor Dr. Dr. h.c. mult. Horst Albach

Manfred Fleischer

The Inefficiency Trap

Strategy Failure in the German Machine Tool Industry

edition sigma

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Fleischer, Manfred:
The inefficiency trap : strategy failure in the German machine tool industry / Manfred Fleischer. - Berlin : Ed. Sigma, 1997
Zugl.: Berlin, Humboldt-Univ., Diss., 1997
ISBN 3-89404-173-0

Design: Rother + Raddatz, Berlin. Cover printing: Grondsatz GmbH., Berlin.

Typesetting: Nina Bonge, WZB

Printing and binding: WZB
Printed in Germany

Contents

Preface 9

Acknowledgments 13

1. Product Differentiation and Performance: An Introduction 15

1.1 The Problem 15

1.2 Previous Research 19

1.3 Central Hypothesis, Methodology, and Outline of the Study 20

2. The Case of the German Machine Tool Industry 23

2.1 A Typical Example of a Medium-Sized Capital Goods Industry 23

2.2 Stylized Fact 1: Considerable Changes in Demand 25

2.2.1 The Product and the Structure of Demand 25
2.2.2 Demand by Users 26
2.2.3 Changes in Demand by Machine Tool Types 28

2.3 Stylized Fact 2: Significant Stability of Concentration 38

2.3.1 Concentration and the Size of the Industry 38
2.3.2 Development of Concentration over Time 41

2.4 Stylized Fact 3: Limited Economies of Scale 44

2.4.1 Static Economies of Scale 45
2.4.2 Dynamic Economies of Scale 50
2.4.3 Underlying Capital Requirements 52

2.5	Stylized Fact 4: Increasing Product Differentiation	54
2.5.1	Product Differentiation as Measured by Product Variety	54
2.5.2	Product Differentiation as Measured by Product Innovation	55
2.6	Stylized Fact 5: Increasing Foreign Competition	61
2.6.1	Import Shares	61
2.6.2	Structure of Imports	63
2.7	Stylized Fact 6: Decreasing Industry Profitability	64
2.7.1	Profit Margins by Firm Size	67
2.7.2	Accounting Rates of Return	68
3.	Theoretical and Empirical Foundation of the Inefficiency Trap Hypothesis	70
3.1	Introduction	70
3.2	A Preliminary Explanation of Structure	74
3.3	A Typical Market: The Market for Machining Centers	80
3.3.1	The Market	80
3.3.1.1	The Demand Function	80
3.3.1.2	The Cost Function	85
3.3.2	A Test of Market Structure	91
3.3.2.1	Introduction	91
3.3.2.2	Cournot-Nash Equilibrium	93
3.3.2.3	Bertrand-Nash Equilibrium	96
3.3.2.4	The Impact of Fixed Costs on Market Structure	97
3.3.2.5	Conclusion	102
3.4	Product Differentiation and Market Structure	103
3.4.1	Introduction	103
3.4.2	Product Differentiation in Spatial Models	104
3.4.3	Combining Horizontal and Vertical Product Differentiation	109
3.4.4	Product Differentiation and Cost Reduction	110
3.4.5	Product Differentiation and Customer Reactions	113
3.4.5.1	The Doubly Kinked Demand Function	113
3.4.5.2	Albach's Nonlinear Duopoly	116
3.4.5.3	Conclusion	119
3.5	An Explanation: The Inefficiency Trap Hypothesis	119

4.	Hypothesis Test I: Analysis of Survey Data from the NIFA Panel	123
4.1	Introduction	123
4.2	Measurement Issues	128
4.2.1	The NIFA Panel	128
4.2.2	Product Differentiation	129
4.2.3	Productive Performance	134
4.2.3.1	Capacity Utilization	134
4.2.3.2	Value Added	135
4.2.3.3	Technical Efficiency	135
4.2.4	Market Performance	138
4.2.5	Intensity of Competition	139
4.3	Variation of Product Differentiation in the NIFA Panel	141
4.4	Development of a Simultaneous Equation Model	143
4.4.1	The Product Differentiation Equation	144
4.4.2	The Efficiency Equation	146
4.4.3	The Profitability Equation	147
4.5	Estimation Results	148
4.6	Conclusion	150
5.	Hypothesis Test II: Analysis of Published Accounts from the Bonn Databank	152
5.1	Methodological Issues	152
5.1.1	Product Differentiation in Strategy Research	152
5.1.1.1	Introduction	152
5.1.1.2	Prior Strategy Measurement Studies in the Machine Tool Industry	154
5.1.1.3	An Index of Product Group Specialization	159
5.1.2	Choice of Performance Criteria	164
5.1.2.1	Limitations of Unidimensional Criteria	164
5.1.2.2	The Hexagon Criterion of Albach	164
5.1.2.3	The Z Value of Altman	167
5.1.2.4	Efficiency Measures	168
5.1.3	Implications for the Test of the Inefficiency Trap Hypothesis	170

5.2 Sample and Data 171
5.2.1 Structure of the International Machine Tool Industry 171
5.2.2 The Sample: German Machine Tool Firms with Published Accounts 172
5.2.3 The Data 173
5.3 Empirical Results 175
5.3.1 Profitability 175
5.3.2 Technical Efficiency 179
5.3.3 Strategy Analysis: Cost Leadership versus Product Differentiation 181
5.3.4 A Second Test of the Inefficiency Trap Hypothesis 184
6. Conclusions 185
7. Appendix 189
8. References 214
List of Figures 230
List of Tables 231

Preface

The author of this book has taken up the challenging task of explaining the considerable loss of employment in the German machine tool industry in recent years. The central question is: Is this loss of employment a structural phenomenon or one related to the business cycle? The answer presented here is very clear and convincing: It is a structural phenomenon. Firms of the German machine tool industry are plagued with their strategy of product differentiation, a strategy which created success in the past, it is true, but is shown to be counterproductive today. Firms which now pursue a strategy of product differentiation without a matching strategy of cost leadership are showing losses and risking their competitiveness.

This clear-cut result is derived convincingly with the use of different methodological approaches; the most interesting among these are the strategy map and the strategy portfolio. These results of these methods (and a number of others) provide convincing evidence for Fleischer's proposition that the German machine tool industry evolved in a way which led itself into an inefficiency trap.

The book is clear and concise. In the second chapter, six "stylized facts" are derived, which describe the major characteristics of the German machine tool industry. Statistics in this section show a significant stability of the firm size distribution, although considerable changes in demand are observed. Foreign competition increases, firms do not meet intensified competition by exploiting economies of scale. Instead, they increase product differentiation which cannot prevent further decreases in profitability. These six facts outline the thesis which Fleischer develops. The German machine tool builders have placed their bets on the wrong horse. As Fleischer proves, greater cost efficiency rather than stronger product differentiation would have been be the more appropriate strategy. Only cost competitiveness has the desired impact on the customers of the machine tool industry, since only the supply of cost efficient equipment keeps them alive in a situation of increasing international competition. The strategy of creating small monopolies around traditional customers and trying preserve this with increasing product differentiation has serious shortcomings. Such a strategy fails to use economies of scale and learning effects.

The third chapter is devoted to a description of the market in the tradition of industrial organization. First, the market for machining centers is analyzed. To this purpose a demand and a supply curve are derived. Using the demand and supply conditions of the market the number of firms which can survive in the market is calculated. A distinctive part of this analysis focuses on the impact of fixed costs on market structure. The second section of this chapter deals with the relationship between product differentiation and market structure. Three types of models are used for the analysis. First, spatial models of product differentiation are based on a positioning of products (sellers) at varying distances from buyers. Second, models incorporating the effects of the cost reduction strategies of product differentiation are postulated. And, finally, a model of an imperfect oligopoly in which customer reactions play an important role apart from the reactions of rivals is utilized. From these, the hypothesis of an inefficiency trap is derived.

The main implication of this work is that the degree of product differentiation in the German machine tool industry is higher than optimal. The inefficiency trap has led to a loss of competitiveness in the national and in international markets. The German machine tool industry has failed to pursue cost efficiency by economies of scale and learning effects. Furthermore, Fleischer demonstrates how product differentiation leads to inefficiency, and how inefficiency leads to losses. In capital goods industries increasing competition leads to strong product rivalry. It follows that firms cannot avoid competition. To remain competitive they have to face strong product-market rivalry by using strategies of cost reduction. The German machine tool industry has completely mistaken these relationships, and therefore, now finds itself in a structural crisis.

In the fourth and fifth chapters, arguments are given to prove the inefficiency trap hypothesis. Two data sets are used. First, the NIFA panel data from the University of Bochum, which includes a large sample of firms from the German mechanical engineering industry. Second, the Bonn Databank, which includes financial data on the published accounts of German stock-market-quoted companies. Fleischer uses this and significant supplementary data to develop a unique measure of product differentiation, which he then uses for regression analysis. Furthermore, following Leibenstein, he applies the concept of X-efficiency and develops indicators to measure the efficiency of machine tool firms.

The NIFA panel data is used to test the inefficiency trap hypothesis in a simultaneous equation model. The model explains product differentiation, efficiency, and profitability. From the Bonn Databank a sample of fifteen of the largest German machine tool firms (observed over a nine year period) is used. According to all performance measures, the German machine tool industry can be divided into two large groups of firms; a group of good performers and a group of bad performing firms. The good performers are more efficient than the bad performers, exhibit a lower degree of product differentiation, and are more profitable.

In this study, Fleischer has investigated the relationship between product differentiation and market structure for capital goods in the case of the German machine tool industry. Like the groundbreaking work by Schwalbach on diversification in German industry, this study is another pioneering work, especially important as it deals with a capital goods industry of strategic significance.

I hope that this study will help to overcome the crisis in the German machine tool industry. But the book is of interest to other industries as well: the inefficiency trap potentially threatens all industries. Therefore, this book and its findings should attract the attention of any corporate manager, as well as policy analysts. Naturally, the book is also useful for industrial economists, since it avoids methodological monism by developing appropriate instruments to study real capital goods markets.

Horst Albach

Acknowledgments

For nearly twenty years, I have been interested in theoretical and empirical work dealing with relationships between innovation and market structure in capital goods markets. About seven years ago, the hypothesis advanced in this book began to shape my thinking. It was when my Italian friend, Secondo Rolfo, asked me whether I would like write a paper on the competitiveness of the German machine tool industry. But, in fact, it was my father, a Siemens engineer, who stimulated my early interest in the many fascinating kinds of machine tools.

Horst Albach was the first to recognize that perhaps I had unwittingly spawned a Ph.D. study rather than a paper on the German machine tool industry. But turning that manuscript into a Ph.D. thesis was by no means a solo effort. It is Horst Albach to whom I should express my sincere thanks for his strong support. His commitment went far beyond his role as my advisor for my doctoral thesis. I owe him great thanks for the direction of this study. Without his generous support this book would not have been written.

I would also like to thank Joachim Schwalbach for his comments and participation. We met in 1977 at the International Institute of Management (IIM) and I was a colleague of his there for more than a decade. I am grateful that, at his present position as a Professor at Berlin's Humboldt University, he did not hesitate to take the time to read and judge my thesis. I am also grateful to the members of my Ph.D. committee at Humboldt University, Lutz Hildebrandt and Wulff Plinke.

I am particularly grateful to two American senior fellows, F. M. Scherer and Dennis C. Mueller, and a "junior" fellow, David B. Audretsch, which I met at IIM as "the Berliner." They have kindly guided my interest in the field of industrial economics. It goes without saying that Bo Carlsson has influenced my economic views on the machine tool industry.

I am also thankful to my WZB colleagues who provided numerous comments and suggestions throughout the various stages of this research. In particular, I thank Rabah Amir, Silke Neubauer, Christoph Schenk, and Michael Tröge.

Whether I was in a bad mood or not, I received a lot of support from my friend Andreas Schmidt, a modern composer and industrial economist. As valuable was the support of Ina Frieser. She, being responsible for the working conditions of famous academicians, knew how to do the right thing at the right time. Herzlichen Dank, Ina and Andreas!

I am most grateful to the people in the office of the industry association of the German machine tool industry in Frankfurt am Main, the Verein der Deutschen Werkzeugmaschinenfabriken e.V. (VDW). Over the years they provided much material support and insightful comments for my work. I am also grateful to a few firms which gave me advice on the competitive situation of the industry, these are, Hahn & Kolb, Heller, Hommel, Index, Pittler, Schuler, and Trumpf. However, there are such rich data sources publicly available that I restrained in bothering them too much. I would like to thank Ulrich Widmaier and his colleagues from the University of Bochum for providing me with the data of the NIFA panel. They and numerous people from the industry are responsible for the development of this new and universal data source on the German mechanical engineering industry.

I particularly want to express my gratitude to Christiane Neumann, WZB's managing director, and to my colleagues, "deputy directors" Christoph Albrecht, Konstanza Prinzessin zu Löwenstein, and Christian Rabe. Their special efforts in alleviating some of the hindrances that are typically involved in the job of a "deputy director" have provided the leeway needed to do this research. Thanks are also due to the staffs of the WZB library and the library of the Produktionstechnisches Zentrum Berlin.

Thomas Brandt, Olaf Grewe, Marcel Trost, and Jiangping Yang were very helpful in providing capable computer assistance and for providing me the access to the right data in the Bonn Database. I am indebted to Kenn Kassman, Kate Matraves, Eva Eszes, and Nathan Musick who over the years have corrected the English of various parts and drafts of this project. Their editing has improved the clarity in numerous cases. I am also grateful for the careful typing of parts of the manuscript by Eva Buchholz and Marie-Antoinette Eggebrecht. Needless to say, Eva Buchholz helped me as "deputy director" of the WZB Research Area "Market Processes and Corporate Development" (formerly known as the IIM). With the support of Heidi Hilzinger, the managing editor of the WZB book series, Nina Bonge did the final technical work on the manuscript before it went to our long-standing printer, Jochen Hecker. Special thanks go to them. It goes without saying that despite the valuable assistance I have received, I remain responsible for all matters of fact or interpretation.

My deepest gratitude goes to my dear wife, Marianne, for her understanding support and love that enabled me to finish this book. I am very fortunate to have her by my side. This book is dedicated to Marianne.

Manfred Fleischer

1. Product Differentiation and Performance: An Introduction

1.1 The Problem

The economic impact of product differentiation on the performance of plants and firms is a key problem in capital goods industries. With very few exceptions, neither the literature relating to industrial organizations nor the literature on strategic management provides sufficient empirical knowledge regarding the economics of product differentiation in capital goods industries.[1] This study fills this gap with a needed empirical analysis of product differentiation and competition in capital goods markets. Further, it explores these areas in detail by stressing their relationship to efficiency and performance. The study focuses on product differentiation, concentrating on the special case of product customization in the German machine tool industry. This is an especially interesting case because the industry has experienced a dramatic drop in employment, giving rise to the question of whether this is a cyclical or structural problem.

The study focuses on product customization because it is the extreme form of product differentiation and leads to maximum product variety. This area is also interesting since it relates to market structure, conduct, and performance. According to neoclassical theory, product differentiation is an element of market structure because it constitutes a heterogeneous market. Product differentiation was a central feature of Chamberlin's (1933) model of monopolistic competition assuming free market entry, whereas to Bain (1956) and mainstream industrial organization theory, it is an important barrier to market entry. Decisions regarding product differentiation are also crucial for the conduct of firms. As such, these decisions become a variable of market conduct. Furthermore, product differentiation is a result of a resource allocation process; thus, product differentiation might well be regarded as belonging to the performance category within the structure-conduct-performance paradigm. Obviously, the different aspects of product differentiation have to be separated within an analysis of competition in capital goods markets.

---

1 Early work in this area was done by Hambrick (1983). For an overview of the pertinent microeconomic literature concerning the economics of product differentiation, see Eaton and Lipsey (1989). See also the collection of classical papers and important recent work edited by Thisse and Norman (1994).

Since market structure has an important impact on the conduct and performance of the firms competing within its boundaries, the analysis of competition in capital goods markets requires a good understanding of market structure. Part of the difficulty with achieving this understanding lies with the problem of overlapping influences. For example, product differentiation might increase social welfare; however, it can also increase the costs of production and distribution and may thereby reduce social welfare as the sum of consumer and producer surplus in the market. It may even promote inefficiencies within the firm. The interesting (and ultimately most important) question is how this all balances out in the end. Therefore, the problem becomes the determination of results—which interactions of what economic forces and conditions (the structure of market demand, the cost structure of firms, etc.) will lead to positive and desirable results? This study offers an explanation for the different ways the structure of capital goods markets influences the behavior and performance of firms.

The analysis of efficiency within the study rests on the assumption that the total industry output demand will be the same, even in the absence of product differentiation. Concentration of total output into fewer firms would then lead to the elimination of some varieties of the product, but not to a loss of demand.[2] What is especially important for this type of analysis is the structure of demand. In this situation of a new equilibrium, the resulting output is different from the output mix produced before. The important issue now is efficiency: the comparison between these two equilibria from the point of view of whether the same output is produced more or less efficiently. From an empirical perspective, the analysis requires the observation of different output mixes, plus a criterion for how to compare these different mixes. In this analysis, changing equilibria of one industry are compared over time. Then, at one point in time, the efficiency of various segments of the industry—those which exhibit a different degree of product differentiation—are compared according to their relative efficiency. A cross-country comparison would be ideal, avoiding some of the limitations of single country research by virtue of increasing the range of experimental settings; however, this is beyond the scope of the present study.

This study focuses on the framework of a national open economy. The central question is the theory of imperfect competition: Does the market mechanism lead to an optimal number of differentiated goods in a capital goods industry? Or, are there situations where market performance deteriorates—what we call inefficiency traps? It is also important to observe the impact of global competitors in

2 One could also imagine that product differentiation shifts the demand function. But, for capital goods markets, it is assumed that product differentiation only creates different demand structures for differences in demand.

the studied market. These competitors usually adopt a two-stage strategy of market penetration. In the first stage, they pursue a strategy of product standardization and cost leadership. In the second stage, they follow a strategy of product differentiation and technology leadership.

The importance of the various types of product differentiation[3] lies in their effect on demand.[4] Therefore, an analysis has to take into account that the total demand for the products of an industry depends on the degree to which individual firms have differentiated their products.

The most remarkable features of any capital goods market include their tremendous heterogeneity,[5] their relatively low economies of scale, and their

---

3 Product differentiation is at the core of nonprice competition. Differences in quality and in variety are due to differences in product characteristics, and are related to product differentiation. This has led to the classification of three types of product differentiation (Abbott 1955):

1. Vertical product differentiation or quality variability. Vertically differentiated products can be ordered according to some quality index, e.g. in the case of machine tools a ranking of the cutting speed or the precision of the cutting process can distinguish "lower" and "higher" quality. Usually, superior quality is preferred by all customers, and it is generally more expensive to produce a higher quality,
2. Horizontal product differentiation or product variety. These differences in product characteristics do not allow for a uniform ranking of products. Consumer rankings of products differ in these cases—as in tastes for preferred colors—and it is assumed that cost differences are random, and
3. Innovative (lateral) product differentiation or product innovation. Innovative changes in product characteristics are preferred by most customers. Innovative differentiation is also regarded as superior in cases of increasing costs. The old quality is substituted by the new quality. Innovative product differentiation is distinguished from the vertical type only in the magnitude of the variability in product characteristics. It is due to R&D and driven by technical progress.

There exists a vast literature on product differentiation as a phenomenon beyond perfect competition and monopoly. The concept was introduced in economic theory by Sraffa (1926), who provided an interpretation of a downward-falling demand curve in competitive markets.

4 "Market demand for a product is the total volume that would be bought by a defined customer group in a defined geographical area in a defined time period in a defined marketing environment under a defined marketing program." (Kotler 1997, p. 133)

5 Heterogeneity relates to the diversity of markets and products. Heterogeneity is the result of product policy decisions taken by firms. Thus, it is the result of the adaptation of the firm to market demand characteristics and competition. Market heterogeneity is measured in terms of cross-elasticity of demand and the specificity of the product bundle. Products belong to the same market if they are interchangeable for most customers in terms of price, quality, and use. A low substitutability or a low cross-elasticity of demand would define separate markets. Thus, product differentiation of the firms leads to an increase of market heterogeneity.

moderate absolute cost advantages. Capital goods markets exhibit a high degree of product differentiation, as is the case in the consumer goods markets. Product differentiation for capital goods is different than with consumer goods. The type of product differentiation in capital goods markets has more to do with the customization of physical product characteristics (see Lancaster 1979 and Plinke 1992 for the problems related to product customization in capital goods industries). Thus, one generally observes a high level of functional and physically differentiated products in capital goods industries, but a minimal level of advertising. It is also important to note that technical innovation plays a key role in these industries. This implies that firms have to obtain, and then maintain, access to the relevant basic technologies in order to constantly make improvement innovations (see Albach 1994, pp. 52-64 for the economic role of technological innovation).

Many of the dynamics observable in capital goods markets are due to two types of efficiency gains. The first are efficiency gains due to (internal) productive efficiency—described as technical or X-efficiency. The second are due to the optimal market fit of the products—what is called market efficiency. As Geroski (1983) has shown, the firm-specific, market power-position depends on the degree of product differentiation, on the conjectured reaction of rivals, on the price elasticity of demand, and on the market share.

One interesting question is, whether the differentiation of capital goods deters "new" firms from entering the industry? Could such differentiation provide an effective form of protection for existing firms (incumbents) in the industry? Gilbert (1989) argues, in his survey of the recent theoretical literature on entry, that product differentiation efforts by incumbents have ambiguous effects as entry barriers. Whether product differentiation makes entry easier or more difficult seems to depend on how it affects the demand for specific products.[6]

There are a number of reasons why the German mechanical engineering industry—particularly the German machine tool industry—was chosen for this study of product customization, product differentiation, and monopolistic competition. As had previously happened with the British and the U.S. machine tool industries, the German machine tool industry is now undergoing severe changes in structure, conduct, and performance. Thus, the industry allows focus on both regularities and changes in competition—especially on regularities regarding the interactions of basic conditions, market structure, conduct, and performance.

---

6 As with Geroski (1983), the important issue according to Gilbert (1989, p. 477) is: "The central question in entry deterrence is the value that is attached to incumbency: Why is it that an established firm may lay claim to a profitable market while other (equally efficient) firms are excluded?"

1.2 Previous Research

Previous studies provide interesting and insightful data and analyzes of the industry.[7] They have not, however, applied the analytical tools of microeconomics, nor have they focused on product differentiation when discussing the issues of competition and competitiveness.[8] Mengel (1933) studied structural change and the business cycle of the German machine tool industry until the end of the 1920s. He concluded that the major constraint of capital-intensive production in the machine tool industry is the business cycle. R&D activities and innovative potential were investigated by von Schöning (1980). Regarding competition and the competitiveness of the industry, the most important study is by Zörgiebel (1983). Based on Porter's (1980) framework, Zörgiebel developed a model of technological competitive strategy and provided the first analysis of strategic groups in the German machine tool industry. Ownership structure was analyzed by Nagel and Kaluza (1988). They also provided a database of German machine tool firms. Vieweg, a researcher in the Ifo-Institute, published a number of articles on the German machine tool and mechanical engineering industries, using patent and other data (Vieweg 1989; 1991; 1993). Recently, a study comparing the German and the U.S. machine tool industries was completed by

---

7 For a comprehensive and international comparative survey covering empirical work concerning the machine tool industry, see Carlsson (1990). An insightful study on the global competition for numerically controlled (NC) and computer numerically controlled (CNC) machine tools was published by Jacobsson (1986). Two remarks should be made with respect to how NC and CNC technologies are approached in this study. First, the development of the NC and CNC technologies is briefly described in table A.5. Second, in general, only the term NC is used although there is an important difference between the two technologies. The logic in the NC technology control units was made of hardwired circuitry, and the hardware had to be changed for new functions. In contrast, the CNC technology uses flexible programmable control units instead of hardwired control and logic units. The CNC technology is nowadays the essence of the modern computerized numerical control of machine tools. Thus, the flexibility of control is the main difference between NC and CNC technologies. Since the 1980s nearly all numerically controlled machine tools use the CNC technology. Thus, the distinction between NC and CNC technology is practically irrelevant. This is the reason why we—like most of the pertinent literature and statistics—use the general term NC machine tools instead of CNC machine tools. One exception is made in table A.5 where we summarize the technological development of numerically controlled machine tools in the United States of America, Europe, and Japan.

8 A number of studies have investigated global competition and the impact of global competition on the restructuring of firms, their products, and their production technologies, but without applying microeconomic theory. See the influential study of the automobile industry by Womack, Jones, and Roos (1990), and the work by Pine (1993) on "mass customization." Pine provides a business policy-oriented view of the issues.

von der Osten (1990). Another comparison of the German and Japanese mechanical engineering industries was undertaken by Vieweg and Hilpert (1993).

A theoretical model of the creation and destruction of markets was developed and tested for the machine tool industry by Wieandt (1994). The plethora of conceptual and empirical studies of patent behavior and patent strategies of firms is thoroughly reviewed in Ernst (1996). He also examines the relationship between the patent behavior of firms and their economic performance (sales growth and sales per employee). Using a sample of 50 firms in the German machine tool industry he finds a positive relationship between patent behavior and performance. Furthermore, Ernst (1996; 1997) has also assessed the suitability of patent data for forecasting technological developments, based on the CNC technology case. Tönshoff (1996) develops an analytical framework of the machine building and selling process that accounts for optimized cross-functional decision-making in module design, machine tool manufacturing, and product marketing.

Other interesting material concerning the industry was published for the 100th anniversary of the foundation of the German Machine Builders' Association (Verein Deutscher Werkzeugmaschinenfabriken e.V., VDW). Glunk (1991) wrote the official anniversary publication and Spur (1991) published a very comprehensive volume on the history of machine tools and the development of the machine tool industry in Germany. Recently a study summarizing the development of the German machine tool industry since 1945, and containing a number of useful statistics was edited by the VDW (Schwab 1996; for the postwar period see also Ottwaska 1964). Three more specific studies should also be mentioned. Fandel, Dyckhoff, and Reese (1990) investigated the determinants of the production of machine tools. Spur, Specht, and Schröder (1994) compared the innovation processes of NC control in the U.S.A., Japan, and Germany. The paper by Spur et al. (1994) is also a very insightful study, highlighting the pathbreaking innovations of machine tool controls. Using the same case studies regarding numerical control technology, Schröder (1995) analyzed the impact of (the so-called) national systems of innovation—specifically, in the case of NC technology innovations. In short, there are a number of interesting studies concerning the German machine tool industry. There is no study, however, which focuses on issues of industrial economics.

1.3 Central Hypothesis, Methodology, and Outline of the Study

The empirical approach of this study is guided by a dynamic view of industrial economics as developed for example by Audretsch (1995). It relates to the basic structure and the basic dynamics of an industry. According to Audretsch the structure of industries is characterized by a high degree of fluidity and turbulence, even as the patterns of evolution vary considerably from industry to industry. The dynamic process by which firms and industries evolve over time is shaped by three fundamental factors: technology, scale economies, and demand. Most importantly, Audretsch's evidence suggests that it is the difference in the knowledge conditions and technology underlying each specific industry that is responsible for the pattern particular to that industry. That is, the nature of innovative activity, that accounts for variations in industry evolution across markets.

In case of the German machine tool industry the particular link between product differentiation and industry evolution plays a key role. A first step towards understanding this link on an empirical level is to test the relationship between competition, product differentiation, and market structure. One of the recent and most comprehensive studies testing the relationship between competition, product differentiation, and market structure is the one by Sutton (1991). Sutton claims that the equilibrium level of concentration depends inter alia on the thoroughness of price competition. His theory predicts, "that if institutional factors cause price competition to become less thorough ... then the *equilibrium* level of concentration will be correspondingly lower." (p. 16)

In this study, it is argued that in the case of the German machine tool industry, institutional factors (via the causation of rigidities) and product differentiation have led to less thorough price competition, thus, firms have been able to pursue cost driven price increases and avoid cost and efficiency control. In other words, the central hypothesis of this study is that the German machine tool industry has evolved in a way which has led it into an inefficiency trap. This situation has arisen for a number of reasons. The most important is the adoption of a strategy which has focused on product differentiation—particularly, a strategy of customizing products to single customer specifications. This strategy was pursued at the expense of a strategy of cost leadership and flexibility.

This study uses microeconomic theory to develop a set of hypotheses which explain the situation of the German mechanical engineering industry. It concentrates on the development of the German machine tool industry. The main hypothesis is tested by utilizing a panel data set covering the German mechanical engineering industry for the period from 1990 to 1993. The data set is the (so-called) NIFA Panel. The data was collected primarily to study the problems and determinants of the organization of manufacturing in the mechanical engineering industries. Therefore, an important step of the study was the development of appropriate economic measures concerning the conduct and performance of firms and plants. The relationships are modeled with a simultaneous equation approach using three equations. The first equation explains product differentiation, the second explains efficiency, and the third explains profitability. The impact of various factors is tested, including plant size, market share, production structure, capacity utilization, capital intensity, competitive intensity, and expected demand.

However, it should be noted that the data of the NIFA Panel lacks exact accounting information. Chapter 5 compensates for this deficiency by utilizing sources which include profitability data based on actual accounting information. This data is available for eight of the ten largest German machine tool producers in 1994 and for four medium-sized firms. Furthermore, data for four large groups (Konzerne) which have significant participation in the machine tool industry is also utilized. This allows a more precise examination of the microeconomic functioning of the machine tool firms, and presents a clearer view of the economic foundation of their strategies.

Since the course of the industry's economic development is assumed to depend fundamentally on its strategy of product differentiation, this study begins in chapter 2 by examining the empirical facts about the industry and its market structure, conduct, and performance. The development of the industry is summarized in six stylized facts. The theoretical foundations of the main hypothesis are then developed in chapter 3. The various models of product differentiation are discussed in order to extract the theoretical results concerning how market structure is affected by: (1) the distribution of consumer demand in the product space, and (2) economies of scale as expressed by fixed costs. Due to the specific advantages and shortcomings of the single models, a set of hypotheses is developed in order to explain the dynamics of competition and equilibrium market structures in the industry. In chapter 4, a simultaneous equation model is created in order to test the developed hypotheses with a new data set covering the German mechanical engineering industry—the NIFA Panel from the University of Bochum. Chapter 5 analyzes profitability, efficiency, and product data from a sample of fifteen of the largest German machine tool firms over a nine year period. The statistical analysis then focuses on the period of 1991 to 1994. Finally, chapter 6 summarizes the main results and draws the conclusions.

2. The Case of the German Machine Tool Industry

2.1 A Typical Example of a Medium-Sized Capital Goods Industry

The German machine tool industry is an excellent starting point for studies concerning product customization, product differentiation, and monopolistic competition. As was earlier the case with the British and U.S. machine tool industries, the German machine tool industry is presently undergoing severe changes in structure, conduct, and performance. Thus, the study of this industry enables one to focus on regularities and changes in competition—especially when observing the interactions of basic market conditions, structure, conduct, and performance.

Until 1989 the study covers only the development of the West German machine tool industry. Since German unification in 1989, the machine tool industry has become unified like many other industries in Germany. Obviously much time and effort has been involved in this process. Since it is now one German machine tool industry, we prefer to use the term German machine tool industry in this study. For reasons of accuracy, the term West German machine tool industry is used in figures and tables when data and statistics refer to the "Old Federal Republic of Germany." The structure of the East German machine tool industry in the former German Democratic Republic is summarized in Berliner Bank AG (1990).

The German machine tool industry is of strategic importance within the mechanical engineering sector. In 1993, the sector was comprised of approximately 5,000 firms with almost one million employees.[9] As a supplier of production technology, the machine tool industry has a great impact on the productivity of related user industries. Between 1990 and 1995, the machine tool industry subclass of the mechanical engineering sector was confronted with a decline in

9 The exact figures for West Germany for 1993 were 5,235 firms with a total employment of 954,335 and a value of shipment of DM 194,222 million. The number of establishments was 5,753. Counted are firms and establishments with 20 employees and more. See VDMA Handbook (1995, pp. 64-65).

employment of about one third.[10] In 1990, the West German machine tool industry consisted of 380 firms with 103,000 employees. In 1995, the whole German machine tool industry had 68,300 employees left.[11] Most of the firms in the German machine tool industry are family owned and, at least partly, owner managed. The dominating legal form in the industry is the private limited liability company ("GmbH"). By firm size, the German machine tool industry in 1990 included 161 firms with 20 to 100 employees, 153 medium-sized firms with up to 500 employees, and 66 large firms of more than 500 employees. Despite the fact that 82.6 percent of firms in the industry are small and medium sized firms, the bulk (60.5 percent) of the employees is concentrated within the large firms.

Immediately below is an overview of the major regularities observed in the industry. It includes a description of the structure, conduct, and performance of the German machine tool industry since the 1960s. The regularities which emerged in the evolution of the industry over three decades are identified as stylized facts (see Schmalensee 1989 for a distinction of stylized facts within a structure, conduct, and performance analysis). The first stylized fact relates to the demand side of the market, that is, considerable changes in demand took place. With respect to the supply side of the market a significant stability of concentration was observed (second stylized fact). This might have given rise to an underestimation of the dynamics of competition by the incumbents. The third stylized fact refers to limited economies of scale in the industry. This might be one reason for the observed stability of the firm size distribution. Since firms tend to adjust their sizes toward the optimal level, the firms—confronted with small economies of scale—have no strong incentive to adjust to an optimal level. Still, economies of scale exist, but the firms have not pursued a strategy of cost efficiency or asset parsimony. Instead, they have continuously increased their degree of product differentiation (fourth stylized fact), despite an increase in foreign competition (fifth stylized fact). Obviously, one would not expect an underestimation of competition to continue. Nevertheless, firms continued to customize their products at the expense of cost savings. However, this strategy could not prevent a significant drop in industry profitability in the early 1990s (sixth stylized fact). The following discussion of the six stylized facts is based on

10 This does not take into consideration the employees of the East German machine tool industry. In 1988, this was estimated at about 53,000 employees (Berliner Bank AG 1990, p. 17). If one includes this figure the gross decline in employment between 1988 and 1995 for the whole German machine tool industry was 78,700 or 53.5 percent. That is, the total number of employees declined from 147,000 in 1988 to 68,300 in 1995.

11 VDMA Machine Tool Statistics (1995); this is the most recent statistical survey and does not include the number of firms or establishments. Therefore, the 1990 figures were used.

an analysis of rich data sources. In particular, two statistical series edited by the industry association should be mentioned; that is, the VDMA Machine Tool Statistics and the VDMA Handbook (covering the whole mechanical engineering industry).

2.2 Stylized Fact 1: Considerable Changes in Demand

2.2.1 The Product and the Structure of Demand

A modern machine tool is an expensive piece of equipment and continues to become ever more technically complex. It represents an investment which can only be justified if its capacity for greater productivity can be exploited. Machine tools are capital goods used for shaping metal. They fulfill a variety of useful production purposes. The German Institute of Industrial Standards (DIN) defines machine tools as,

> "... mechanized and more or less automated production equipment which, by movement between tool and workpiece, produces a given form or change of the workpiece." (DIN-Normblatt 69651)

Machine tools are power-driven elements and they are usually component parts of larger manufacturing systems. There are at least three broad product categories of machine tools—those used for metal cutting, those utilized in the forming of metal, and a classification comprised of miscellaneous tools and accessories. These three product areas delineate the structure of the industry. Only two of these subsections are of major interest to this study—the manufacture of machine tools for metal cutting and for metal forming.

Demand in this industry becomes effective in the form of orders. Generally, there are two types of machine tool orders—dealers' orders, and user or final purchasers' orders. The importance of each depends on the type of machine tool. Usually, dealers' orders are oriented towards standard or general purpose machine tools, whereas specialized machine tools are normally purchased directly by the machine tool user from the machine tool producer or by a special order placed through a dealer.

The structure of demand for machine tools has changed considerably throughout the course of industrialization. The end-users in the early days were mainly producers of steam engines, bicycles, sewing-machines, and guns. Most customers today produce automobiles, airplanes, agricultural, and construction equipment, high-tech weapons, and other sophisticated end products.

In the 1950s, the German demand structure for machine tools was characterized by heavy investment in capital equipment, which amounted for approximately 80 percent of the total demand for machine tools. This situation has changed considerably over time. Today, the mechanical engineering industry absorbs roughly 30 percent of total machine tool production, the automotive industry accounts for 20 percent, and the electrical/electronics industry absorbs an additional 20 percent (Vieweg 1989, p. 28). The share of German machine tools consumption (as a percentage of gross equipment investment between 1960 and 1994) ranges from 3 to 6 percent (see table A.1 in the appendix).

2.2.2 Demand by Users

Because the current (short-term) demand for machine tools is predominantly for replacement purposes, further insight into the demand structure for machine tools can be obtained by examining the existing stock of machine tools in Germany. By comparing the machine tool stock of 1976 with that of 1990, one can clarify the relationship between replacement and expansion demand. This comparison also reveals the growth, decline, and/or exodus of the industries that purchase machine tools.

The VDW Machine Tool Inventory estimates that 1.39 million machine tools were in use in 1976.[12] In the last 15 years, the stock of machine tools has shrunk by more than 25 percent to approximately 1.02 million units in 1990 (VDW Machine Tool Inventory 1990). The number of numerically controlled (NC) machine tools produced between 1970 and 1975 was 2,843 units (von Schöning 1980, p. 197). Offsetting exports with imports during this time period leads to an estimated stock of approximately 3,000 NC machine tools in 1976. In 1990, the stock of NC machine tools was estimated at 120,000 units.

Over the past 15 years, the stock of machine tools in all industries decreased by 26.6 percent. The stock was reduced from 1.39 million in 1976 to 1.25 million in 1980 and to 1.02 million in 1990. The two main reasons for this decline are: (1) the reduction of the number of firms in the manufacturing sector, and (2) the increased productivity of modern machine tools—the standard assumption here is that there is an "exchange rate" of 1:4; i.e., one numerically controlled lathe replaces four conventional lathes (The Engineer 1984, cited by Carlsson 1990, p. 177). A similar reduction of the stock of machine tools has been observed in the U.S.A. (American Machinist 1983).

---

12 This estimate is based on a sample of 1,800 firms, who used altogether more than 365,000 machine tools (VDW Machine Tool Inventory 1976).

Table 2.1: Stock of Machine Tools in the West German Manufacturing Sector According to Industries

	1990		Change
	Stock (units)	Share in percent	1990 to 1976 in percent
All industries	1,020,000	100.0	-26.6
Machinery	336,600	33.0	-33.5
Motor vehicles incl. suppliers	265,200	26.0	45.6
Fabricated metal products (EBM)	183,600	18.0	-38.0
Electrical equipment	163,200	16.0	-40.1
Steel forming	40,800	4.0	-61.4
Aircraft	10,200	1.0	
Others	20,400	2.0	

Incl. stock of NC machine tools: Change 1990 to 1985 = 89.1%

in 1990	121,000
in 1985	64,000

Average age of machine tools:

in 1976, all machine tools	14 years
in 1990 (for machines often in use)	
• Conventional machine tools	18.6 years
• NC machine tools	6.3 years

Sources: VDW Machine Tool Inventory (1976; 1990). The share of the stock of single industries was changed in the 1990 survey due to a more accurate assignment of firms to industries. Based on 2% "Others" in the 1990 survey the 1976 figures were adjusted proportionately. The Aircraft Industry was not mentioned in the 1976 data.

The largest stock of machine tools is found in the mechanical engineering sector, which has 33 percent of all units (see table 2.1). The stock in this sector decreased in absolute numbers by 33.5 percent in the period observed. The second largest stock of machine tools is found in the automobile industry, which accounts for 26 percent of the total. This is the only industry which has shown a strong increase in its machine tool stock in the past 15 years—an increase of 45.6 percent. Industries with comparable stocks include fabricated metal products (18 percent) and electrical equipment (16 percent). Both of these industries displayed a sharp reduction in the number of machine tool units. The stock in steel forming (4 percent of total machine tool stock) and in the aircraft industries (1 percent of the total stock) is also significantly lower.

The most recent structure of demand for machine tools is revealed in table A.2. This data is based on the first demand structure survey ever undertaken for the German machine tool industry (completed by the VDW in 1995). It shows the percentage of total units of machine tool types supplied to particular user industries. The data is based on the customer structure of approximately 90 VDW firms, and thus offers a rough estimation of the actual demand structure of the German machine tool industry. It is interesting that this structure is comparable to the structure of the stock of machine tool as shown in table 2.1. The mechanical engineering industry has the highest demand with an average of 26 percent for all types of machine tools. This is underscored by the very high values shown for the most important machine tools such as machining centers (39.5 percent) and lathes (37.6 percent). The second highest demand is found in the motor vehicles industry, and in this industry's primary suppliers (9.5 plus 9.3 percent, respectively). The motor vehicle industry has a very high demand for special purpose machinery such as flexible transfer lines (55.5 percent) and gear cutting machines (33.8 percent). The third largest user of machine tools is the fabricated metal products industry with an average demand share of 18.5 percent.

2.2.3 Changes in Demand by Machine Tool Types

The structure of demand by types of machine tools has changed over recent decades. An analysis of that change is confronted with two dilemmas. First, only production and trade data for six-digit product groups is available. Second, an intertemporal comparison has to deal with changes in product classification, as well as with the incompleteness of the data. One can solve these problems in the following way. In order to obtain the needed insight into the demand structure by type of machine tools (as reflected in the production statistics) one can compare the various time periods at two levels of aggregation. Production statistics are taken as an indicator of demand, since they reflect adjustments to changes in demand. In the case of Germany—having an export ratio averaging more than 50 percent—it also represents the changes in foreign demand.

The overall structure in Germany is slightly different from the international average. In 1989, Germany produced 69.7 percent (in value terms) of all cutting machine tool types, and 30.3 percent of the forming type of machine tool. By contrast, the international averages are 27 and 73 percent, respectively. Thus, it seems to be the case that the few large German producers of presses, bending, shearing, and punching machines pursued a more successful strategy of growth than their counterparts in the field.[13]

When one examines the two years 1960 and 1989—years for which the data is comparable (see table 2.2)—the number of demanded "planning, shaping, slotting, and broaching machines" decreased at an annual rate of 8.1 percent. The highest increase in demand (except for "other machine tools") was 4.5 percent per year for "wire working machines." In real value terms, the highest average annual increase (4.9 percent) was enjoyed by "shears and sheet metal working machines."

The rapidity of these changes is revealed by the six-digit product group data comparison of 1982 and 1989—a period of time where the classification scheme remained constant. The demand for "toggle lever presses," as represented by the average annual rate of growth of real output, increased at 39.9 percent per year (see table 2.3). The highest reduction of real output, at 45.5 percent, was exhibited by the product class "shears and punching machines with manual and foot operation."

Extending the period of comparison over three decades, the changes are less dramatic but they reveal how stable the changes in the structure of demand are. Between 1960 and 1989, the real output of "multi spindle boring units" rose by an average of 8.7 percent (see table A.3). The largest reduction in real output appeared in the group "small lathes," with -10.5 percent per year.

In order to reveal the "value structure of demand," a measure analogous to the traditional measure of "Kilogram-prices"[14] was utilized. Since the weight of iron is no longer a good indicator of the value of machine tools, the measure of "unit value" was applied. The unit value is the average value of a unit produced in a specific product group.

---

13 This structure goes back to the development of the heavy-metal industry in the Ruhrgebiet. At the turn of the century a concentration in the production of large machine tools took place in the region, particularly of large presses. The ability to use the Rhine river for difficult transports facilitated the concentration of the production of metal forming machine tools. See Spur (1991) and figure 2.1.

14 Kilogram-prices have been the traditional unit for calculating the prices of machines in the mechanical engineering sector (Hoffmann 1965, pp. 571-574). Due to the important impact of the price of iron on the value of machines, the prices for the unit weights of iron and steel were used to calculate the price of a machine.

Table 2.2: Machine Tool Production by Type for West Germany, 1989 and 1960: Average Annual Growth Rates of Units, Value, and Unit Value

		1989			1960 Production in prices of				Average annual growth rate 1960-1989 (percent)		
Product Code	Type of machine tool	Units	Value DM 1,000	Unit value DM	Units	1960 Value DM 1,000	1989 Value DM 1,000	Unit value DM	of units	of real value	of unit value
32111	Planing, shaping, slotting and broaching machines	275	5,7831	210,295	3,208	67,402	221,079	68,915	-8.1	-4.5	3.9
32112	Lathes, cutting-off machines, threading machines	8,374	846,882	101,132	14,038	267,200	876,416	62,432	-1.8	-0.1	1.7
32113	Turret lathes, automatics	2,936	1,253,970	427,101	5,991	163,159	535,162	89,328	-2.4	3.0	5.5
32114	Drilling, boring and tapping machines	14,770	287,856	19,489	16,457	128,957	422,979	25,702	-0.4	-1.3	-1.0
32115	Milling machines, horizontal boring and milling machines	9,132	1,507,215	165,048	8,919	224,147	735,202	82,431	0.1	2.5	2.4
32116	Sawing and filing machines	9,163	327,483	35,740	10,438	35,274	115,699	11,084	-0.5	3.7	4.1
32117	Grinding, lapping and polishing machines	20,738	1,653,034	79,710	40,469	236,415	775,441	19,161	-2.3	2.6	5.0
32118	Gear cutting machines	919	430,582	468,533	1,678	81,080	265,942	158,488	-2.1	1.7	3.8
32119	Other machine tools, metal cutting type	25,333	2,628,201	103,746	2,286	90,231	295,958	129,465	8.7	7.8	-0.8
32110	Accessories, parts and components for machine tools, cutting type		1,402,077			112,759	369,850				
3211	Machine tools, cutting type	91,640	10,395,131	113,434	103,848	1,406,624	4,613,727	44,428	-0.4	2.8	3.3
32121	Hammers, forging, riveting, bending and straightenig machines etc.	3,633	478,254	131,642	4,869	49,704	163,029	33,483	-1.0	3.8	4.8

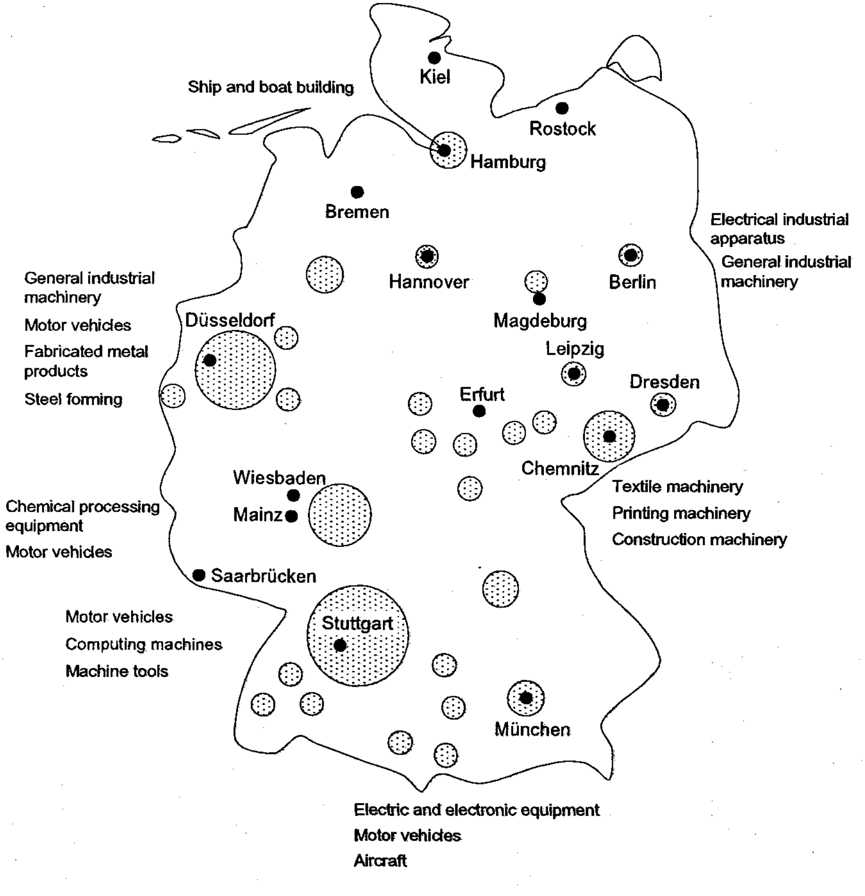
Table 2.2: continuation

32122	Mechanical presses	14,451	748,486	51,795	8,227	206,032	675,785	82,142	2.0	0.4	-1.6
32123	Hydraulic presses	2,577	625,496	242,723	1,946	98,405	322,768	165,862	1.0	2.3	1.3
32124	Shears and sheet metal working machines	14,922	1,283,823	86,036	14,360	96,958	318,022	22,146	0.1	4.9	4.8
32125	Wire working machines for the production of bolts, srews etc.	15,988	675,355	42,241	4,505	97,347	319,298	70,876	4.5	2.6	-1.8
32126	Special machines for the production of bolts etc., rolling machines	388	106,724	275,062	1,554	37,142	121,826	78,395	-4.7	-0.5	4.4
32120	Accessories, parts and components for machine tools, forming type		594;734			53,824	176,543				
3212	Machine tools, forming type	51,959	4,512,872	86,854	35,461	639,410	2,097,265	59,143	1.3	2.7	1.3
	Machine tools, totals	143,599	14,908,003	103,817	138,945	2,046,034	6,710,992	48,300	0.1	2.8	2.7
	Production value per employee (DM): (prices adjusted to 1989)			152,903				65,859	2.95%		
	Employment 1989 and 1960:			97,500				101,900	-0.15%		

Note: General price index for machine tools: 1960 = 35,4 ; 1989 = 116,2 ; basis 1985 = 100.

Sources: VDMA Machine Tool Statistics (1960/61; 1989).

Figure 2.1: Geographical Distribution of German Machine Tool Firms and User Industries in 1990



Source: Based on Spur (1991, p. 14).

Table 2.3: The Products with the Highest and Lowest Annual Growth of Real Output in the West German Machine Tool Industry, 1982-1989

Rank	Product	Average annual rate of growth of real output, 1982-1989 (percent)
1	Other metal cutting machines, not elsewhere classified (n.e.c.)	49.5
2	Toggle lever presses	39.9
3	Other mechanical presses	30.1
4	Spinning machines	20.5
5	Other wire working machines	18.4
6	Other lathes	15.9
7	Other metal forming machines, n.e.c.	14.9
8	Assembly units	11.9
9	Sheet rolling machines	14.4
10	Other hydraulic presses	10.6
11	Cylindrical grinding machines for special purposes	10.4
12	Hydraulic drawing presses	9.9
13	Ultrasonic, electrical discharge, electronic beam and laser machine tools	7.0
14	Gear grinding, lapping, polishing machines	6.4
15	Tool milling machines	6.1
62	Single spindle chucking automates	-7.5
63	Riveting machines	-8.2
64	Special purpose planing and shaping machines	-10.0
65	Wire bending and spring winding machines	-11.3
66	Concrete bar bending machines	-11.4
67	Eccentric presses over 160 tons	-12.0
68	Special purpose hammers	-12.1
69	Lathes over 800 mm diameter	-12.5
70	Other grinding, lapping and polishing machines	-12.6
71	Lathes for precision mechanics	-14.5
72	Circular cold and hot sawing machines	-15.2
73	Cutting-off machines	-16.3
74	Chain making machines	-18.8
75	Hammers for drawing-out and die-forging hammers	-20.4
76	Shears and punching machines with manual and feet operation	-45.5

Note: The sample consists of 76 six-digit commodities out of a total of 87 categories which are classified in 10 five-digit groups of metal cutting and 7 five-digit groups of metal forming machine tools (see table 2.2). Real output is defined as quantity of units.

Sources: VDMA Machine Tool Statistics (1982/83; 1989).

In order to measure the increase in the value of specific types of machine tools, the average annual growth rate of the unit value (DM per unit) over the period ranging from 1960 to 1989 was taken. This growth rate was plotted, together with the unit value in 1989 (in thousand DM), in a two-dimensional diagram (see figure 2.2). The following types of machine tools are found below the zero growth line and below a unit value of DM 100,000: drilling machines, mechanical presses, wire working machines, and other cutting machine tools. Together, these categories represent 29 percent of the total production value in 1989.

The demand for machine tools in most developed countries exhibits several common features. Nevertheless, there is no uniform development. The demand in Germany was manifold (see figure 2.3). Most of the capital equipment of Germany was damaged during the Second World War. The rebuilding of the capital stock led to a significant growth of demand in the 1950s. That demand was oriented towards high-quality (combining higher productivity and modern designs), due to the opportunity to equip plants with the latest machinery. Demand was still strong at the beginning of the 1970s, due to a domestic investment boom. The slow upswing of 1973 ended with the oil price shock recession of 1975. Consumption of machine tools dropped by approximately 50 percent in this period.

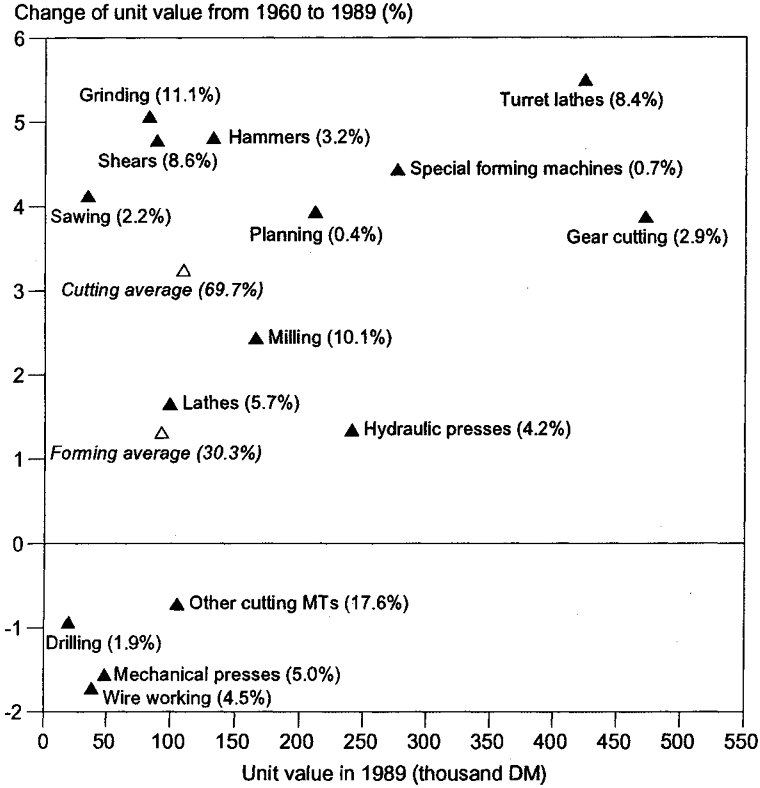
Demand was then partly stabilized by exporting to centrally planned economies—countries like the former USSR. The following upswing increased domestic demand, which could not be met by domestic producers. This sparked a demand for imports. Japanese producers were the prime beneficiaries of this situation and substantially increased their share of imports into Germany—from 3 percent in 1975 to 17.6 percent in 1989 (VDMA Machine Tool Statistics 1974/75; 1989).

One of the most severe qualitative changes in the demand structure for machine tools was due to the development of numerically-controlled machine tools. The change can be labeled severe because demand for NC machine tools developed very slowly in Germany (and in other developed countries). Thus, the impact of NC machine tools on future technological competition was not perceived early enough (see table A.5). U.S. entry took place in 1955, Japanese entry in 1956, and the entry of the West German machine tool industry was in 1957. This, however, is a simplified picture of a very complex process. When analyzing the diffusion of NC machine tools in Germany (see figure 2.4), one cannot simply conclude that German firms entirely missed that aspect of development. But, as Jacobsson (1986) has shown, the diffusion of CNC lathes in Germany lagged behind Japan and the U.S.A.[15] Today, a considerable demand for NC machine tools also exists in German industries. As shown with

15 In 1976, the domestic market for CNC lathes in the U.S.A had a volume in units of 1,321; in Japan 1,202; and in Germany 730. In 1984, the volume was 4,575 for the U.S.A; 10,551 for Japan; and 1,001 for Germany.

the analysis of the stock of machine tools in Germany, demand for NC machines has grown—primarily because of substitutability.

Figure 2.2: Unit Values in 1989 and Unit Value Changes from 1960 to 1989 by Type of Machine Tools

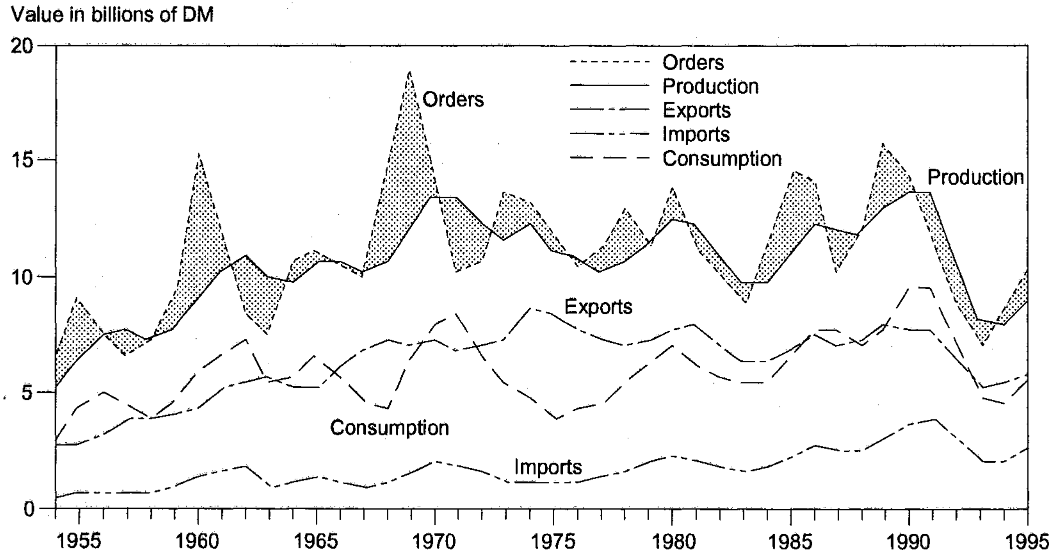


Product group plots based on unit value growth from 1960 to 1989 for the West German machine tool industry

Note: The share of the respective product group as a percent of the total production volume in 1989 is shown in parentheses. Due to the exclusion of the group "accessories & parts" the shares do not add-up to 100 percent.

Sources: Elaboration of VDMA Machine Tool Statistics (1960/61; 1989).

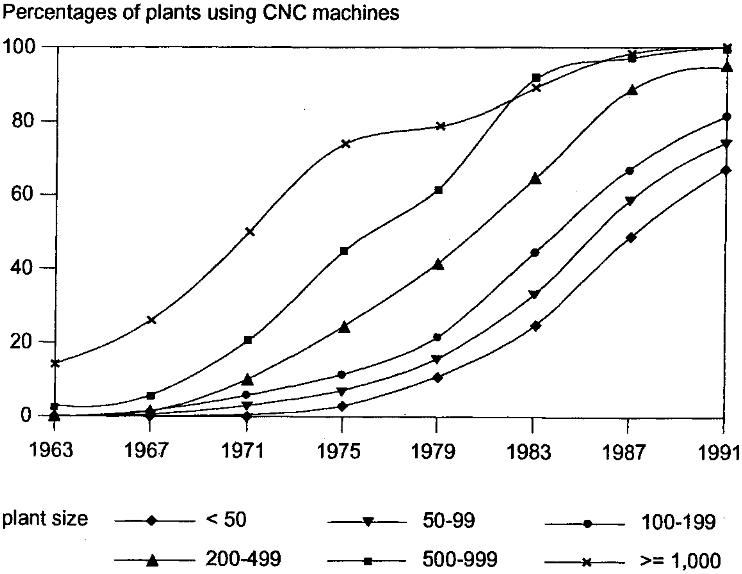
Figure 2.3: Orders, Production, Consumption, Exports, and Imports in Real Values for the German Machine Tool Industry from 1954 to 1995



Note: Prices adjusted to 1985. Since 1991 the figures cover the whole German machine tool industry including the New States of Germany.

Sources: VDMA Machine Tool Statistics (various years); Jahresgutachten 1995/96 des Sachverständigenrates zur Begutachtung der gesamtwirtschaftlichen Lage (p. 392).

Figure 2.4: Diffusion of CNC Machines in the West German Mechanical Engineering Industry



Source: Hauptmanns, Saurwein, and Dye (1992, p. 70).

Thus, the general picture of machine tool demand drawn by a strategic study on the European machine tool industry also holds for Germany:

> "The overall decline in machine tool volume has been the result of the growth in CNC machines replacing a greater number of conventional machines, the growth in multifunctional machines, the move towards FMC ("Flexible Manufacturing Cells"), and FMS ("Flexible Manufacturing Systems"). However, there has been a growth in demand for machine tools in real value terms ... The development of systems in itself has no such negative impact in the demand for NC machines because systems contain NC machines. Also, the uptake of FMS has been slow while the increase in flexible manufacturing in a broader sense is linked to the demand for NC machines." (CEC Report 1990, p. 20)

The structure of the demand for machine tools in Germany and the demand met by the German machine tool industry has now been analyzed. The changes in the structure of demand are obvious. Thus, it is reasonable to conclude that there were considerable changes in the demand for machine tools. The following section focuses on the second stylized fact, which relates to the supply-side of the market.

2.3 Stylized Fact 2: Significant Stability of Concentration

2.3.1 Concentration and the Size of the Industry

Until the relatively recent past, the concentration of domestic production and the size of the industry exhibited significant stability. In 1974 a steady decline of the number of firms began. This stabilized somewhat in 1990 with 380 firms in the German machine tool industry.[16]

Over the last fifteen years, a number of firms (such as Deckel, Gildemeister, Maho, Müller-Weingarten, Traub, and Trumpf) have sought to become dominant in the industry, but no single firm has been able to achieve this. Trumpf has managed to hold the top sales ranking for the past five years; however, as table 2.4 shows, there is significant mobility in the ranking of the firms.

Another important recent trend worth noticing is the increased concentration of the industry. This is primarily due to the rising merger activity of the Rothenberger Group and the impact of German unification. To some extent, the fluctuations in table 2.4 were only temporary, and have been due to the difficulties of specific firms like Deckel, Maho, and Gildemeister. Due to the bankruptcy of the merged Deckel Maho AG in 1994—a firm with total sales of DM 1,286 million in 1990—this change may become permanent. However, the shifts in rank mobility—including the recent bankruptcies—suggest an increasing intensity of competition. Small increases in concentration and greater competitive pressures go hand in hand in the German machine tool industry.

---

16 Since the accounting procedures have changed, the overall figures might differ in various sources. For example, the VDMA Machine Tool Statistics (1990, p. 6) estimates 380 as the total number of establishments in the West German machine tool industry in the fourth quarter of 1990. The VDMA Machine Tool Statistics (1993, p. 6) lists the number of firms in the West German machine tool industry of 1990 as 245. The difference between 380 and 245 is due, at least in part, to the fact that a number of firms are multi-plant firms and to measurement error. The following main focus in tables and figures is on the firm. In case the VDMA Machine Tool Statistics were used the firm corresponds to the establishment ("Betrieb").

Table 2.4: The 20 Largest German Machine Tool Firms in 1990 and 1994 Ranked According to the Sales of the Group ("Konzern")

Rank 1990	Rank 1994	Firm	Sales (in million DM) 1990	Sales (in million DM) 1994	Firm sales as share (%) of the 1990 production volume of DM 16,425 million in West Germany		3-, 6-, 10-, and 20-firm concentration ratios 1990
1	1	Trumpf	725	785	4.41		
2	7	Gildemeister	716	406	4.36		
3	5	Pittler	665	433	4.05	→	CR3 = 12.8
4	-	Maho	650	-	3.96		
5	3	Schuler	640	677	3.90		
6	-	Deckel	636	-	3.87	→	CR6 = 24.6
7	2	Thyssen	470	710	2.86		
8	8	Traub	453	402	2.76		
9	6	Müller-Weingarten	453	414	2.76		
10	13	Index	360	240	2.19	→	CR10 = 35.1
11	16	Boehringer	356	184	2.17		
12	10	Heller	350	300	2.13		
13	-	Mauser	300	-	1.83		
14	11	Ex-Cell-O	252	258	1.53		
15	18	Chiron	215	170	1.31		
16	4	Dörries Scharmann	214	441	1.30		
17	15	Pfauter	200	193	1.22		
18	-	Schütte	194	-	1.18		
19	-	Schaudt	130	-	0.79		
20	19	Klingelnberg	130	169	0.79	→	CR20 = 49.4
	9	Grob-Werke		310			
	12	Ingersoll		254			
	14	J. Dieffenbacher		200			
	17	Umformtechnik Erfurt		179			
	20	Alfing Kessler		141			

Note: Since 1990, the Journal "Produktion" has published a ranking of the largest machine tool producers in Germany. This table is based on its ranking of firms in 1990 and 1994. The only East German firm explicitly ranked in 1994 is Umformtechnik Erfurt. In case of Thyssen, it is Thyssen Maschinenbau GmbH including Hüller Hille and Diedesheim. Note to the 1994 ranking: Deckel AG and Maho AG merged to Deckel Maho AG which went bankrupt in 1994. Three units of the Deckel Maho AG (Deckel Maho GmbHs in Geretsried, Pfronten, and Seebach) continue their work as part of the Gildemeister Group. The Dörries Scharmann AG merged with the Schiess AG in 1992. Dörries Scharmann is now being restructured. It belonged to the Bremer Vulkan AG, which is bankrupt. The Böhringer GmbH belongs to the IWKA Group.

Sources: Elaboration of Produktion, No. 39, September 26, 1991, p. 3; and Produktion, No. 43, October 26, 1995, p. 3.

Table 2.5: Various Measures of Concentration of the West German Machine Tool Industry, 1987-1993

Industry Definition (SIC/SYPRO-No.)		Number of firms	CR3	CR6	CR10
"3220 Machine Tools & Tools"	1987	917	6.2	11.0	16.3
	1993	927	6.6	11.6	17.1
20 largest firms (see table 2.4)	1990	380	12.8	24.6	35.1
"3211 Machine Tools, Cutting Type"	1988	443	13.3	21.1	28.7
	1993	427	11.2	18.4	25.7
"3212 Machine Tools, Forming Type"	1988	304	21.0	29.7	38.1
	1993	279	22.2	30.2	38.9
"3218 Tools"	1988	905	9.2	15.5	21.0
	1993	1,047	11.3	16.3	20.8

Source: See table 2.4 and Monopolkommission (1996, pp. 84, 157-158, 230).

Concentration ratios measure how much of the total output in an industry is produced by the largest firms in that industry. In German statistics the most common concentration ratio is the three-firm concentration ratio (CR3). Comprehensive measurements concerning the concentration of the German machine tool industry are published by the German Monopolies Commission. To assess how concentrated the German machine tool industry is, figures from the period 1987 to 1993 have been selected (see table 2.5). With the range of three-firm concentration between 6.2 and 12.8 percent, and the number of firms ranging between 380 and 927, the structure of the German machine tool industry is quite atomistic. The degree of concentration changes for more narrowly defined markets, such as for single commodities or types of machine tools, is still classified as "moderately concentrated" (for example, the CR3 for "machine tools, forming type" is 21 percent in 1988). The CR3 for "tools for machines and precision tools" is, at 9.2 percent, considered low. With a CR3 of 13.3 percent, the production of "machine tools, cutting type" is at the lower boundary of what is considered moderate concentration. Checking the rank mobility of the firms in the industry shows how the degree of concentration has changed over time. Table 2.4 indicates a very high mobility in the sales ranking among the seven largest firms within a short interval (between 1990 and 1994). Perhaps this mobility could be a short term phenomenon explained by chance or by unusual shifts in demand. However, this mobility could also indicate a competitive struggle for position and, as such, be an indicator of dynamic competition. Unfortunately, at this point in time there is no further data available which could lead to an intertemporal comparison for the stability of industry positions.

2.3.2 Development of Concentration over Time

Looking at the industry as a whole, concentration does not seem to have changed considerably over time. However, the picture changes when looking at segments of the market (see table 2.6). The CR3 for "machine tools, cutting type" fluctuated, but did not change from 1978 to 1993. The CR3 for "tools" fluctuated and increased by 79.4 percent, with a strong increase between 1991 and 1993 (54.8 percent). With a concentration of 11.3 for "tools" in 1993, the increase in concentration was not dramatic, due to the low absolute value. The situation is different for "machine tools, forming type" (the manufacture of mechanical and hydraulic presses), where the CR3 increased steadily from 14.5 in 1978 up to 22.2 in 1993, which is an increase of 53.1 percent.

A closer look at the concentration process can be based on the frequency distributions of firm sizes in the German machine tool industry. Table 2.7 shows how the number of firms (establishments), as well as employment, decreased drastically in the two lowest size classes (up to 100 employees). In the size class of firms larger than 1,000 employees, the number of firms dropped from 18 to 14 in 1990, but the total number of employees increased in this same period by 24.5 percent. The most rapid increase took place in the size class "501-1,000 employees" with an increase of 57.6 percent for firms and 28.7 percent for employees.

Table 2.7 might give the impression that the changes in firm size were significant. However, figure 2.5 shows that this is not the case. Average firm sizes remained amazingly stable.

This stability is also illustrated when examining entry and exit data for the industry as a whole. From the post-war period until 1955 a large number of firms can be seen entering the industry. Since 1955, mainly exit has been observed. Also, the net entry figures of the large SYPRO Industry "3220 Manufacturing of Metal Working Machines, Tools for Machines, and Precision Tools" are quite low (see table 2.8). Between 1980 and 1994 the average number of firms was 908. The average net entry (entry minus exit) during this seven year period was ten firms. A positive net entry rate of 0.33 percent (or three firms) is low. It is assumed that this entry took place in fields with low entry barriers (industry subgroups such as tools for machines and precision tools, control devices and handling equipment, machine trade, and manufacturing consulting and engineering).

Table 2.6: Concentration Ratios According to SIC and Commodity Groups West German Machine Tool Industry, 1978-1994

Year	Prod. value (mill. DM)	No. of firms	CR3	CR6	CR10	CR25	CR50	Herfindahl-Hirshman-Index
"Manufacturing of Metal Working Machines, Tools for Machines and Precision Tools" (Industry Concentration SYPRO 3220)								
1983	14,700.0	830		10.7	16.2	31.6	47.2	62.0
1987	21,130.4	917	6.2	11.0	16.3	29.5	43.7	57.4
1988								
1989	24,362.4	1,020		11.2	16.7	30.1	44.0	
1990	27,158.7	1,030		11.0	15.9	28.5	41.7	
1991	26,616.8	1,033		10.0	15.2	27.9	41.1	
1992	23,791.2	1,005		15.9	16.2	29.3	42.0	
1993	18,959.5	927	6.6	11.6	17.1	30.6	43.3	58.5
1994	18,375.1	873		11.2	16.5	30.3	43.2	57.6
"Machine Tools, Cutting Type" (Commodity Group 3211)								
1978	5,227.1	467	11.2	19.6	27.8	47.3	65.6	131.5
1980	6,865.3	469	11.6	19.8	28.4	47.9	66.0	134.2
1982	6,706.2	458	9.8	17.6	25.9	46.5	65.8	121.6
1984	6,560.8	434	11.2	19.6	27.2	45.0	64.3	127.4
1986	9,293.5	447	11.8	20.7	28.3	45.8	64.0	133.0
1988	9,599.7	443	13.3	21.1	28.7	46.1	64.0	137.3
1990	11,394.0	463	11.6	19.9	26.9	43.7	61.8	123.5
1991	11,016.0	462	9.3	16.5	23.9	42.4	61.0	107.5
1993	6,525.0	427	11.2	18.4	25.7	44.4	62.8	123.0
"Machine Tools, Forming Type" (Commodity Group 3212)								
1978	2,455.3	356	14.5	24.3	33.8	52.9	69.5	169.9
1980	3,036.0	332	15.3	25.3	34.8	53.2	71.3	180.4
1982	3,092.0	327	16.5	26.5	35.3	57.1	73.4	193.9
1984	2,870.7	294	18.4	28.6	37.3	57.0	72.7	213.9
1986	3,765.9	307	22.3	31.2	38.8	57.4	73.1	259.9
1988	3,867.3	304	21.0	29.7	38.1	57.6	74.0	247.9
1990	4,779.0	326	20.3	29.6	38.1	56.7	72.6	244.4
1991	4,873.0	309	21.1	29.1	36.6	56.2	73.4	231.3
1993	3,640.0	279	22.2	30.2	38.9	58.9	74.7	261.7
"Tools for Machines and Precision Tools" (Commodity Group 3218)								
1978	2,678.9	815	6.3	11.4	17.1	30.0	43.2	58.7
1980	3,464.5	845	6.0	11.0	16.8	30.1	43.2	58.1
1982	3,649.9	817	6.9	12.3	17.8	31.3	44.0	61.9
1984	4,094.9	810	7.9	13.3	18.9	31.9	44.0	65.0
1986	5,389.2	826	7.6	13.4	19.1	31.5	43.2	64.1
1988	5,756.8	905	9.2	15.5	21.0	32.8	43.7	73.5
1990	7,568.0	1,026	8.1	13.9	19.1	30.9	41.4	62.3
1991	7,701.0	1,053	7.3	13.0	18.1	30.2	40.5	57.7
1993	6,366.0	1,047	11.3	16.3	20.8	32.5	42.6	81.8

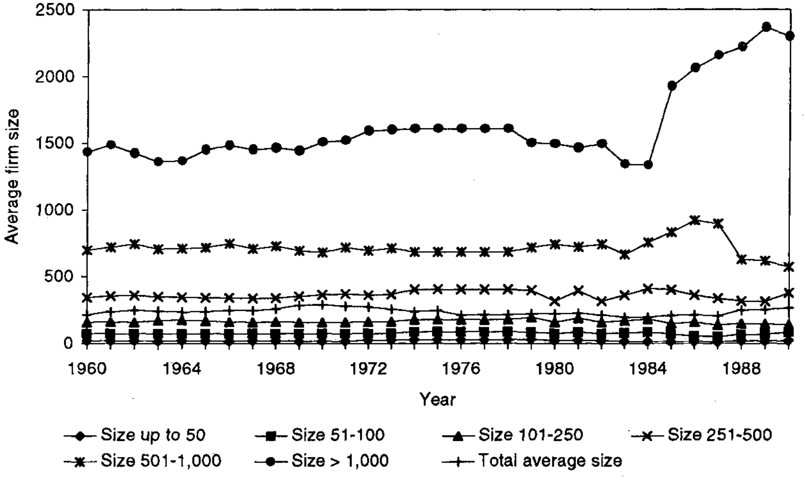
Sources: Monopolkommission (1996, pp. 157-158); Statistisches Bundesamt (1989-1994).

Table 2.7: Distribution by Firm Size for the West German Maschine Tool Industry, 1960 and 1990

Firm size in employees	1960 Firms number	1960 Firms percent	1960 Employees number	1960 Employees percent	1990 Firms number	1990 Firms percent	1990 Employees number	1990 Employees percent	Change 1960-1990 in the number of firms percent	Change 1960-1990 in the number of employees percent
to 50	192	41.0	3,979	4.3	110	28.9	2,244	2.2	-42.7	-43.6
51-100	76	16.2	5,644	6.0	51	13.4	4,284	4.2	-32.9	-24.1
101-250	90	19.2	14,325	15.4	98	25.8	13,158	12.9	8.9	-8.1
251-500	60	12.8	20,510	22.0	55	14.5	20,604	20.2	-8.3	0.5
501-1,000	33	7.0	22,983	24.6	52	14.5	29,580	29.0	57.6	28.7
over 1,000	18	3.8	25,799	27.7	14	3.7	32,130	31.5	-22.2	24.5
Totals	469	100.0	93,240	100.0	380	100.0	102,000	100.0	-19.0	9.4
Average firm size			199				268		35.0	

Sources: VDMA Machine Tool Statistics (1960/61; 1990).

Figure 2.5: Average Firm Size in Employees for Six Size Classes in the West German Machine Tool Industry, 1960-1990



Note: Data for 1974, 1975, 1977, and 1978 is missing. Therefore, the line chart uses a straight line interpolation for these missing values.

Sources: VDMA Maschine Tool Statistics (various years).

Table 2.8: Official German Manufacturing Statistics for SIC/SYPRO-No. 3220 "Manufacturing of Metal Working Machines, Tools for Machines, and Precision Tools" (includes only West Germany)

Year	No. of firms	Total employ-ment (firms)	Sales (million DM)	Average firm size	Net entry	Sales per empl. (in thou-sand DM)	No. of plants	Total employ-ment (plants)	Average plant size	Plant to firm-ratio
1980	843	147,572	15,069	175		102.1				
1981	848	145,253	15,188	171	5	104.6				
1982	837	141,111	14,694	169	-11	104.1				
1983	830	133,310	14,722	161	-7	110.4	930	134,732	145	1.12
1984	834	128,437	15,470	154	4	120.5	932	131,232	141	1.12
1985	846	136,175	17,949	161	12	131.8	937	138,435	148	1.11
1986	869	144,242	20,805	166	35	144.2	962	145,634	151	1.11
1987	917	145,547	21,130	159	48	145.2	1,009	147,127	146	1.10
1988	907	144,732	21,802	160	-10	150.6	998	144,631	145	1.10
1989	1,020	155,535	24,362	152	113	156.6	1,116	153,959	138	1.09
1990	1,030	163,656	27,159	159	10	166.0	1,123	161,518	144	1.09
1991	1,033		26,617		3		1,120	158,364	141	1.08
1992	1,005	149,269	23,791	149	-28	159.4	1,087	145,857	134	1.08
1993	927	124,671	18,960	134	-78	152.1	996	121,352	122	1.07
1994	873	107,348	18,375	123	-54	171.2	941	105,330	112	1.08
Averages:	908	140,490		157			1,013	140,681	139	1.10

Sources: Statistisches Bundesamt (various years).

It can be concluded that the concentration of manufacturers in the German machine tool industry is stable. And, as the overall figures indicate, concentration is quite low. For the industry as a whole, the Herfindahl-Hirshman-Index was 58.5 in 1993 (the value for a monopoly would be 10,000). This leads to the third stylized fact, the observation of limited economies of scale.

2.4 Stylized Fact 3: Limited Economies of Scale

The aim of this section is to provide some information on the limited economies of scale in the German machine tool industry. The following procedures can be utilized in order to gain an estimate of these economies of scale. There are roughly four techniques to measure this relationship. Some are suitable for the minimum efficient plant size, others for the minimum efficient firm size, and some are suitable for both (for an overview see Scherer and Ross 1990, pp. 111-118). The techniques can be categorized as follows: (1) analyzing profitability as a function of size, (2) statistical cost analysis (3) the survivor technique, and (4) the engineering approach. The estimations of economies of scale in this section are based on the survivor technique. The survivor technique applies the idea that firm or plant sizes that survive and increase their share of industry production are efficient. This estimation procedure was developed by Stigler (1958). It relies on the direction of market forces, comparing at two points in time the size classes of firms/plants and identifying the one with the highest growth in share. According to Stigler, the estimated efficient firm size is the "one that meets any and all problems: strained labor relations, rapid innovation, government regulation, unstable foreign markets, and what not" (p. 56).

The existence of economies of scale depends on the characteristics of the production function in the machine tool industry. If long-run average costs or unit costs fall with greater production volume instead of rising proportionally, then we have economies of scale until a point where they are exhausted. These economies of scale are due to the existence of fixed costs in R&D, production, marketing, and administration. There are at least three levels at which these economies of scale can be analyzed: the product, the plant, and the firm with one or more plants. When the output volume is reached where the economies of scale are exhausted, the minimum efficient scale (MES) is attained. This is an important parameter of the market structure, since it tells us how much room is left in a market (of a certain size) for efficient producers in the long-run competitive equilibrium.

This study's estimation will distinguish between static and dynamic economies of scale. Static economies of scale are related to the output and decreasing unit costs for a certain time period with a given state of technology and a given set of factor prices. With changing technology and different factor prices, changes in the economies of scale will also occur. Dynamic economies of scale are a result of learning processes and the accumulation of experience over time. With production, workers and managers become more efficient. Moreover, entrepreneurial activities are assumed to generate learning.

2.4.1 Static Economies of Scale

This section explores the range in which economies of scale in the German machine tool industry might fall. In order to accomplish this, a number of proxy measures commonly used by industrial economists in their empirical work were applied. The "mid-point" plant size by Weiss (1963), for example, identifies the hypothetical plant where "half of the output of an industry comes from plants larger than its mid-point plant and half from smaller plants" (p. 73). This is equal to the median of the firm size distribution. Since the complete plant size distribution of the German machine tool industry was not available, the figures for the "mid-point" size class were used to approximate the minimum efficient scale measure.

Another proxy measure used is that proposed by Comanor and Wilson (1967). They suggest the use of "the average plant size amongst the largest plants accounting for 50 percent of industry output" (p. 428). This measure, which is larger than the mid-point, has also been approximated using the largest employment size classes of the firm size distribution.

Table 2.9: Various Estimates of Minimum Efficient Scale (MES) and Minimum Efficient Plant Size (MEP) for the Machine Tool Industry (in employment figures)

Approach of MES and MEP measurement	Weiss (1963) U.S.A. 1954	Own calculation West Germany 1960	Lyons (1980) U.K. 1968	Own calculation West Germany 1989
"Survivor technique"	500			615
"Mid-point measure" (Weiss)		467		440
"True mid-point" (median)				200
"50% largest firms" (Comanor/Wilson)		956		1,000
"Plant-to-firm ratio measure" (Lyons)			197	
Industry size				97,500
Concentration CR4	18%			
MES and MEP as percent of industry sales or employment			0.27%	0.63% (survivor)

Sources: Weiss (1963); Lyons (1980); VDMA Machine Tool Statistics (1960/61; 1989).

Table 2.9 shows the estimates of minimum efficient size as measured by the number of employees.[17] The range is between 200 (true mid-point, the median

17 Since multi-plant firms are very rare in the West German machine tool industry—the number of plants is only 5 to 10 percent larger than the number of firms (see table 2.8). There is no sound basis to measure economies of multi-plant operation. This study

based on individual distribution data for 1989) and 1,000 (50 percent of the largest firms as per Comanor and Wilson). According to the survival technique, the minimum efficient scale of the German machine tool industry in 1989 was 615 employees. This seems very reasonable although the values fluctuate according to the changes of the size distribution. Comparing 1989 with 1960, the single measures are quite stable.

Since the calculated measures of the economies of scale in the German machine tool industry are stable over time, additional insights into scale economies derived from the production of specific types of machine tools are of interest. For that purpose the only relevant data available is for 1959.[18] The employment data for 1959 distinguishes employment according to various types of machine tools production. This data allows both the calculations, using the "mid-point" and the "50 percent of the largest plants," to be made.

The minimal efficient plant size is calculated in terms of employees and in units per year. The units per year were derived from calculating the average output in units per employee. As table 2.10 indicates, the lowest efficient size was 64 (using the mid-point) and 100 (using the largest firms) for the production of "sawing and filing machines." The largest minimum efficent size found was 635 (mid-point) and 1,199 (for the largest firms) in the category, "turret lathes and automatics."

The table 2.11 indicates the range of the "lower measure MEP1" (mid-point) and the higher "MEP2" (half of the larger plants). If one examines the lower measure MEP1, the range for the minimal efficient plant size is from 113 units of hydraulic presses per year to 514 units of grinding and lapping machines per year. Even more interesting is the minimum efficient plant size as related to the size of the market, which indicates how great the difficulties are for attracting customers away from their suppliers (in order to exploit full economies of scale). Less than ten producers of "special machines for the production of bolts and rolling machines" would have the capacity large enough to achieve the available economies of scale in this area of manufacturing. The production of "grinding, lapping, and polishing machines" could be efficiently undertaken by roughly 60 producers.

Table 2.10 provides new insights regarding scale economies for specific types of machine tools. However, there are a few qualifications to be made. First, the estimates are entirely based on data derived from the plant and firm size distributions. Thus, the results are closely related to the existing and unspecified

---

assumes plant and firm size as being equal since the German statistics are related to plant size in a very broad sense ("Betriebsgröße").

18 Employment and production data given for specific product groups is only available in VDMA Machine Tool Statistics (1950-1959).

production technology. Second, the data does not allow one to distinguish between optimal plant scale and the optimal size of firms. But, at least in the detailed analysis for 1959 in tables 2.10 and 2.11, economies of scale at the plant level were captured. Regardless, global competition, economies in R&D, and marketing are certainly important. Third, considering the economies of scale in individual European countries, we must recognize that the measure of minimum efficient plant size depends very much on the size of the home market. However, due to the large export orientation of the German machine tool industry, this qualification is less relevant. Fourth, employment may not be a good indicator for capturing economies of scale. Instead, one might use a variable that measures capital investment and the age of the capital stock.

Table 2.10: Minimum Efficient Plant Size (MEP) for 14 Product Groups of the West German Machine Tool Industry for 1959 (in employment figures)

	MEP1 (empl.) (Weiss: "mid-point")	MEP2 (empl.) (Comanor/Wilson: "50% largest plants")
Planing, shaping, slotting and broaching machines	264	351
Lathes, cutting-off and threading machines	299	446
Turret lathes, automatics	635	1,199
Drilling, boring and tapping machines	175	256
Milling machines, horizontal boring and milling machines	404	787
Sawing and filing machines	64	100
Grinding, lapping and polishing machines	182	382
Gear cutting machines	465	629
Hammers, forging, riveting, bending machines etc.	134	188
Mechanical presses	356	633
Hydraulic presses	245	367
Shears and sheet metal working machines	121	179
Wire working machines	176	291
Special machines for production of bolts etc, rolling machines	162	252
Average machine tools cutting type	311	519
Average machine tools forming type	199	318
Average machine tools	263	433

Sources: Elaboration of VDMA Machine Tool Statistics (1950-1959).

Table 2.11: Minimum Efficient Plant Size (MEP) for 14 Product Groups of the West German Machine Tool Industry for 1959 (in units per year sorted according to MEP1/Industry Output)

	MEP1 (units) (Weiss)	MEP2 (units) (Comanor/ Wilson)	MEP1/ Industry Output (percent)	MEP2/ Industry Output (percent)
Special machines for production of bolts etc., rolling machines	154	240	11.2	17.5
Gear cutting machines	168	228	10.7	14.6
Planing, shaping, slotting and broaching machines	240	320	8.7	11.6
Turret lathes, automatics	435	822	8.5	16.0
Hydraulic presses	113	170	6.9	10.4
Hammers, forging, riveting, bending machines etc.	263	369	6.1	8.6
Mechanical presses	373	663	5.2	9.2
Sawing and filing machines	412	641	4.9	7.6
Wire working machines	165	272	4.2	6.9
Milling machines, horizontal boring and milling machines	308	600	3.6	6.9
Drilling, boring and tapping machines	457	669	2.9	4.3
Shears and sheet metal working machines	393	582	2.8	4.2
Lathes, cutting-off and threading machines	324	482	2.6	3.9
Grinding, lapping and polishing machines	514	1,080	1.6	3.4

Sources: Elaboration of VDMA Machine Tool Statistics (1950-1959).

An analysis of statistical cost curves and engineering estimates would provide further information concerning this important aspect of the industry's structure. It would certainly be very useful to analyze cost and performance data derived from company accounts. Unfortunately, these were not available.

In a study of a sample of fourteen German machine tool firms, Zörgiebel (1983) gathered information on economies of scale as measured by the engineering approach. This approach utilizes information from engineers who plan and design new production units and plants. It also entails a considerable amount of information concerning alternative plant designs, the related investment, and operating costs.

Two-thirds of the firms surveyed by Zörgiebel felt that there were no economies of scale in their production of machine tools. These firms were not only producers of special purpose machines, as might be expected. Plus, when comparing the costs of NC milling machines, the largest cost decreases were not only associated with computer programming, the design, and the planning of the production but also with the input price of control units. Similar decreases can also be expected in the manufacture of mechanical units.

According to the information gathered by Zörgiebel, a minimum efficient plant size of 600 employees is necessary to produce large scale systems such as transfer machines and flexible manufacturing systems. A plant size of more than 1,000 employees is regarded as the upper limit since it would increase unit costs (due to increasing inflexibility and complexity). Thus, 800 to 1,000 employees was regarded as the optimal size for producers of manufacturing systems.

One of the most comprehensive studies of economies of scale in the British machine tool industry was undertaken by Pratten (1971). Pratten concluded that "economies attributable to larger factories appear to be small in relation to other factors affecting performance" (p. 175) and these "conclusions about the importance of economies for large firms are difficult to draw" (p. 179). This study reached a similar conclusion. In addition, new insights covering the German machine tool industry are provided. Enough empirical evidence was available to conclude that static economies of scale are limited in the German machine tool industry.

Although the simple distinction between static economies of scale and dynamic economies of learning ignores the explicit recognition of technological change, additional insight concerning the dynamic economies of the German machine tool industry can be obtained.

2.4.2 Dynamic Economies of Scale

Concerning the long-run behavior of cost, it is reasonable to assume that the average unit costs and marginal costs are not constant. In fact, as output is increased over time unit cost actually decreases in a number of very important industries. For example, when the cumulated output was doubled, real unit costs decreased by 20 to 30 percent for a number of products (Henderson 1968). This relationship, which is based on the impact of increased know-how and experience, is called the experience or learning curve. The "standard" version of the curve assumes that real unit costs decrease exponentially with respect to the cumulative output (as well as a constant elasticity). In some markets, the experience curve is a crucial determinant of market structure, conduct, and performance. This section considers whether there is any real impact of learning concerning the production of machine tools in Germany. It should also be mentioned that there is no data available to test for learning effects in marketing and distribution.

The precise estimation of the experience curve presents measurement difficulties because it is not easy to calculate unbiased unit costs. This is especially true for machine tool firms since they are usually producing heterogeneous products. This is a general problem of the field: how to allocate fixed costs for multiple products? Nevertheless, by looking at the long-run cost behavior of some "representative" types of machine tools in the industry as a whole, we can see an indication of the relevance of dynamic economies of scale. Thus, this study analyzes one traditional product with a comparatively high volume, the universal lathe up to 800 mm diameter. In addition, two products with more advanced technology—numerically-controlled turret lathes and machining centers—were analyzed. For the latter two products, there are five observations each (1985 to 1989) and for the former, 30 observations (1960 to 1989). The production value was deflated by a product specific price index in order to calculate real unit costs. It was appropriate to estimate a linear "cost function" based on the industries' production statistics. One of the study's interesting findings is that there is no effect of exponential learning and no decrease in real unit costs observed in table 2.12.

Table 2.12: Estimated Parameters of Cost Functions for the West German Machine Tool Industry Based on Production Value

	Lathes (1960-1989)	NC Turret Lathes (1985-1989)	Machining Centers (1985-1989)
Output at the			
- beginning	6,940	497	1,118
- end (cumulated)	133,644	2,623	7,300
Real unit costs (in thousand DM)			
- beginning	64	264	561
- end	92	298	552
Slope of regression line (in percent)	0.022	1.04	-0.13
Intercept	59.2	280.3	580.1

Sources: Elaboration of VDMA Machine Tool Statistics (various years).

Since production values at the industry level were used instead of using direct labor costs at the firm level, the estimated "cost functions" for lathes, NC turret lathes, and machining centers convey only a rough indication of the underlying relationship within the German machine tool industry. With this caveat in mind one can conclude that there is no clear indication of learning effects at the industry level. The very small increase in the unit costs of lathes might be due to the increase in the value of their components, such as drives, transmissions, and control units.

Seemingly contrary to this conclusion, Hirsch's (1952) estimates are based on data of a large American machine tool producer covering the period 1945 to 1950. The estimations are based on direct labor costs for 27 lots with about 600 machines, either new products or new models of (semi-) automatic machine tools. Hirsch found that labor progress, management progress, and progress of material supplies are highly interrelated. Hirsch estimated the progress ratios (for machining and assembling of machine tools) that measure the percentage decline in direct labor requirement associated with a doubling of cumulative output. The estimated progress-ratio means are 11.5 percent for machining and 26.3 percent for assembling. As Hirsch (1952, p. 147) pointed out, "(T)hus, after 30-40 lots have been completed, further labor savings are very small." The results of this study are based on industry production values in which the single firms and single models of machine tools are averaged out. Therefore, one can assume that the number of lots already reached is larger than 30, and thus the results are in line with Hirsch's conclusion that further labor savings based on learning are small.

In light of the above analysis the third stylized fact becomes clear: only limited economies of scale exist in the German machine tool industry, and unit costs decrease with the increase of product volume (at least within the limits of 600 to 1,000 employees). Another important related factor has to do with sunk cost: the necessary capital requirements for setting-up plants and running them. This information is useful for the later analysis of the impact of fixed cost on competition. Thus, the next section provides figures concerning capital requirements in the machine tool business.

2.4.3 Underlying Capital Requirements

Information on the funds needed to construct a new machine tool assembly plant, as well as on plants to produce major components and parts, is not readily available. In general, the funds needed depend very much on the type of machine tool to be produced, on the depth of manufacturing ("Fertigungstiefe"), on the degree of flexibility and automation of the plant, and on the resulting production volume and the unit cost aimed at. To proxy capital requirement one has to rely on the few available sources.

The CEC Report (1990, p. 159) mentions three Japanese figures regarding investment in new machine tool plants. The first example is the Kawasaki Plant of Toshiba Tungaloy. This plant consisted of 50 machine tools with a total system cost of about DM 1.9 million or DM 38,000 per unit of machine tool (that is a total of Yen 140 million; the 1989 exchange rate was Yen 100 equal DM 1.37). The second figure concerns the modernization of the same plant. The plant was modernized with system costs of about DM 6.85 million or DM 1.14 million per FMS unit (a total of Yen 500 million for six FMS units). The third example is Brother Industries, who have modernized a plant with 25 FMS units at DM 4.11 million or DM 164,000 per FMS unit (a total of Yen 300 million). The investment costs for these two plants range from DM 4.11 million to DM 6.85 million.

In Germany itself, Maho has invested DM 33 million in the newly acquired East German plant for machining centers in Seebach (Thuringia) (Produktion 1992b, p. 40). For its new plant in Kempten (Bavaria) it is estimated that Maho has invested more than DM 100 million to produce milling machines and machining centers.

Other examples which reveal the capital requirements for plant modernization can be found by analyzing investment figures from annual reports. For example, in 1991 Traub (Traub AG 1991, p. 54) invested DM 12.9 million with roughly an equal share in "buildings" and "plant & machinery." The corresponding figure for the Pittler Group (Pittler 1991, p. 46) was DM 14.7 million. The investment intensity (investment per employee) of the industry as a whole in 1990 was DM 10,070 or 5.1 percent of the sales value (VDMA Handbook 1991, p. 82).

Increasing capital intensity (gross fixed assets per worker) gives further indication of rising capital requirements. Brödner (1990) argues that there is such an ever-increasing capital intensity in the metal working industry of Germany. The gross fixed assets per worker grew (at 1980 prices) from DM 37,000 in 1960 to DM 118,000 in 1983 (Brödner 1990, p. 35). Thus, the capital requirements tripled.

Zörgiebel (1983, p. 168) states that all the firms he has surveyed perceive the capital requirement as a high barrier to entry. That is true for the setup costs of new production and distribution systems, as well as for the capital needed for maintaining inventories and acquiring technological know-how. The capital requirements are especially high in the early stages of entry, when the firm is new and unknown to the market participants. As Zörgiebel points out, capital requirements increase with increasing complexity of production and product. Furthermore, in cases of special purpose machines, the producer usually has to supply the credit for the production needed to fill a new order.

The above figures indicate the magnitude of expected capital requirements. Raising such sums are certainly high obstacles to the entry of new competitors—especially when faced with very low profit margins. Thus, recent entry into the industry is mainly the foreign direct investment of European and Japanese machine tool firms into distribution and service networks in Germany.

2.5 Stylized Fact 4: Increasing Product Differentiation

2.5.1 Product Differentiation as Measured by Product Variety

The basic unit used to measure the extent of product differentiation is a single product, called the *product item* (see Kotler 1997, p. 432 for the definition of seven levels of the product hierarchy). A group of related product items is a *product line.* The composite of products offered by a firm is the *product mix* which corresponds to the degree of product differentiation. The number of different product lines refers to the *width* of a firm's product mix, whereas the *depth* of the product mix refers to the number of items (variants) offered by the company within each product line. The *length* of the product mix refers to the total number of product items of the firm.

The width, depth, and length of the product mix are the basic dimensions for measuring the patterns of product differentiation.[19] Firms operate within a spectrum of narrow or broad product program, with respect to a wide or deep product mix, and whether they exhibit a low, medium, or high degree of product differentiation.

When undertaking these measurements the degree of product differentiation has to be distinguished from the degree of product diversification. The usual methods applied to product diversification measurement cannot be used. For example, methodologies based on SIC (standard industrial classification) counts[20] measures the activities found in the four-digit SIC classification of industries. Machine tool firms usually operate in only one four-digit SIC industry. It makes sense, therefore, to draw the border line between product diversification and product differentiation at this point. Usually, machine tool firms rely only on

19 Kotler (1997, p. 436) introduces a fourth dimension of the product mix, that is, the consistency of the product mix which refers to how closely related the various product lines are in end use, production requirement etc.

20 For a comprehensive and often used measure of diversification, see Rumelt (1974). For a review of diversification studies, see Ramanujan and Varadarajan (1989). For an indepth analysis of diversification in German industry see Schwalbach (1987a; 1987b).

product differentiation since they are manufacturing products in just one of the two broad classes ("machine tools, cutting type" or "machine tools, forming type"). Instead of the SIC classification this study uses the product classification scheme of the industry association (as expressed in the VDW's "Red Book," as the "Directory of Machine Tool Suppliers" is commonly known) to measure product differentiation. This classification scheme was changed considerably in 1989, which may in itself be indicative of a significant amount of "cumulative product differentiation."

Until 1981, the VDW used twelve major product classes or "Hauptgruppen." In 1989, this number more than tripled—to 38 major classes. These new classes offer a truer reflection of the present state of machine tool technology. This study has developed a unique methodology to capture product differentiation (also see chapter 5).

The width and the depth of the product mix was combined to create an index of the product differentiation of firms. The index measures the extent to which a firm is specialized into one product group (as compared to the overall number of product items). To achieve this, the total number of product items that the firm produces in a product class (as defined in the VDW's Red Book) were counted.[21]

The twelve class classification system used in the 1950 and 1981 VDW Directories was utilized to measure the change in product differentiation over time. Only product groups in which the firm was supplying at least one product item were totalled. Since the classification scheme did not change in the period from 1950 to 1981, it can be used to show how product differentiation has changed over more than three decades. Table 2.13 illustrates a significant increase in product differentiation. The share of one-product group producers diminished from 65.5 percent to 37.3 percent. The changes from 1950 to 1981 in all other product groups indicate a significant increase in the pursuit of product differentiation strategies by German machine tool firms.

2.5.2 Product Differentiation as Measured by Product Innovation

This section examines the role of product innovation as a differentiation strategy in the German machine tool industry. For this, a relatively novel measure of the innovative output of the machine tool industry is used—the number of new products brought to the market ("innovation counts"). This measurement approach was first used by Mensch (1975), then by Gellman Research Associates

21 For details on the index see section 5.1.1.3.

Table 2.13: Changes in the Degree of Product Differentation in West German Maschine Tool Firms, 1950-1981

Degree of product differentiation	Number and percentage of firms differentiated according to the VDW Product Group Classification					
	No. of firms	1950 percent of firms		No. of firms	1981 percent of firms	
Low:			65.5			37.3
One product group	308	65.5		123	37.3	
Medium:			32.4			54.2
Two product groups	102	21.7		96	29.1	
Three product groups	36	7.7		47	14.2	
Four product groups	14	3.0		36	10.9	
High:			2.2			8.6
Five product groups	4	0.9		17	5.2	
Six product groups	4	0.9		6	1.9	
Seven product groups	2	0.4		3	0.9	
Eight product groups	0	0		2	0.6	
Number of VDW-Firms	470			330		

Note: This table uses the classification system developed and utilized by the VDW. This classification system remained unchanged from 1938 to 1981. It distinguishes between twelve major groups of machine tools. The firms classified were members of the VDW. In 1950, we could use the degree of product differentiation for 470 firms, and in 1981 for 330 firms.

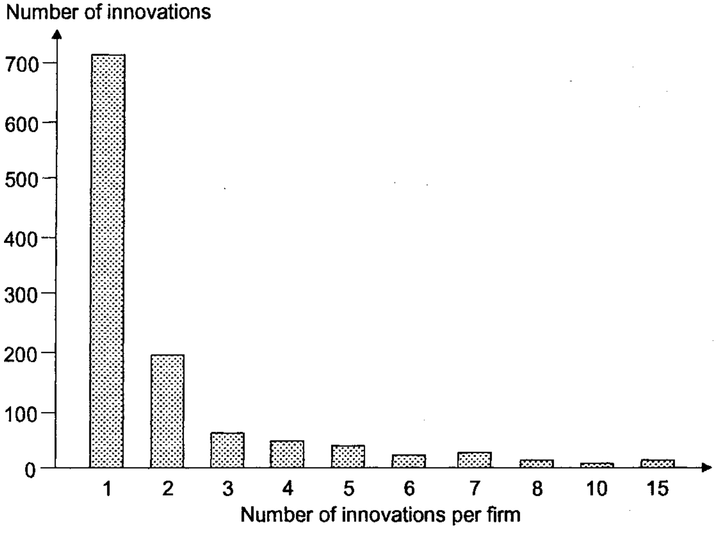
Sources: Elaboration of VDW Red Book (1950; 1981).

(1976, in a report prepared for the United States National Science Foundation), and more recently by SPRU of the University of Sussex (Pavitt 1984, covering British manufacturing industries). The first application of this measurement approach to innovations in the machine tool industry was done by Baily and Chakrabarti (1988).

In these studies, experts have been used to select significant (in terms of technological importance and economic impact) product and process innovations. In addition to the experts, trade and business periodicals were important sources of innovation data. The two major reservations regarding the validity of this approach are: (1) a possible misrepresentation of the sample of significant innovations, and (2) an inappropriate scaling of the significance of the innovations.

The approach used in this study is essentially the same as that used by Gellman, and later by Baily and Chakrabarti. The four leading German machine tool periodicals—"Werkstattstechnik," "Werkstatt und Betrieb," "VDI-Zeitschrift," and "Zeitschrift für wirtschaftliche Fertigung"—were used to collect product innovation data for 1989. A total of 1,139 new product entries were collected. Out of these, 192 major machine tool innovations were found. The percentage of the 192 major product innovations found in each periodical was 64.1 percent in Werkstattstechnik, 32.8 percent in Werkstatt und Betrieb, 1.6 percent in VDI-Zeitschrift, and 1.6 percent in Zeitschrift für wirtschaftliche Fertigung. Thus, two periodicals were found to report the large majority of product innovations in Germany. For the large majority of the firms, only one product innovation was announced in 1989 (see figure 2.6). This might have to do with the firms' internal policies—perhaps there is the requirement that at least one product innovation must be brought forth for each of the bi-annual exhibitions (the "EMO" and "Metav"). The pattern found in the 61 firms with three or more innovations (see table 2.14) shows that out of these 61 firms, 43 are component manufacturers, fifteen are machine tool producers, and three are distributors. The impact of the component producers on the innovative behavior of the German machine tool industry is obvious.

Figure 2.6: Frequency Distribution of 1,139 Product Innovations Made by Firms of the West German Machine Tool Industry in 1989



Note: The innovation counts include machine tools and components for the production of machine tools.

Table 2.14: Innovations Made in Machine Tools and Components in West Germany, 1989 by Firm and Number of Innovative Entries (firms with three and more innovations)

Firm	Number of innovations by component producer	machine tool producer	distributor
Siemens	15		
Bosch	10		
ABB	8		
SKF Bewegungstechnik	8		
Hahn & Kolb			7
Heckler & Koch		7	
Heidenhain	7		
Peddinghaus		7	
Deckel AG		6	
Grossenbacher	6		
Maho AG		6	
Mannesmann Rexroth		6	
AEG	5		
Allen-Bradley	5		
Atlas Copco	5		
Hertel AG	5		
Honeywell	5		
Leroy-Somer Elektromotoren	5		
Schunk	5		
Techno-Commerz	5		
Baumer electric	4		
Boehringer		4	
Drumag	4		
FAG Kugelfischer	4		
Hoerbiger	4		
PSI	4		
Schaudt Maschinenbau		4	
Schleicher	4		
SMC Pneumatik	4		
Tesa SA	4		
Traub AG		4	
Zeiss	4		
Bohner & Köhle		3	
Desoutter	3		
Elan	3		
Gildemeister-DeVlieg		3	
Hoffmann Werkzeugmaschinen			3
Hottinger Baldwin	3		
Index		3	

Table 2.14: continuation

Indramat	3		
Intergraph	3		
Joisten & Kettenbaum		3	
Kaltenbach	3		
Kontron Elektronik	3		
Krautkrämer	3		
Kuka	3		
Leuze	3		
Mannesmann Demag		3	
Optilas	3		
Reis	3		
RWZ	3		
Schuler Pressen		3	
Schunk Werth Meßtechnik	3		
SKF	3		
Stenzel			3
Tebis	3		
Trumpf GmbH		3	
Vogel AG	3		
Wegu-Meßtechnik	3		
Wild Leitz	3		
Zoller	3		

The total sample of 1,139 innovations was screened to see if they could be judged to be machine tool innovations. For example, did they show an improved speed of operation, reduce material requirements, reduce input requirements, or add additional or improved functions. The distribution of the resulting innovations is shown in table 2.15. The largest percentage of these innovations (23.4 percent) are made in transfer machines, machining centers, and flexible manufacturing cells and systems. 16.7 percent are in grinding machines and 13 percent are in turning machines. Thus, more than half of the innovations are in technologically important product groups. Product innovations in advanced fields, such as laser technology based machine tools (3.1 percent) and electric discharge machines (2.6 percent), are less frequent. This might have to do with a low rate of diffusion for these technologies in the user industries. The innovative output of the German machine tool industry in 1989 clearly reflects the firms' attempts to differentiate their products.

The data on product differentiation collected over more than three decades indicates a significant increase in product differentiation. Data on product innovation collected for 1989 indicates strong efforts with respect to product differentiation. Thus, there is much empirical evidence for the fourth stylized fact of increasing product differentiation. This leads to the next important issue—foreign competition.

Table 2.15: Distribution of 192 Product Innovations by VDW-Code of Machine Tool Types for 1989

VDW89 Code	Description	Number of product innovations
8	Transfer machines, machining centers, flexible manufacturing cells and systems	45
6	Grinding machines	32
1	Turning machines (lathes)	25
5	Sawing machines	13
3	Milling machines	10
4	Planing, shaping, slotting and broaching machines	9
34	Other mechanical presses	8
2	Drilling and boring machines	7
23	Thermal beam cutting machines (plasma and laser technology)	6
20	Spark erosion machine tools, EDM	5
44	Other metal forming machines	5
28	Combined punching, nibbling, metal forming and beam cutting machines	5
7	Honing, lapping and polishing machines	3
11	Special purpose machines for metal cutting purposes	3
29	Other separating machine tools	3
36	Bending and straightening presses	3
40	Hammers	2
26	Shears for profiled material	2
30	Eccentric presses	1
32	Toggle lever presses	1
42	Bending and straightening machines	1
43	Drawing machines	1
10	Gear cutting machines	1
25	Shears for sheet metal working	1

Note: The product innovations were filtered out of a total of 1,139 new product announcements in 1989. The sample was drawn from four journals reporting on production technology (VDI-Zeitschrift, Werkstattstechnik, Werkstatt und Betrieb, and Zeitschrift für wirtschaftliche Fertigung).

2.6 Stylized Fact 5: Increasing Foreign Competition

Foreign imports have always tended to offer a chance to increase industrial competitiveness. The German machine tool industry learned this exhausting lesson (among others) at the turn of this century when Germany imported 40 percent of all U.S. exports of machine tools. It is said that this was due partly to lower American prices, partly due to low German custom tariffs, and partly to helpful German distributors. Furthermore, German machine tool imitations worked less accurately than the originals (Buxbaum 1919). It has been argued that it took the German machine tool industry more than a decade to catch up with the American machine tool industry in terms of competitiveness (Schlesinger 1928). No doubt there has been a strong and positive correlation between increasing import competition and increasing domestic competitiveness.

2.6.1 Import Shares

As shown in table A.1, the import ratio (imports divided by consumption) grew from 11.1 percent at the end of the 1950s to 20.6 percent in 1960. Between 1960 and 1974 the import ratio fluctuated around 20 percent, and rose to 28.7 percent in 1975. It then grew steadily until 1995, at which time imports accounted for 44.1 percent of German consumption of machine tools.

As table 2.16 indicates, Switzerland was and is the largest machine tool exporter to West Germany. One exception should be pointed out: in the period from the end of the 1950s to the early 1960s, U.S. firms had a 39.1 percent share of all West German machine tool imports. It is important to note that imports from East Germany (the German Democratic Republic; G.D.R.) were counted separately during this time period as part of "Intra-German Trade." In order to include the impact of this, we have calculated the "G.D.R. Share of Imports" which was 5.4 percent in 1960 and 2.3 percent in 1990.

When comparing the five largest machine tool countries exporting to Germany, the ranking is obviously very stable. The 1990 ranking is: Switzerland, Japan, Italy, Great Britain, and Austria. The only change in that ranking from the 1980 ranking was the decline of France from fourth in 1980 to the sixth in 1990, and vice versa for Austria.

When comparing the entire period from 1952 to 1990, the tremendous decline of the U.S. share has to be mentioned, as does the sharp increase in the amount of imports from Japan. The Japanese share rose from 1.1 percent in 1970 to 15 percent in 1990 (see table A.7 for a comparison of the price competitiveness of West German and Japanese mechanical engineering products; see also Kravis and Lipsey 1971). Similarly impressive is the rise of imports from Italy. In 1952 the Italian share was just one percent. In 1990 it had risen to 14.5 percent. Less dramatic decreases of shares for the following countries should also be mentioned: Great Britain, France, Czechoslovakia, and the G.D.R.

Table 2.16: Import Shares in West Germany for Machine Tools by Countries, 1952-1990 (in percent)

	Percent of total import value				
Import from	1952	1960	1970	1980	1990
Switzerland	49.3	24.2	21.9	26.6	25.9
Japan			1.1	12.0	15.0
Italy	1.0	3.9	11.4	12.1	14.5
Great Britain	7.5	5.6	10.6	7.3	6.5
Austria	2.5	4.0	3.2	3.9	6.0
France	7.2	5.2	11.7	8.8	5.9
U.S.A.	21.4	39.1	12.3	6.3	4.6
Spain		0.3	2.6	3.7	3.8
Netherlands	1.5	2.9	5.2	2.8	3.4
Sweden	3.0	3.7	3.4	3.5	2.5
Belgium/Luxemburg	4.5	4.3	4.5	3.3	2.1
Taiwan					1.6
Denmark	0.5	0.4	0.6	1.3	1.1
Czechoslovakia		4.4	3.9	1.7	0.8
Yugoslavia		0.1	1.7	0.6	0.8
Soviet Union		0.7	1.5	0.5	
Poland		0.3	1.0	0.7	
Hungary		0.7	0.7	1.5	
Rumania			0.8	0.5	
Other countries	1.7	0.3	1.8	2.7	5.4
Totals (percent)	100.0	100.0	100.0	100.0	100.0
Total import value in million DM	40.2	308.2	777.3	1,807.0	4,397.0
Import ratio (percent)	8.6	20.6	24.2	32.7	38.7
G.D.R. share of imports (Intra-German Trade)	1.0	9.4	8.3		2.3

Note: The absolute values of the imports are included in table A.6.

Sources: VDMA Machine Tool Statistics (various years).

Is there a rationale behind the developments described above? Two factors are relevant: (1) the closeness of the various markets to the exporter, and (2) the international position of the exporter. Both factors, as well as a third, explain the dominant and stable import position of Swiss firms in the German market. The third factor is cross-country ownership. A number of significant machine tool producers in Germany have their headquarters in Switzerland (Fischer/Weber and Liebherr to name but two). Cross-country ownership works vice versa as well. German ownership of firms in other exporting countries is also significant, especially in the cases of Austria and Italy.

The vicinity of the market argument, based on low transportation and service costs, also holds for the import shares of Italy and Austria. The influence of market vicinity could also help explain declines in the international positions of France and Great Britain. In the case of the USA, the erosion of their international position has certainly played a role.

Imports were helped by the periods of peak demand for machine tools in West Germany. Those peaks often led to unacceptably long delivery times by the domestic suppliers and in turn to good market opportunities for exporting countries. One indicator of demand peaks is the ratio of the stock of orders to the production volume. This value (see table A.1) had an average of 1.13 in the increasing growth period from 1954 to 1970 and declined (on average to 1.02) in the period from 1971 to 1995. Excluding sales from stock, there has been a general delivery time of more than a year for the domestic supply of machine tools. This has led to a demand in West Germany for foreign imports. However, this coincides with the observation that a high ratio of orders to production volume does not automatically lead to an increase in the import ratio.

2.6.2 Structure of Imports

Another significant feature about increasing import competition relates to the composition of the imports. This study, therefore, concentrates on the period from 1985 to 1990, and on the most interesting types of products—NC machine tools. They are most interesting because of their productivity enhancing potential. In 1990, total machine tool imports to West Germany were DM 4.4 billion, including DM 1.9 billion of NC machine tools—a share of 43 percent. The highest share of the NC imports was 16.9 percent for machining centers in 1990 (see table A.14). Of particular interest are the groups of machine tools with a share exceeding 10 percent of NC imports, that is, lathes, turret lathes, milling machines, grinding machines, and EDM & Laser machine tools. Here the annual increase of imported units was in the range of 13 to 27 percent. Interestingly, all these imports (except grinding machines) exhibited a significant annual decrease in the unit value ("import price") ranging from 3.1 to 15.3 percent. Regarding the activities of Japanese firms in the West German market, two figures related to innovative products are worth mentioning. Their 1990 share of EDM & Laser machine tools imports to Germany is roughly 40 percent, and their share of machining centers imports is 53 percent (VDMA Machine Tool Statistics 1990).

Two aspects concerning the impact of imports need to be separated. First, the impact on the German machine tool industry itself, and second, the impact on the market for machine tools in Germany. The impact on the industry is that they now perceive an increase in competitive intensity, plus they now have to take into consideration Japanese imports (Produktion 1992d). One question is whether these imports and the dominating position of Japanese firms in the global market are behind the poor profit position of a number of large German machine tools companies. Whatever the answer may be, the results of the analysis of the import figures are clear. There is much empirical evidence supporting steadily increasing foreign competition. This leads directly to the final stylized fact—decreasing industry profitability.

2.7 Stylized Fact 6: Decreasing Industry Profitability

Profitability is an important yardstick to evaluate industry performance. Nevertheless, profitability must be carefully interpreted since it also depends among others on the causes and effects of fluctuations of demand and the prices of inputs and outputs. However, in the business literature, high profits are regarded as a major criterion of good performance. But among economists, high profits signal departures of price from marginal cost, reflecting a misallocation of resources and an unnecessary redistribution of income from consumers to investors. Another way of looking at industry performance is to consider productivity. Table 2.17 compares the real production value as a measure of labor productivity over time as well as the number of firms and employment. However, the long-run competitiveness of the indiustry is better indicated by looking at profitability measures.

Concerning profitability, the mechanical engineering industry in most industrial countries belongs to the poorly performing industries. In West Germany it ranks 7th out of 9 industry groups for the period from the mid 1960s until 1982 (Schwalbach and Mahmood 1990, p.113). In fact, Oppenländer's (1990, p. 264) analysis of the cost structure of the German manufacturing sector for 1984 reported that, "firms of the machine tool industry with 1,000 employees and more" are among the lowest performing 4-digit industries of the survey. That group occupied the rank of 396 out of a sample of 405 entries. The 22 large

Table 2.17: Development of the German Machine Tool Industry from 1976 to 1995: Indices on the Number of Firms, Employment, and Production Value

Year	Indices			
	Number of firms	Employment	Real production value	Real production value per employee
1976	100.0	100.0	100.0	100.0
1977	100.0	102.1	95.9	94.0
1978	100.0	101.5	99.5	98.0
1979	97.8	103.1	106.1	102.9
1980	97.8	102.1	114.7	112.3
1981	93.6	102.1	112.6	110.4
1982	97.8	97.4	101.4	104.0
1983	94.6	86.6	94.0	108.5
1984	92.4	85.6	91.1	106.5
1985	92.4	90.7	101.5	111.9
1986	93.6	95.9	114.6	119.5
1987	100.0	96.4	111.4	115.5
1988	82.6	96.9	109.1	112.6
1989	83.6	102.6	119.2	116.2
1990	82.6	106.2	125.2	118.0
1991		101.0	125.5	
1992		92.3	100.1	
1993		75.3		
1993		85.1	74.8	88.0
1994		74.2	72.8	98.1
1995	71.7	70.4	84.8	120.4

Note: The figures in the grey shaded areas include the New States of Germany. The original data for 1976 was as follows: number of firms 460, employment 97,000, and the real production value in prices of 1991 DM 13,732 million. Since 1991 the number of firms is no longer reported due to problems of measurement. The index for 1995 is based on 330 firms. The estimation ranges from 300 to 330 firms.

Sources: The number of firms is based on VDMA Machine Tool Statistics (various years). Data on employment is based on VDMA Machine Tool Statistics (1995). The production values for 1976 to 1978 are based on VDMA Machine Tool Statistics (1989). The production values for 1979 to 1995 and the price index (1991 = 100) are based on VDMA Machine Tool Statistics (1995).

machine tool firms which belong to this group reported a total loss of DM 160 million in 1984. The 39 machine tool firms of the size class "500 to 999 employees" ranked 393rd, having reported a total loss of DM 104 million. In

1993, ten years later, we find losses about four times larger than in 1984, that is, DM 601 million respectively DM 481 million (see table 2.18).

Table 2.18: Distribution of Profits and Profit Margins by Firm Size for the West German Machine Tool Industry, 1990-1994

Firm size in employees (from ... to ...)		1990	1991	1992	1993	1994
20-49	Number of firms	432	432	426	426	
	Profit (million DM)	229.6	63.9	21.5	53.0	
	Profit margin (percent)	10.1	3.2	1.1	2.9	
50-99	Number of firms	266	264	265	223	
	Profit (million DM)	202.0	148.2	24.6	-149.6	
	Profit margin (percent)	7.2	5.2	0.9	-7.1	
20-99	Number of firms	698	696	691	649	623
	Profit (million DM)	431.6	212.1	46.1	-96.6	11.4
	Profit margin (percent)	8.5	4.4	1.0	-2.4	0.3
100-499	Number of firms	264	267	254	229	211
	Profit (million DM)	412.9	-79.7	-437.4	-936.5	-637.3
	Profit margin (percent)	4.2	-0.8	-5.1	-13.4	-8.5
500-999	Number of firms	44	45	40	33	21
	Profit (million DM)	-22.9	-77.9	-245.8	-481.5	-78.0
	Profit margin (percent)	-0.4	-1.4	-5.1	-14.3	-3.0
1000 & more	Number of firms	26	25	20	17	15
	Profit (million DM)	122.7	-177.7	-613.6	-601.4	-294.5
	Profit margin (percent)	1.6	-2.4	-10.6	-14.4	-7.5
Total industry (all firms)	Number of firms	1,032	1,033	1,005	928	873
	Profit (million DM)	947.4	-118.2	-1,259.6	-2,120.8	-1,009.5
	Profit margin (percent)	3.4	-0.4	-5.3	-11.5	-5.5

Note: The industry is defined as "Metalworking Machinery" (SIC Code 3220). The profits and profit margins include entrepreneurial income, that is, the profits and profit margins of the smaller firms are overestimated.

Sources: Elaboration of Statistisches Bundesamt (various years), Fachserie 4, Reihe 4.3.2.

There are mainly two approaches of studying profitability: (1) industry-based studies of price-cost margins (PCM), and (2) company-based studies of rates of profits on investment. The Oppenländer (1990) figures belong to the former approach whereas the Schwalbach and Mahmood (1990) profitability ranking belongs to the latter one. A brief look at the results of both methods will provide further insight into the profitability development of the German machine tool industry.

2.7.1 Profit Margins by Firm Size

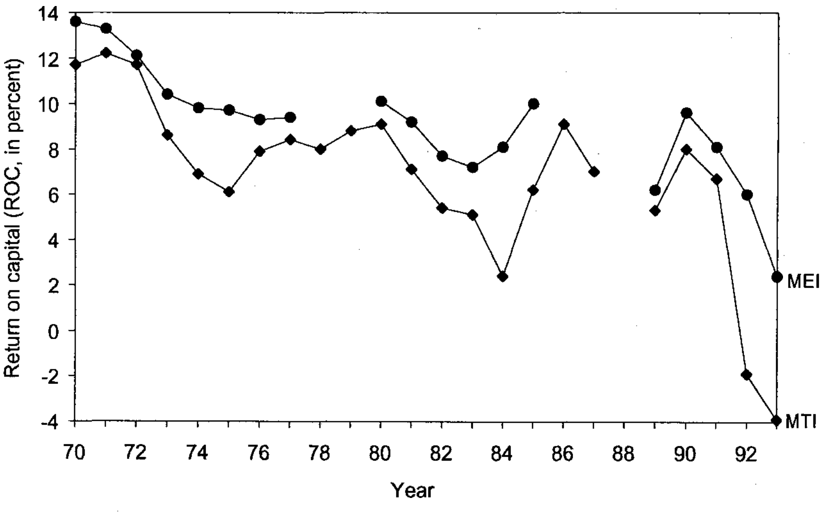
The first way of looking at an industry's profitability is to analyze a measure comparable to the so-called price-cost margin. This method was applied by Uhlmann (1989) and Oppenländer (1990) to German industry. Uhlmann has computed profit measures for 4-digit industries of the West German manufacturing industries for 1977 to 1987. For his study, Uhlmann used a calculation based on the cost structure survey data of the Federal Statistical Office. This calculation used adjusted sales and computed profits as gross sales minus costs for materials and all purchased items minus taxes, interest payments, payroll costs, and depreciation. The derived industry profit was then divided by adjusted sales to compute the profit margin. This profit margin is similar to the price-cost margin (PCM), which generally deducts costs—i.e. the PCM is equal to sales minus material costs minus in-plant payroll costs divided by sales. PCM is a crude measure of net profitability. It signals how much a price is above the "marginal" or manufacturing cost.

We have applied the same method as Uhlmann (1989) for computing profits and profit margins of the West German machine tool industry, except for an adjustment for entrepreneurial income. Table 2.18 shows profits and profit margins of the West German machine tool industry for the period 1990 to 1994. Before going into detail, we should note a few reservations. In each year profit margins decrease with increasing firm size, that is, it seems to be that small machine tool firms are more profitable than the large ones. This is mainly due to the use of unadjusted data. That is, for the large corporations management salaries are included in the payroll cost, but for the small- and medium-sized firms this is not the case. Now, Irsch (1988) has taken this into account with a reduction of the entrepreneur's renumeration. This leads to a considerably smaller difference in the profitability of small versus large firms. Since small firms operate with a less diversified product portfolio, they are exposed to a higher risk, which is indicated by a higher variance of small firms' profits. Irsch (1988) has adjusted profits by an additional reduction of an estimated risk premium and has found no significant influence of firm size on profitabilty. For the purpose of our study it is not neccessary to make assumptions about the adjustment of entrepreneurial income of small firm risk. It is enough if we just take the development of the profit margin for the West German machine tool industry from 1990 to 1994. The decrease from 3.4 to -5.5 percent is obvious. The table also highlights the enormous structural adjustment which happened in that five year period in the industry. The number of firms with 500 and more employees went down from 70 in 1990 to 50 firms in 1994, that is a shake-out of 28.6 percent of the large firms.

2.7.2 Accounting Rates of Return

Until very recently there was no available systematic time series data on accounting rates of return for the German machine tool industry.[22] The data now available provides a clear indication of profitability erosion in the 1980s and a sharp decline beginning in 1990 (see figures 2.7 and 2.8). This profitability data is based on accounting figures that the VDW has collected from its member companies.

Figure 2.7: Return on Capital before Tax for the German Machine Tool Industry (MTI) and the German Mechanical Engineering Industry (MEI), 1970-1993



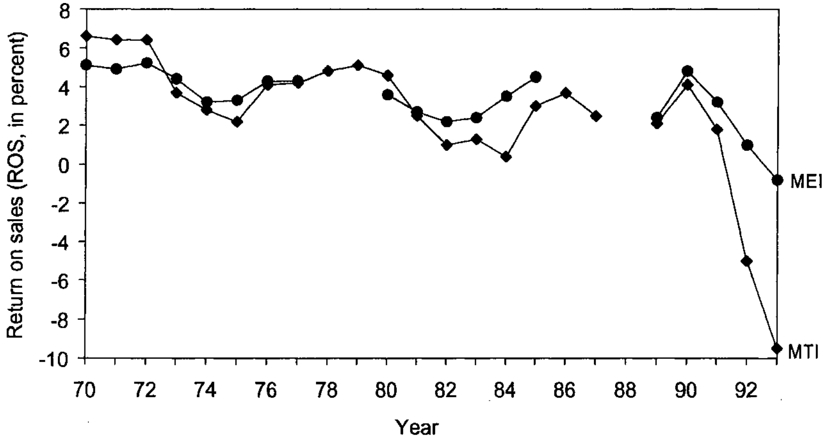
Source: Adapted from Schwab (1996, p. 51).

A third source of profitability data is to directly use the profit and loss statements of the large machine tool firms. This will be done in chapter 5. As indicated by figure 2.8, the sharp decline in profitability began in 1990.

---

22 This has changed with the publication by Schwab (1996). It is a Masters Thesis concerning the development of the German machine tool industry since 1945, edited by the VDW. It serves as an unofficial statistical document since it includes a number of statistics which were previously unavailable in such a comprehensive form. Of particular interest is the profitability data concerning return on capital and return on sales since 1971 (Schwab 1996, p. 51). The profitability measures are "before tax."

Figure 2.8: Return on Sales before Tax for the German Machine Tool Industry (MTI) and the German Mechanical Engineering Industry (MEI), 1970-1993



Source: Adapted from Schwab (1996, p. 51).

The development of the German machine tool industry is characterized best by the six stylized facts described and analyzed above. The important task now is to provide a reasonable explanation of this development, and to test the explanation with a meaningful dataset. This will be done in the next three chapters.

3. Theoretical and Empirical Foundation of the Inefficiency Trap Hypothesis

This chapter is devoted to a detailed analysis of the theoretical and empirical foundations of market behavior in capital goods markets. It focuses upon the microeconomic analysis of competition in markets for machine tools.[23] The goal of this chapter is the explanation of the stylized facts observed in chapter 2.

The foremost issues in analyzing competition in capital goods markets are to understand how market processes direct the competitive behavior of the suppliers in meeting demand. The best way to undertake this analysis is to use the methodology of industrial organization.

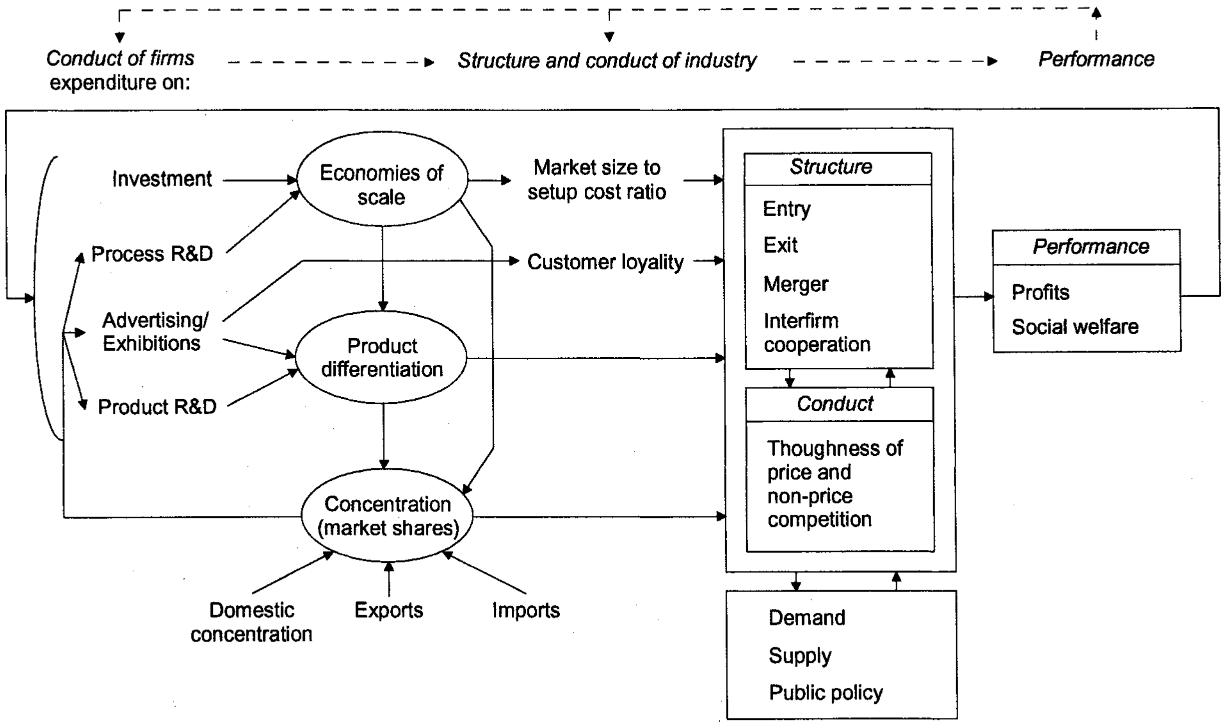
3.1 Introduction

Three aspects of markets are characterized in the industrial organization literature: market structure, market conduct, and market performance (Scherer and Ross 1990). Market structure is characterized by the number of firms that compete in a market, the relative size of the firms (concentration), technological and cost conditions, demand conditions, and barriers to entry. Market conduct is defined by pricing behavior, product strategy, R&D and innovation, and advertising. The main properties of market performance include profits and social welfare. Social welfare is the amount of consumer and producer surplus generated in a market. Using these definitions, the following simple graph of influences within the structure-conduct-performance paradigm can be created (see figure 3.1).

---

23 Such markets are also an arena for potential exchange. A timely example for the exchange of machine tools are large exhibitions like the "Exposition Mondiale de la Machine-Outil" (EMO). These exhibitions are world markets for the exchange of metalworking equipment and services. The EMO is a biannual European exhibition organized by the European Comittee for Co-operation of the Machine Tool Industries. See Albach, Fleischer, and Jin (1994) for a discussion of institutional issues of markets.

Figure 3.1: Graph of Influences within the Structure-Conduct-Performance Paradigm for Mechanical Engineering Industries



Sources: Based on Hay and Morris (1991, p. 240) and Sutton (1991, p. 136).

Capital goods and consumer goods markets differ to a great extent.[24] The difference of competition in capital goods markets and consumer goods markets is primarily due to the differences in the nature of the customers and in the product characteristics. The buyers in capital goods markets are individuals and organizations who acquire capital goods and services to be used in the production of further products or services for sale or rent to others. Thus, the demand for machine tools is derived demand—derived from the demand for final goods. In essence, there exists a producer market which demands the machine tools for the production of its own final goods. This market consists mainly of business firms. These buyers tend to differ from normal consumers. They are oriented more toward profitability than satisfaction. Another significant difference is that industrial purchasing often implies the involvement of several people in the purchasing decision process.

Furthermore, capital goods themselves are distinctively different from those goods purchased by consumers for their own use. Finally, the strategic variables used in competition are regarded as being different.[25] Thus, there is a significant difference as to how, and for which strategic variables, resources are committed (as emphasized by Corey).[26]

The problem of competition in capital goods markets is a problem of product competition and cost efficiency. The questions of how the competitive products should be located in the characteristics space, and how to achieve competitive costs and prices are essential. However, the literature covering industrial organizations is entirely devoted to the analysis of product differentiation of consumer goods (see the literature review in Eaton and Lipsey 1989). Thus, a reasonable question arises: whether the problem of optimal product differentiation exists for capital goods as it does for consumer goods? The extent of economies of scale plays a key role for the differentiation of capital goods. To use economies of

---

24 Capital goods markets have several characteristics that contrast sharply with consumer goods markets. These characteristics are fewer buyers, larger buyers, close supplier-customer relationship, geographically concentrated buyers, derived demand, inelastic demand, fluctuating demand, professional purchasing, several buying influences, direct purchasing, reciprocity, and leasing, see Kotler (1997, pp. 204-206).

25 According to Ames (1968, p. 102), the primary difference lies in the marketing-mix variables: "Changes in marketing strategy (in industrial markets) are likely to be based on product design, cost, or service innovations. Contrast this with a consumer goods company, where advertising, promotion, and merchandising are generally the core elements of the marketing plan."

26 "If any general statement can be made regarding characteristic differences between industrial and consumer-goods marketing strategy, then, it would stress the relative emphasis on technical service and field selling for the former and on media advertising for the latter." Corey (1976, p. 2)

scale extensively, firms must produce one type of capital goods over an extended period of time before producing the next type. To haphazardly produce the output according to the maximal degree of product differentiation would be inefficient due to unexhausted economies of scale.

Each machine tool can be uniquely produced in a variety of designs. The complete range of these designs defines the maximal degree of product differentiation. The single properties are such that each variant is more-or-less suited to certain production processes than others. Production at the maximal degree of product differentiation implies production of custom-built machine tools. The fact that there are numerous standard machine tools which are still produced today provides evidence for the existence of scale economies in the machine tool industry.

Another special feature of product differentiation in the capital goods case is flexibility. Capital goods are defined by their flexibility. Flexible machine tools are ones that are general purpose machines used for batch work in manufacturing and in various workshops for one-off piece work. The less flexible machine tools are created for special purposes. They are defined by their capability of economically machining a specific workpiece or a family of workpieces. In this sense, the choice between a flexible machine and a specialized one does not exist for consumer goods.

An important difference with relevance for the analytical treatment of capital goods is that the choice is confined to product differentiation and efficiency. There is nothing like the uniform welfare density or the uniform income consideration (see Lancaster 1979, p. 324). Demand for capital goods—and in particular for machine tools—depends in large part on the size of the industry which would use them.

The choice of the optimal degree of product differentiation is based on the conditions that demand must be sufficient to justify the production of a highly specialized machine tool. How this relates to the degree of economies of scale in the capital goods industry and in the consumer goods industry is also significant.

When reviewing the state of the art analysis of product differentiation from an analytical perspective (from microeconomic theory and the theory of industrial organization) one gets the impression that product differentiation of consumer goods is a well-developed theoretical concept. The situation for capital goods is quite different. As Lancaster (1979)[27] argues, the analysis of optimal product

27 Lancaster (1979, pp. 322-324) discusses the problem of variety in capital goods. We prefer to use a broader concept of product differentiation including product customization, product diversification, and product variety. This because it is reasonable to observe product differentiation at various levels, including at the general level of capital goods. In other words, the definition rests on whether one focuses on only one good—as

differentiation in capital goods is more complex than that of product differentiation in consumer goods. This might be one reason why modern industrial organization theory is not concerned with the problem.

In modern industrial organization theory, product differentiation is analyzed within the concept of strategic interaction. Such an analysis of market behavior (particularly of oligopolistic markets) focuses on strategic interactions among rival firms using game-theoretic analysis (see Shapiro 1989a for a review of modern theories of oligopoly behavior). The characteristic feature of theories concerning new industrial organization[28] is the mathematical modeling of strategic interaction using game-theory.

For example, in the Cournot model each firm treats the output of its rival as fixed and then decides on the quantity to produce. Such behavior is typical for the machine tool industry. In the Bertrand case, competitors set prices given their rivals' prices. This leads to a continuous undercutting of prices until each firm charges a price that equals marginal cost, but in reality competitors may often end up in a situation where price is lower than marginal cost. The Bertrand model shows how the equilibrium outcome depends on the firms' pricing behavior. It lacks realism for the study of capital goods markets, except in situations of intense competition and price wars. This is because the model assumes that one firm can capture all of its rivals' sales by offering a lower price. For a number of reasons this seldom happens in capital goods markets.

The most important implication for the purpose of this study is that a comprehensive analysis of product differentiation for capital goods needs to use methods of traditional and modern industrial organization theory. The next section provides an overview of these methods and their relationship to the German machine tool industry as a whole, and to its most interesting market, the market for machining centers. However, it begins with a traditional but important analysis of structure.

3.2 A Preliminary Explanation of Structure

Traditional analysis of structure begins with the analysis of size distributions. Size distributions provide a good picture of the overall structure of a market or industry. The general pattern of firm size distributions observed for the German

---

in our case with machine tools—or on two or more goods, say if we would distinguish various different types of machine tools.

28 See Bresnahan (1989) for the basic approach of the "New Empirical Industrial Organization" and the differences between it and the structure-conduct-performance paradigm of traditional industrial organization.

machine tool industry are highly skewed. Because those distributions can be generated by stochastic processes, the question is whether this can be regarded as an "empirical law" driving the evolution of market structure in the German machine tool industry.

One explanation of such a stochastic process is Gibrat's law of proportionate growth: "According to this law, the probability of a given proportionate change in size during a specified period is the same for all firms in a given industry—regardless of their size at the beginning of that period." (Mansfield 1962, pp. 1030-1031) In other words, the observed market structure is the result of pure historical chance, exemplified by a random walk. Quite recently Sutton (1996) has made an attempt to unify traditional theory of market structure with game-theoretic analysis. He concludes, that strategic influences will affect the structure of individual submarkets, however, "the overall size distribution derive from statistical effects that override what is going on 'within submarkets'." (Sutton 1996, Chapter 11, p. 38)

For the analysis of industry structure, it is certainly important to know whether the formal explanation based on probability theory holds or not. Several empirical investigations have provided tests of the basic proposition that firm growth rates are independent of firm size. According to a number of these studies, growth rates tend to decline with firm size in the United States. These findings imply a constraining tendency toward rising concentration over time (Scherer and Ross 1990, p. 144).

Studies in this area have to deal with two sorts of assumptions—those related to the assumed logarithmic normal distribution, and those related to the underlying data. First, the distribution-related assumptions are: (1) that the growth rates are independent of size; (2) that the determinants of growth are normally distributed, and (3) that the interaction of determinants is multiplicative. Such assumptions lead to a stochastic growth process that yields a skewed distribution, and more specifically, the logarithmic normal distribution. This distribution can be approximated by using a Pareto distribution, which allows the linear estimation of a double-logarithmic model. The parameter estimated, the Pareto coefficient, is a measurement of the inequality of the distribution. The higher the Pareto coefficient, the lower the amount of inequality in firm sizes (Steindl 1965) and, thus, the higher the competition in that industry.[29] Second, the data related assumptions lead to three formulations of Gibrat's law (Mansfield 1962). These are that Gibrat's law holds for: (1) all firms including those leaving the industry, (2) only firms emanating in the industry, and (3) only for firms exceeding the minimum efficient size in the industry.

29 Note that this conclusion of early stochastic modeling of market structure rests on the understanding of competition that competition is more intense among equal competitors.

Simon and Bonini (1958) have summarized the essential aspects of Gibrat's law:

> "A stochastic process ... that will generate the normal distribution of the variate will of course, when applied to the logarithm of the variate, generate the log-normal. But in applying the assumptions to the logarithm of the variate, we have in effect, assumed the law of proportionate effect ... by introducing some simple variations into the assumptions of the stochastic model—but retaining the law of proportionate effect as a central feature of it—we can generate the log-normal distribution, the Pareto distribution, the Yule distribution, Fisher's log distribution, and others—all bearing a family resemblance through their skewness." (Simon and Bonini 1958, p. 609)

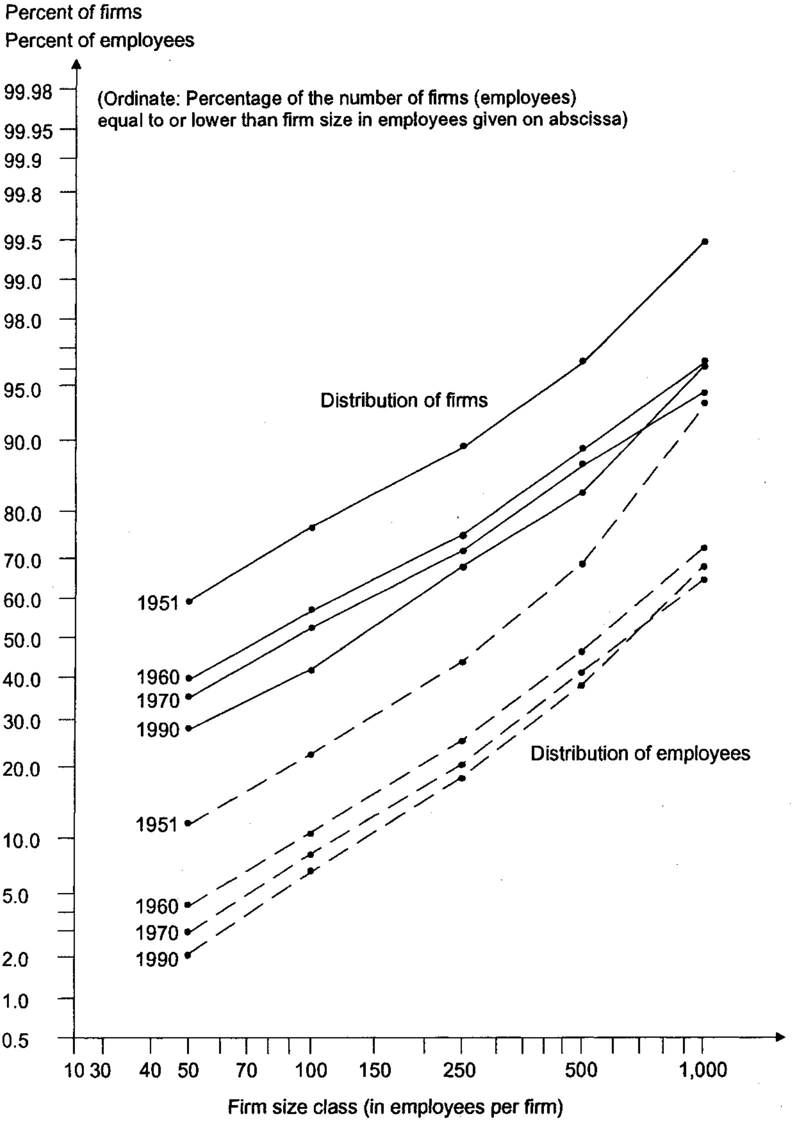
The difference between the Yule distribution and the log-normal distribution lies in the birth rate for new firms. In the case of the log-normal distribution, the firms are already in the system; whereas a random walk with the steady introduction of new firms results in a Yule distribution. This can be approximated by using a Pareto distribution. Thus, there are two main types of distributions to be distinguished in empirical studies:[30] (1) the Yule/approximated Pareto distribution, and (2) the log-normal distribution.

Based on the assumptions of the log-normal distribution and the Pareto curve (and given that firms leaving the industry are not included), this study examines the development of the West German machine tool industry since 1951 based on five points of observation—the years 1951, 1960, 1970, 1980, and 1990. The goodness-of-fit between the theoretical lognormal distribution and the given empirical distribution is tested by using probability paper to directly compare the data of the size distributions according to the number of firms and the number of employees. Thus, one can assess the extent to which Gibrat's law holds true for the West German machine tool industry in each period. Second, by estimating the Pareto coefficients, one can identify how the market structure has evolved.

The distributions according to firms and employees are plotted on probability paper (see figure 3.2; for the purpose of clearness the data for 1980 was left aside). It should be mentioned that the slope of the line is also a measure of

30 Regarding the fit of empirical data, Simon and Bonini (1958, p. 611) conclude: "The log-normal function has most often been fitted to the data, and generally fits quite well. It has usually been noticed, however, that the observed frequencies exceed the theoretical in the upper tail, and that the Pareto distribution fits better than the log-normal in that region. This observation suggests ... that the data should be fitted with the Yule distribution."

Figure 3.2: Firm Size Distribution in the West German Machine Tool Industry, 1951, 1960, 1970, and 1990 (on probability paper)



concentration. In the case of an equal distribution of the firm sizes, the figure would show a vertical line because the greater the value of the slope (Pareto coefficient) the more equal are the firms in size. One important qualification to this distribution data is that the observation of the largest size class is truncated due to the undefined upper bound. This problem could be solved by using the mean values of each size class and plotting those on the respective frequency values. In order to obtain results comparable to the literature (see Steindl 1965), it was decided to omit the largest size class due to the undefined upper bound.

The lines for "the distribution of firms" and for "the distribution of employees" on the probability paper show that Gibrat's law would hold for all the included size classes for 1960 and 1970. These periods exhibited quite equal growth rates and, thus, represent the industry in equilibrium. This situation can be contrasted with 1951 and 1990. In 1951, both of the largest size classes, "250-500 employees" and "500-1,000 employees," are not on the straight line of proportionate growth. In 1990, this was also true for the largest size class. The size class "500-1,000 employees" is most out of equilibrium and not in line with Gibrat's law.

Although the probability plot does not allow any conclusion regarding statistical significance, primarily due to the missing size class "more than 1,000 employees," one can speculate on the reasons related to the outlined disequilibrium. The effect of mergers seems to be especially strong in the size class "more than 1,000 employees." There may also be underlying structural factors that result in such a disequilibrium. Such structural factors are likely to relate to the general supply of materials, labor, and capital, as well as to "a threshold to growth." (Albach, Bock, and Warnke 1984)

More detailed data on the distributions would allow a more rigorous statistical testing. Being aware of the risk of over-interpreting the available data, the Pareto coefficients for the discussed distributions are estimated. For this purpose the most simple version of Gibrat's law of proportionate effect is used, that is the derived Pareto distribution (Steindl 1965, pp. 30-33). This differs from Simon's model which allows us to include a birth-and-death process (Ijiri and Simon 1964).

In the case of the assumed Pareto distribution, i is a measure of firm size, and $F(i)$ equals the number of firms with the size of i or larger. If there is only one firm of size i then $F(i)$ will be the rank of that firm in the industry:

$$\log F(i) = a + b \log i \tag{3.1}$$

Fitting the data to this Pareto function the following coefficients are obtained (see table 3.1). As previously mentioned, the higher the coefficient, the lower the inequality between firms. Steindl has pointed out that:

> "(T)he Pareto coefficient for firms is usually found in the range between 1.0 and 1.5. For all corporations in the U.S. it is approximately 1.1. For German firms, by turnover, it is about 1.1 in manufacturing and about 1.3 in retail trade; for German firms by employment, it is about 1.2 in manufacturing." (Steindl 1965, p. 194)

The coefficients for the German machine tool industry range from 0.70 to 1.15 (using the five size classes but without the largest, "more than 1,000 employees"). Omitting the largest class has led (because of higher frequencies in the second largest class) to a higher level of inequality among firms in the periods, 1951 and 1960. The distribution has actually become more equal since 1951.

Table 3.1: Estimated Pareto Coefficients for the West German Machine Tool Industry, 1951-1990

$F(i)$ in year	b
1951	0.70
1960	0.95
1970	1.05
1980	1.04
1990	1.15
Rank distribution of the 20 largest firms in 1990	1.26

Looking at the upper tail of the distribution in 1990, by using the rank distribution for the largest 20 firms, one obtains a Pareto coefficient of 1.25. These coefficients for the past decade of the German machine tool industry correspond well with those found by Steindl for industries at large.

The important result of these estimations is that the German machine tool industry has a structure comparable to manufacturing industries as a whole. This is consistent with the findings using the probability chart analysis. Two qualifications need to be stressed. First, the omission of the largest size class led to "higher" inequality in the early years, and to a lower inequality in the most recent years. Since Simon's model was not used, an interpretation of the birth-and-death process in the population is not possible. But the analysis has shed some light on the equilibrium between the counteracting forces driving the structure of the German machine tool industry. However, this type of structural analysis provides no detailed insight into the competitive reaction of firms. Particularly lacking is information concerning product differentiation strategies. Therefore, the next section analyzes the demand and supply structure of a typical machine tool market.

3.3 A Typical Market: The Market for Machining Centers

3.3.1 The Market

3.3.1.1 The Demand Function

An example of a typical machine tool sold in an expanding market is a machining center (see Weck 1988, pp. 182-197 for a definition of machining centers and a description of the various types). A machining center is a machine tool which integrates a number of operations (such as boring, milling, tapping, and others) all operating on one part. It is either a stand-alone machine or part of a flexible manufacturing system.[31] Numerical control and an automatic tool changer are characteristic in machining centers. Machining centers usually are the core of a flexible manufacturing system. Each machining center is the equivalent of several machines, each having a specific function.

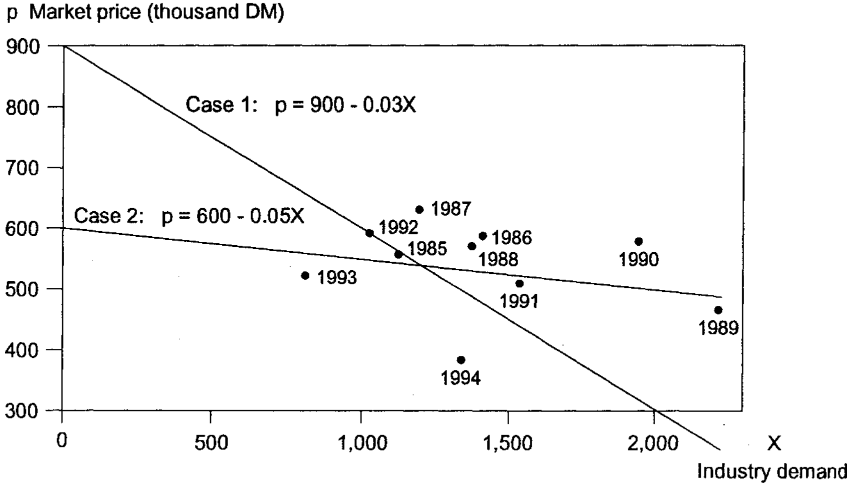
In our case study of machining centers, the data for the estimation of an idealized demand function covers the period from 1985 through 1994. The average price dropped during this time period, while the number of units sold increased—from DM 560,000 and 1,118 units sold in 1985 to DM 385,000 and 1,343 units sold in 1994. The prices are real prices, adjusted to 1985 DM levels (see figure 3.3). How this demand is matched by German suppliers of machining centers and flexible manufacturing system is indicated in table 3.2.

The elasticity of demand for machine tools depends on substitutability. For instance, if there are good substitutes which the buyers can turn to as alternatives, then the demand is relatively elastic. In the case of machine tools that need replacing, the substitutes in "economic terms" are the existing stock of the original machine tools and the internal rate of return for the particular machine tool. If the internal rate of return for the existing machine tool is high, no purchase for renewal will be undertaken.

---

31 As with machining centers, most flexible manufacturing systems are used in metal-cutting operations for the production of prismatic parts, especially for the automobile and the mechanical engineering industry. In Germany, the first flexible manufacturing system was introduced in 1969 by Heidelberger Druckmaschinen AG. The introduction was aided by a government grant and done in cooperation with the University of Stuttgart—using Kearney & Trecker machines and Siemens computers and software. In the early days, machine tool firms produced flexible manufacturing systems primarily for their own purposes, as with Gebr. Heller Maschinenfabrik (see de Pay 1987 for a case study of Gebr. Heller's flexible manufacturing system).

Figure 3.3: Demand Functions for Machining Centers
Case 1 "Steep Slope" and Case 2 "Flat Slope"



There is very little data published on the demand and supply structure of this type of product. A partial exception are the catalogues of machine tool distributors. They usually publish a price list for the machines they distribute. The information this provides, however, is not sufficient for this analysis.

Thus, the only reasonable way to obtain information concerning the demand for machining centers is to use data from the production statistics. Using such data requires the computation of unit values for the machines produced in a certain period, based on the production value of that product group. The unit value is then taken as an average price for that product. The amount of products produced in the respective period becomes the demand. Obviously, there are serious reservations regarding the use of such a method to obtain information on the demand for machining centers. Nevertheless, for the analysis of market structure on an aggregate level, one can use this information to minimally make a distinction between cases involving the demand for machining centers. A scatter plot of unit values (indicating prices) together with the amounts of machining centers produced in the period from 1985 through 1994 has been created in this way in order to estimate the inverse market demand function (with X being the market demand and p the market price). But, before estimating the demand function a further assumption has to be made. This assumption relates to the type of demand function to be used.

Table 3.2: The Market for Machining Centers (MCs) in 1990: Rough Estimation of Share and Volume for West German Machine Tool Firms

Firm	Market share (percent)	Est. sales vol. in units* for the following prices: DM		Overall sales in DM	Employment	Per capita sales in DM	1st major product group	2nd major product group	Estim. MC sales share (percent)
		500,000	800,000						
1. Maho AG	23.8	714	446	714,000,000	3,679	194,074	milling mach.	transfer, MC, FMS	50
2. Deckel AG	21.2	636	398	636,000,000	2,470	257,490	milling mach.	spark eros., EDM	50
3. Heller	11.5	345	216	345,000,000	1,700	202,941	milling mach.	transfer, MC, FMS	50
4. Grob	7.3	220	138	275,043,200	1,700	161,790	transfer, MC, FMS	spec. purp. cutt.	40
5. Hüller Hille	4.9	148	93	370,000,000	2,000	185,000	units f. m. cutt.	transfer, MC, FMS	20
6. F. Werner (W&K, Berlin)	4.3	128	80	160,000,000	600	266,667	transfer, MC, FMS		40
7. SHW	3.0	90	56	90,000,000	340	264,706	milling mach.	transfer, MC, FMS	50
8. Chiron	2.9	86	54	215,000,000	590	364,407	units f. m. cutt.	transfer, MC, FMS	20
9. Heidenreich & Harbeck	2.7	80	50	100,030,400	230	434,915	transfer, MC, FMS		40
10. Alfing Kessler	2.7	80	50	200,000,000	950	210,526	units f. m. cutt.	transfer, MC, FMS	20
11. Stama	2.5	76	48	95,020,800	328	289,698	transfer, MC, FMS	drilling & bor.	40
12. Dörries Scharmann	2.5	75	47	250,000,000	1,100	227,273	lathes & autom.	grinding mach.	15
13. Ex-Cell-O	2.4	72	45	181,000,000	900	201,111	units f. m. cutt.	transfer, MC, FMS	20
14. Waldrich Siegen	1.4	42	26	140,000,000	750	186,667	lathes & autom.	milling mach.	15
15. Steinel	1.3	40	25	100,000,000	500	200,000	units f. m. cutt.	transfer, MC, FMS	20
16. Bohle	1.3	39	24	39,000,000	115	339,130	transfer, MC, FMS	milling mach.	50
17. Diedesheim	1.0	30	19	100,000,000	650	153,846	lathes & autom.	drilling & bor.	15
18. H. Kolb (W&K, Köln)	1.0	29	18	73,000,000	221	330,317	drilling & bor.	transfer, MC, FMS	20
19. Hohnsberg	0.9	27	17	90,000,000	500	180,000	units f. m. cutt.	drilling & bor.	15

Table 3.2: continuation

20. Lindenmaier AG	0.7	22	14	56,000,000	180	311,111	units f. m. cutt.	transfer, MC, FMS	20
21. Buderus	0.4	12	8	30,000,000	230	130,435	grinding mach.	transfer, MC, FMS	20
22. Elha	0.3	10	7	26,000,000	140	185,714	drilling & bor.	transfer, MC, FMS	20
Total	100.0	3,002	1,877	4,285,094,400					

Product classification according to the new classification of the 20th edition of the VDW Red Book (1989).

Based on data for machining centers for cubical workpieces ("NC-Bearbeitungszentren für kubische Werkstücke", Product Code 321196).

Estimated MC industry sales based on an averages price
of DM 500,000 = 3,002 units
of DM 800,000 = 1,877 units
(actual prices)

Actual sales in 1990 = 1,929 units
Actual price in 1990 = DM 688,000

* Firm sales for machining centers (MC) were estimated based on diversification and sales figures. If a firm produced MC or milling machines in its first and second major product groups a share of 50 percent was taken. If a firm's first major product group included machining centers then 40 percent of their sales were accounted for by MCs. For the second major group a 20 percent share was taken. In cases where it was only known that they produced MCs a share of 15 percent was taken.

Sources: VDMA Machine Tool Statistics (1990); VDW Red Book (1989); American Machinist Blue Bulletin (1990); Tecnologie Meccaniche (1990; 1991; 1992).

The demand function must be considered because it is an aggregate of individual market behavior. Empirical studies of pricing behavior in German manufacturing industries reveal oligopolistic pricing behavior (see Wied-Nebbling 1975 and Simon 1989 for an overview of studies concerning pricing behavior). For example, oligopolistic interdependence happens in cases where a firm lowers a price, and as the results of the Wied-Nebbeling survey indicate, then expects that rivals will match this reduction. This is not expected for periods with an upswing in the business cycle or in boom periods. When a firm increases a price, it does not expect its rivals to match the price increase. Again, this does not hold true in boom periods (see Wied-Nebbeling 1975, pp. 187-188). Based on the negative slope of the demand curve, this behavior implies that demand is more inelastic when rivals match a price change than when they do not.

The above assumptions concerning oligopolistic rivalry are only one example of relevant demand conditions and possible rival firm reactions. Although there are numerous alternatives for oligopolistic market situations (for an overview of modern theories of oligopoly behavior, see Shapiro 1989a), three typical demand curves (see figure 3.4) can be distinguished:

1. Chamberlin's (1933) demand curves DD' and dd' of the small group oligopoly solution. The above mentioned two reactions are distinguished. The quite flat demand curve dd' for the case where rivals did not match the price change, and the steeper one DD' for the case where rivals did match the price change.
2. The kinked demand curve as advanced by Hall and Hitch (1939), and Sweezy (1939). The upper end of this curve is the dd'-curve and the lower end is the DD'-curve. Sweezy had assumed that rivals would match price reductions, but hesitate to follow price increases. The interpretation by Hall and Hitch was based on firm interviews regarding price policy. They found that businessmen seek prices to cover average cost, regardless of marginal revenue and marginal cost. Thus, Hall and Hitch assumed that changes in demand would shift the kink to the right or left, and leave prices unchanged; and
3. Albach's (1973) demand function. This demand function models latent demand and customer reactions to competitive demand. It has its roots in Gutenberg's (1955) doubly kinked demand curve. Gutenberg's curve is characterized by two corners which define an inside range, the so-called "monopolistic region." Albach uses a hyperbolic sine function to model this particular demand structure. Empirical studies have provided evidence that this type of demand function is relevant for explaining industrial pricing

behavior in various market situations (see Simon 1989 and Brockhoff 1988 for estimations of a logistic Gutenberg demand function).

The observed price-quantity relationhips allow the estimation of all three types of demand functions. To keep the major portion of this analysis simple, the demand constellation (1) will be used for the following discussion. Two cases are distinguished. One with relative inelastic demand ("steep slope"), and the other with quite elastic demand ("flat slope"). To provide a deeper understanding of the market processes typical for the machine tool industry, this chapter concludes with an analysis using a model that is based on Albach's (1996c) demand function.

The functions for the two cases with a linear demand structure are:

CASE 1 ("steep slope"): $$p = 900 - 0.3\,X \tag{3.2}$$

CASE 2 ("flat slope"): $$p = 600 - 0.05\,X \tag{3.3}$$

3.3.1.2 The Cost Function

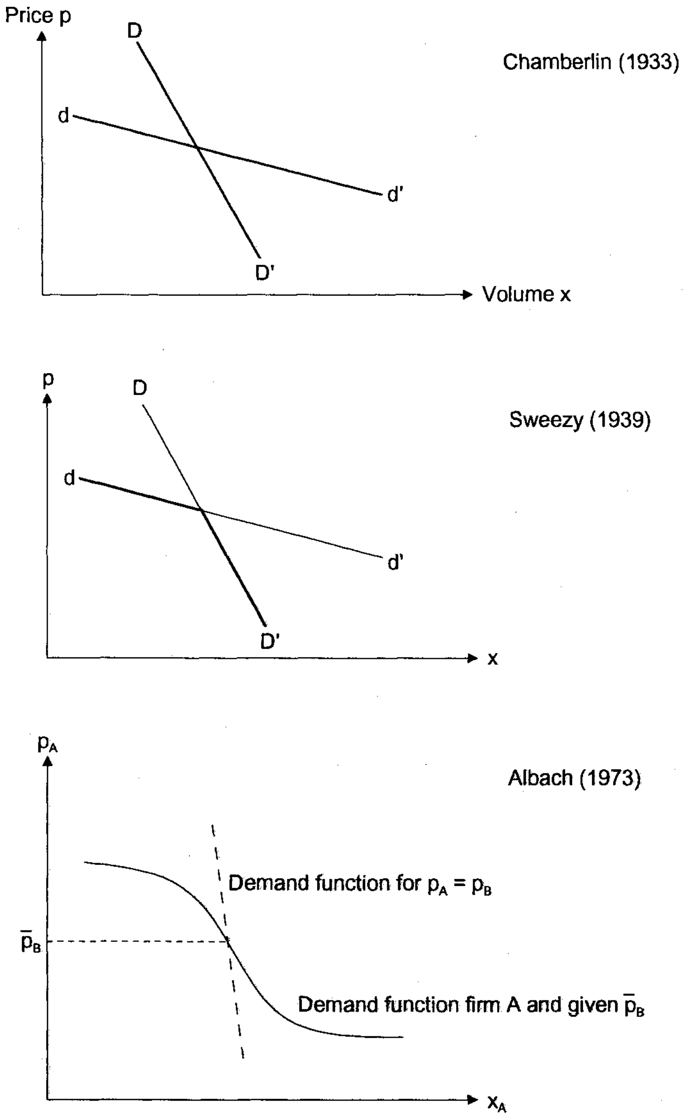
The cost function is a relationship between the cost of production and the level of output of a firm. The purpose of this section is to show how the structural factors of a machine tool firm affect this relationship. Cost behavior is the result of many forces. Among the few important determinants of costs are: size of plant, prices of input factors (labor and materials), rate of output (i.e., utilization of fixed plant), quality of input factors, size of lot, technology, and the organization of manufacturing.[32]

Little is known about how these determinants are to be modeled in the cost function of a machine tool, such as the production of a machining center. Fandel, Dyckhoff, and Reese (1990, pp. 137-191) provide a comprehensive review of the production technology used in the machine tool industry. They do not report any systematic knowledge concerning production functions or cost functions. According to Fandel et al. the relevant issues in the manufacturing of machine tools are the following.

Changes in wages and other input prices are important. These affect the cost per unit of input, as well as the cost minimizing factor combination of labor,

32 See e.g. Fandel (1994) for an overview of the various classification of the determinants of cost behavior. For the pupose of this analysis, the determination of the functional relationship is done at an aggregated level. This is neccessary in order to carry out a microeconomic analysis of market structure.

Figure 3.4: Three Typical Demand Structures



materials, and capital. Although high wages promote substitution of capital equipment for labor inputs, and ought to stimulate research and development of automatic machinery, it seems not to have done this in the case of the German machine tool industry.[33]

There have apparently been few significant adoptions of labor-saving equipment due to technical advances[34], except for the normal adoption of NC/CNC-technologies. One exceptional (and in the end unsuccessful) example is the Kempten plant designed by the Maho AG.

It seems that an efficient organization of manufacturing is one crucial determinant of cost behavior. Evidence for this is indicated by the fact that the vertical division of labor may have pushed up labor costs and created inefficiencies. A VDMA study of 5,500 mechanical engineering firms has revealed that 59.9 percent of the employees work on indirect tasks such as planning, and only 40.1 percent are involved in the production of machines (P. Brödner 1990, p. 36).

Brödner (1990, p. 37) cites another study indicating production inefficiencies due to the high degree of vertical division of labor in the German machine tool industry. This study of the German machine tool manufactures' association, VDW, reported overhead costs two-thirds higher in larger firms (from 251 to 1,000 employees) than in firms with 51 to 100 employees. Brödner argues that industrial productivity depends to a large extent on the skills of the workforce, and that a more appropriate work structure would allow efficiency gains.

Short-run costs are those associated with variation in the utilization of fixed plant or other facilities, whereas long-run cost behavior is a result of changes in the size and the kind of plant. This distinction is based upon the degree of adaptation of all input factors when related to rate and type of output. In a firm, the adjustment to higher or lower output, to new equipment, and to new product designs typically take time, and might involve significant costs, called adjustment costs.

Adjustment is, first and foremost, related to input factors. Adjustment costs are those costs which arise solely from a change in the level of use of an input. Regarding input change within a certain period, there are two dimensions:

---

33 See the estimated capital coefficients in chapter 5. These estimations for the past decade are in the range of 0.05 to 0.08 for a sample of large firms of the German machine tool industry.

34 For a discussion of mass production technologies for the manufacturing of machine tools see E. Brödner (1960). He provides some interesting insights in particular on very large plants in Russia. Canesi (1990) provides an analysis of detailed case studies on the production of milling and boring machines in Italian plants. He argues that there are significant cost advantages in using high-output machinery like FMS.

variable and fixed inputs. One can think of variable inputs as having zero adjustment costs and fixed inputs as having infinite adjustment costs for changes within one period.

In order to estimate a short-run cost function for the manufacture of machining centers, one need to understand which factors are truly variable at which costs. This is because there are differing adjustment costs for different types of input factors.

The market for machining centers in 1990 is analyzed in this study as one relevant example. The percentage breakdown of the costs (the percentages in brackets are the figures for 1976) in the mechanical engineering industry for 1990[35] are:

- 46.4 (39.4) percent for material, merchandise, and other inputs bought,
- 32.5 (41.7) percent for total labor cost, and
- 17.8 (18.9) percent for other costs (maintenance, depreciation, capital costs, and taxes).

Since the costs for materials and other inputs bought are the main variable costs, the increase of this share over time is significant. This share of costs can be assumed as being proportionately variable for the total output and thus, constant per unit. Total labor costs can be regarded as fixed in the short-run, with the exception of cost increases for overtime hours and other extra payments. Since the fixed labor costs are constant in total, they vary per unit with the output rate. The "other costs" are partly fixed. It is reasonable to assume that 50 percent of this category might be varied in the very short-run, as with maintenance and depreciation costs. For the purpose of the following analysis, it can be assumed that half of the costs are fixed and the other half are variable costs. Since fixed costs have an important impact on market structure, they cannot simply be dropped.

The shape of the cost function plays a key role in determining the theoretically optimum level of production. Economic theory generally assumes that marginal costs rise continuously as output rate increases above some given level, and that the resulting average cost curve has a U-shaped relation to output (Panzar 1989). Since most industrial production processes are of a complementary nature, it is reasonable to assume that marginal cost is constant when transforming the input factors into outputs, at least over a normal output range.[36]

---

35 VDMA Handbook (1993, p. 82). The figures are averages for 5,391 firms.

36 Gutenberg (1983). Gutenberg provides evidence on constant marginal cost in industry. For a recent overview, see Fandel (1994).

Based on technologies applied in the machine tool industry (as well as on a number of other factors) it is reasonable to consider a Cobb-Douglas production function as the base for deriving a cost function.[37] The first reason for this choice is based on the appropriateness of the estimations achieved. The second reason is due to the modeling strategy—the desire to use a simple model of production technology which captures the cost-minimizing behavior of firms in the long-run. This works because of the assumption that, at least in part, the production process is characterized by factor substitution. This is particularly true for production processes in small and medium sized firms based on workshop manufacturing. Thus, the production of parts in the machine tool industry can be done using more labor with universal machines or with less labor and more specific machines. For the task of assembling machine tools, there exists the possibility of buying larger components and substituting them for labor. Finally, it can be argued that while the single production sub-processes are based on a strict complementarity of the factors of production, the possibility to combine these sub-processes in different ways creates an overall possibility of substitution.

Using the estimated parameters of the Cobb-Douglas production function for the plants of the mechanical engineering industry in the NIFA Panel, the following cost function can be defined:

$$C = 1.6\, X\, w^{0.82}\, r^{0.18} \tag{3.4}$$

This cost function tells both how the total cost of production C increases as the output X increases, and how cost changes if the wage rate w and the price of capital r change. Since $\alpha_1 + \alpha_2 = 1$, the production function has constant returns to scale, the costs will increase proportionately with output, and no fixed costs occur. But this is only valid in the long-run. In the short-run, fixed costs must be considered.

Again, it is important to note that labor in the production function is the amount of skilled labor in the production process. It is used to find inefficiencies in the production process. For the analysis of market structure the situation is different. In this case, total labor should be considered for the development of a cost function for the entire firm. It then becomes meaningful to use total employment and the stock of machinery as a measure of fixed cost in a short-run cost function.

The basic proposition is that cost function variable inputs are material and other inputs bought in short-term supplies. Therefore, it is necessary to treat the

---

37 See chapter 5 for the application of a Cobb-Douglas production function for the estimation of technical efficiency of firms.

cost function for the market structure analysis as a separate issue, since the cost function based on the Cobb-Douglas production function is linear, has no fixed costs, and therefore, no level of minimal efficient scale.

The characteristics of the fixed factors play a dominant role in the determination of the firm's cost behavior. Within the normal range of the output level (from 0 to 100 percent), it is assumed that in the short-run there will be no continuous or discontinuous segmentation of other input factors—such as material, etc. Above the capacity of 100 percent, adjustment is possible using extra payment for overtime hours. This is typical for the mechanical engineering industry, as a survey by Wied-Nebbeling (1975) has shown. 28.6 percent of the firms studied have no capacity reserve, and 48.9 percent have a reserve of 1 to 10 percent. What is also interesting is the pattern of unit cost for firms. The following distribution of patterns of unit cost have been reported:

- 10.2 percent with strongly declining unit cost,
- 57.1 percent with weakly declining unit cost,
- 16.1 percent with U-shaped unit cost, and
- 2.0 percent with increasing unit cost (Wied-Nebbeling 1975, p. 287).

To summarize the cost situation, it is assumed that for any output level, fixed and variable inputs can be mixed in minimum-cost proportions at all levels within the normal capacity range—e.g. the cost curve is linear with a slight quadratic term[38] over this output range. Beyond that range, costs rapidly increase due to the rigidity of the capacity constraints (marginal costs are nearly constant at the normal level of operation). The pattern is a very flat U-shaped average cost curve. This cost pattern is represented by the following cost function:

$$C_i(x_i) = f + c_i x_i + d_i x_i^2 \tag{3.5}$$

with $C_i(x_i)$ as total cost, f being the fixed cost for one period, c_i the linear term, and d_i the small quadratic term of the marginal cost. For the production of machining centers, the following cost parameters are assumed:

38 The quadratic term is assumed to capture the fact that firms in the machine tool industry have some problems obtaining the right inputs at the right time from their suppliers. This very small increase in variable cost due to the quadratic term can be regarded as the net effect for the supply of various inputs. Furthermore, the scale of the production of machining centers is so small that significant economies cannot be achieved by the suppliers. A correct modeling of this effect could only be achieved by applying a discontinous cost function. Therefore, the simplifying assumption of a small quadratic term in the cost function is made.

$$C_i(x_i) = f + 300\, x_i + 1\, x_i^2 \tag{3.6}$$

The variable costs are a rough assumption based on the above cited cost structure of the mechanical engineering industry. They are based on the assumption that 50 percent of the unit value of a machining center can be taken as variable cost, assuming the firm is at the point of capacity production. Variable costs are then roughly half of the unit value (given a unit value of DM 600,000 per machining center, the variable cost would be DM 300,000). The quadratic term is negligible for small capacities but increases with increasing capacity. This term captures rising costs for the provision of appropriate material inputs. The values in the function are measured in thousand DM.

Since the above cost function describes the short-run pattern of cost it does not cover the important adjustment costs. It should nevertheless be noted that adjustment costs and labor costs increased significantly over the past three decades. Since labor costs are to a large extent fixed costs, then the amount of fixed cost has increased over time with no parallel shift towards higher returns to scale. The main effect of this has been an increase in total unit cost. This, together with the increasing efficiency of the larger plants, was the reason for the stability of the market structure (until import competition became stronger).

3.3.2 A Test of Market Structure

3.3.2.1 Introduction

In this and the next section, basic issues of market structure are discussed and applied to the market of machining centers. One important question one can use to direct the evaluation of the functioning and performance of markets like the German machine tool industry is: whether they contain too many plants who's capacities are too small to exhaust all the economies of scale? If these small plants would expand, would their average unit costs of production continue to fall? Are these small plants—with respect to their larger rivals—more inefficient, or are the larger plants the inefficient ones unable to capture economies of scale? As discussed with respect to adjustment cost, there is the presumption that some of the large firms within the German machine tool industry have higher costs than the medium-sized and small-sized firms. In chapters 4 and 5, evidence will be provided that these higher costs are a result of inefficiencies resulting from far too much product differentiation.

The relevant types of market structure range from perfect competition to monopoly. Perfect competition is a market where a large number of firms sell a homogeneous product and no firm is large enough to influence the market price by its output decision. It is assumed that buyers and sellers have perfect information, that there are no transaction costs, and that there is free entry and exit. Monopoly is a market structure where there exists a single firm selling a product with no close substitute. Two market structures that lie between the extremes of perfect competition and monopoly are monopolistic competition, and oligopoly. Monopolistic competition describes a market structure in which there are many firms selling differentiated products, and there is free entry and exit. An oligopolistic market structure is a structure where there are only a few firms (each of which is large, relative to the total industry), where the policy decision of a single seller affects the other firms noticeably, and where each firm considers how its rivals will react to its policies. It is a market situation with strategic interaction.[39] The products of the firms in an oligopolistic industry can be either homogeneous or differentiated.

The main difference between these four market structures lies in the nature of the demand conditions that the firms are confronted with. In the perfect competitive market, the firm is a price taker and the firm's demand function is horizontal. In the case of the monopoly, the firm's demand function is the market demand function, it slopes downward from the left to the right. In the model of monopolistic competition, each firm is confronted by a downward-sloping demand function due to product differentiation. In case of an oligopolistic market structure, the demand conditions confronting the individual firm depend upon the assumptions regarding the way in which other firms will react to its own policies. Members of such a market can either coordinate or adopt intensely competitive behavior (see Albach 1996c for a timely analysis of narrow oligopolies). Therefore, the outcome is usually quite indeterminate because it provides a wide range of possible outcomes. The equations for the most typical types of market structures for the market of machining centers are given in the following subsection.

An important result arising from the analysis of the structure of the German machine tool industry is that this industry shows quite a stable structure, with only very recent changes (see chapter 2 of this study). Two possible explanations are relevant. First, it can be argued that competition in this industry is characterized by the Gutenberg type of monopolistic competition, which Albach established as a hyperbolic sine function in 1973. The doubly kinked demand function is the main characteristic in this respect. The second explanation can be based on static theories of oligopoly.

39 The reasoning behind such strategic interaction of firms is usually the following on part of the firms: "If I choose A, then he chooses B, then I get X, however, if I choose C, and he chooses D, then I get Y ..." and so on.

For the following case study, a dynamic market segment of a considerable size and relevance in global competition was chosen: the market for machining centers and flexible manufacturing systems. Since the latter are based on machining centers, this whole market segment may be understood as being composed of machining centers. The range of demand functions for machining centers, which was presented in the introduction, is used here for an analytical distinction of two cases.

The most interesting models from static oligopoly theory (for this analysis) are the Cournot and Bertrand models. These simple models treat the market situation as one-shot games, since firms produce and sell outputs just once in these models. They allow the explanation of prices and quantities that will be chosen by competing firms. The Cournot model explains quantity competition and the Bertrand model price competition. Both models allow the exploration of the relationship between competition and market structure in the machine tool industry. Since machine tool firms are interested in using their capacity—due to a significant level of fixed costs, among other reasons—the firms pursue quantity competition. Therefore, a detailed analysis of Cournot competition is provided. On the other hand, the industry is confronted with increasing price competition due to increases in imports of quality machine tools at a good value. This requires an exploration of Bertrand competition.

Since the models ought to determine the price or the quantity that will prevail in equilibrium, a concept of equilibrium is necessary which defines when a market is in equilibrium. An important equilibrium concept that will be used in the following is the Nash equilibrium. According to Nash, a market is in equilibrium when firms are doing the best they can, given what competitors are doing. In the following section the Nash equilibrium will be more properly defined.

3.3.2.2 Cournot-Nash Equilibrium[40]

A market is characterized as a Cournot oligopoly if: (1) there are few firms in the market, (2) these firms serve many customers, (3) the products offered are either homogeneous or differentiated, (4) each firm assumes that the competitors will hold their output constant if it changes its output, and (5) barriers to entry exist (no entry).

40 More detailed derivations of the profit maximizing equilibrium conditions for the different market situations can be found in microeconomic textbooks such as Tirole (1988); Kreps (1990); Gravelle and Rees (1992); or Mas-Colell, Whinston, and Green (1995).

In a Cournot oligopoly, each of the firms must decide how much to produce, and the firms must make their decisions simultaneously. When making these decisions, each firm takes into account what the competitors are doing.

Below, the basic model is outlined. It represents a market with a fixed number of n firms competing. Let x_i equal the output of firm i, the equation is then:

$$X = x_1 + \ldots + x_n = \sum_{i=1}^{n} x_i \tag{3.7}$$

as the total output of the industry and p is the market price.

If $x = (x_1, \ldots, x_n)$ is the output vector, then the profit function can be written as:

$$\pi_i = x_i \, p(X) - C_i(x_i) \tag{3.8}$$

The Cournot equilibrium is an output vector $x^C = (x_1^C, \ldots, x_n^C)$ having the property that no single firm i can increase its profit by choosing an output level different from x_i^C, given that the other firms are choosing x_j^C $(j \neq i)$.

The general inverse demand function is:

$$p_i = a_i - b_i x_i - g\, x_j \quad i, j = 1,2 \quad i \neq j \quad where\ g > 0. \tag{3.9}$$

The products are substitutes since an increase of firm j's output shifts down the demand and revenue functions of firm i. If the firms' outputs are homogeneous, then:

$$a_1 = a_2 = a \ \ and \ \ g = b_1 = b_2,$$

and the outputs must sell at identical prices corresponding to the sum of the firms output, then there is only one demand function:

$$p = a - g\,(x_1 + x_2) \tag{3.10}$$

With the general inverse demand function and the cost function $C_i(x_i) = c_i x_i$, the firms' profit function, as a function of output, is:

$$\pi_i\,(x_1, x_2) = p_i x_i - c_i x_i = (a_i - c_i - g\, x_j)\, x_i - b_i\, x_i^2 \tag{3.11}$$

$$i, j = 1,2 \quad i \neq j$$

The profit function is strictly concave in x_i for given x_j with a maximum at:

$$x_i = \frac{a_i - c_i - gx_j}{2b_i} \tag{3.12}$$

Given any output x_j that firm i expects the other to produce, its best response is x_i. The above function defines the firms' reaction functions:

$$x_i = A_i - B_i x_j \qquad i,j = 1,2 \quad i \neq j \tag{3.13}$$

where $A_i \equiv (a_i - c_i)/2b_i$ and $B_i \equiv g/2b_i$.

The slopes of the reaction functions are negative because increases in output x_j reduces firm i's profit maximizing output. The intersection point of these two reaction functions is given by simultaneously solving the two above defined equations:

$$x_i^C = \frac{A_i - A_j B_i}{1 - B_i B_j} = \frac{2b_j(a_i - c_i) - g(a_j - c_j)}{4b_1 b_2 - g^2} \quad i,j = 1,2 \quad i \neq j \tag{3.14}$$

The following table shows the output solution for each of the market structures outlined in the introduction of this section, including the subcases for both differentiated and homogeneous outputs.

Table 3.3: Equilibrium Outputs for Different Market Structures

Equilibrium outputs	Product differentiation	Homogeneous output
Cournot-Nash	$x_i^C = \frac{2b_j(a_i - c_i) - g(a_j - c_j)}{4b_1 b_2 - g^2}$	$x_i^C = \frac{a - c}{3g}$
Perfect competition	$x_i^* = \frac{b_j(a_i - c_i) - g(a_j - c_j)}{b_1 b_2 - g^2}$	$x_1^* + x_2^* = \frac{a - c}{g}$
Monopoly	$x^m = \frac{b_j(a_i - c_i) - g(a_j - c_j)}{2(b_1 b_2 - g^2)}$	$x_1^m + x_2^m = \frac{a - c}{2g}$

Source: Adapted from Gravelle and Rees (1992, p. 303).

3.3.2.3 Bertrand-Nash Equilibrium

Important assumptions used in modeling oligopolistic competition are easily understood when comparing Cournot and Bertrand competition. Even in cases where only two firms are in a market, Bertrand competition firms will set the competitive price-taking price—they set price to marginal cost.[41] Obviously, this makes a difference because it is important whether firms choose prices or quantities. The understanding of Bertrand competition is also important for the analysis because Kreps and Scheinkman (1983) have shown that the end result of Cournot competition can be reached in a two-stage game as a subgame perfect equilibrium. In the first stage, firms choose capacities. In the second stage, firms compete with prices. The result is equivalent to the standard Cournot outcome.[42] It must still be checked, however, whether firms fix quantities and then allow prices to adjust to whatever level allows them to be sold, or if they set prices and then produce what is demanded. For this, it is necessary to understand the properties of a Bertrand market.

A Bertrand oligopoly is characterized by the same basic properties as a Cournot oligopoly—a few firms serve many customers and barriers to entry exist. However, the Bertrand assumptions are different, in that firms produce identical products at a constant marginal cost.[43] The most important distinction is that firms engage in price competition and react optimally to prices charged by competitors. Furthermore, consumers have perfect information and there are no transaction costs.

In the case of homogeneous products, it can be shown that the Nash equilibrium is at $p_1^B = p_2^B = c$, of the competitive outcome, as mentioned above. Firms price at marginal cost and they do not make profits. The Nash equilibrium in prices is thus expressed as a pair of prices (p_1^B, p_2^B) such that each firm's price maximizes that firm's profit, given the other firm's price.

The derivation of the equilibrium solution for Bertrand competition with differentiated products is as follows. First, the demand function has to be derived

---

41 This is what Tirole (1988) has called the Bertrand paradox, since according to Tirole (1988, pp. 210-211) "it is hard to believe that firms in industries with few firms never succeed in manipulating the market price to make profits." Note the discrepancy between Cournot and Bertrand outcomes partly disappears in the case of product differentiation.

42 This result is not robust to variations in the assumption on the form of rationing by the lower priced firm—which is what should happen when the lower-priced firm does not completely satisfy its demand (see Davidson and Deneckere 1986 for a solution with an efficient rationing assumption).

43 There are also models with Bertrand competition analyzing the case of product differentiation.

from the usually applied inverse demand function. Then, the profit function has to be maximized for the given p_i, leading to the reaction function of firm i. The same has to be done for firm j. The intersection of both reaction functions then provides the pair of prices (p_1^B, p_2^B) which is the Nash equilibrium. In the case of differentiated products, the Bertrand prices and outputs are more competitive than Cournot prices and output but still generate positive profits, depending on the degree of substitutability.

3.3.2.4 The Impact of Fixed Costs on Market Structure

Several questions can be raised about the Cournot equilibrium. Is it reasonable to expect that: (1) each firm makes an autonomous decision concerning what quantity of product it should produce? and (2) all firms make their decisions at the same time? For the study of machine tool markets, these assumptions seem to be quite realistic, since firms want to make full use of their capacities. The firms of the machine tool industry know that the price they receive will depend on the total output of the industry. Thus, it is assumed in the Counot model that the firms knew the output level of the competitors and that they would treat this output as fixed. Knowing this, the firms then make their production decisions.

There are several good reasons to assume that a Cournot market situation is a given in the machine tool industry—at least in part. Also, the study of a single-period model is particularly relevant for this industry, as each firm is searching for a profit-maximizing plan for each period. The basic features of the non-cooperative market equilibrium can be studied within such a simple setting while recognizing that the structure is endogenous in equilibrium.

The purpose of the following analysis is to determine the adjustment of the market structure towards equilibrium, with respect to the impact of fixed costs. Using the generalized cases of the inverse demand function (3.2) and of the cost function (3.6), the profit function is:

$$\begin{aligned} \pi_i(x_i) &= px_i - C_i(x_i) = (a - bX)x_i - f - c_i x_i - d_i x_i^2 \qquad (3.15) \\ &= ax_i - b(x_i + \sum_{j \neq i}^{n} x_j)x_i - f - c_i x_i - d_i x_i^2 \\ &= ax_i - bx_i^2 - bx_i \sum_{j \neq i}^{n} x_j - f - c_i x_i - d_i x_i^2 \end{aligned}$$

The firm i's first-order condition for profit maximization is:

$$\partial\pi_i / \partial x_i = a - 2bx_i - b \sum_{j \neq i}^{n} x_j - c_i - 2d_i x_i = 0 \tag{3.16}$$

Due to the symmetry of the equilibrium $x_i = x_j$ for all i and j, that is:

$$\sum_{j \neq i}^{n} x_j = (n-1)x_i$$

The equation (3.16) can also be written:

$$a - c_i - 2x_i(b + d_i) - b(n - 1)x_i = 0$$

Solving for x_i yields:

$$x_i = (a - c_i) / (b + 2d_i + bn) \tag{3.17}$$

Total industry output is:

$$X = n\, x_i = (a - c_i)n / (b + 2d_i + bn) \tag{3.18}$$

Using the inverse demand function leads to the market price:

$$p = (ab + 2ad_i + bc_i n) / (b + 2d_i + bn) \tag{3.19}$$

and a profit for the *i-th* firm:

$$\pi_i\,(x_i) = (c_i - a)^2\,(b + d_i) / (b + 2d_i + bn)^2 - f \tag{3.20}$$

Using the generalized results for the equilibrium, the formulas to compute the equilibrium values for the machining center market can be derived. For this purpose the inverse demand function for machining centers (3.2) and the cost function (3.6) are used. For the demand of CASE 1 ("Steep Slope") and CASE 2 ("Flat Slope") the equilibrium outputs are:

$$x_{i/\mathrm{STEEP}} = 600/(2.3 + 0.3n) \tag{3.21}$$

$$x_{i/\mathrm{FLAT}} = 300/(2.05 + 0.05n) \tag{3.22}$$

The total output of the industry is $X = nx_i$, and, when normalizing for n:

$$X_{\mathrm{STEEP}} = 1{,}998n / (7.67 + n) \tag{3.23}$$

$$X_{\mathrm{FLAT}} = 6{,}000n/(41 + n) \tag{3.24}$$

The market price for the cases is:

$$p_{\mathrm{STEEP}} = 900 - 180n/(2.3 + 0.3n) \tag{3.25}$$

$$p_{\mathrm{FLAT}} = 600 - 15n/(2.05 + 0.05n) \tag{3.26}$$

The profit for firm i is:

$$\pi_{i/\mathrm{STEEP}} = 5.2*10^6/(7.67 + n)^2 - f \tag{3.27}$$

$$\pi_{i/\mathrm{FLAT}} = 3.78*10^7/(41 + n)^2 - f \tag{3.28}$$

Equations (3.21)-(3.24) show that x_i must fall as n increases. The number of firms increases and at the same time the industry output X increases. Increasing n leads to an increase of industry output X. It also leads to a decrease in the market price p. As equations (3.23) and (3.24) show, X rises to 1,998 for the former case, and to an industry output of 6,000 in the latter one—as n increases to infinity. The market price in both cases converges to 300 (see tables 3.4 and 3.5).

The relationship between the demand and the cost conditions, particularly the relationship between market size and fixed costs, determines the number of firms actively supplying the market. To demonstrate this for the German machining center market, the above model was used to calculate the active number of firms, dependent on the amount of fixed costs per period. The table for the first case, with a more inelastic market demand function, shows the fixed costs (in thousands of DM) in the first column. The second column represents the largest sustainable value for the number of firms, n. For example, with fixed cost of DM 10 million, profits will be negative at any Cournot equilibrium with $n > 15$ and will not be negative for $n \leq 15$. The third column illustrates the market price for the equilibrium condition. The fourth column gives the output, x_i, for the single firm, followed by the total output of the industry, X. The last column provides the profit for the single firm. The table for the second case, with the more elastic demand function, provides comparable summary information.

Comparing the equilibrium results for the two demand situations reveals that under low elastic demand a monopoly will occur if fixed costs are DM 65 million. In the elastic demand situation, no supply would be created under such fixed cost requirements. In the case of great elastic demand, a monopolist would "appear" and be able to cover the fixed costs of DM 21 million. For the former case, market price would be DM 830.8 thousand with an output of 231 units. In the latter case, a market price of DM 592.9 thousand would yield an output of 143 units.

Table 3.4: Cournot Equilibrium for Various Fixed Costs and Levels of n for the Machining Center Market of the German Machine Tool Industry CASE 1: Steep Slope of the Demand Function

Fixed cost f	Max. no. of firms for $\pi_i \geq 0$ max n	Market price p	Output of each firm x_i	Industry output X	Profit of each firm π_i
65,000	1	830.8	230.8	231	4,230.8
50,000	2	775.9	206.9	414	5,648.0
45,000	3	731.3	187.5	563	703.1
40,000	3	731.3	187.5	563	5,703.1
35,000	4	694.3	171.4	686	3,204.1
30,000	5	663.2	157.9	789	2,410.0
25,000	6	636.6	146.3	878	2,840.6
21,000	8	593.6	127.7	1,021	186.1
20,500	8	593.6	127.7	1,021	686.1
20,000	8	593.6	127.7	1,021	1,186.1
19,000	8	593.6	127.7	1,021	2,186.1
18,000	9	576.0	120.0	1,080	720.0
17,000	9	576.0	120.0	1,080	1,720.0
16,000	10	560.4	113.2	1,132	660.7
15,000	10	560.4	113.2	1,132	1,660.7
14,000	11	546.4	107.1	1,179	923.5
13,000	12	533.9	101.7	1,220	444.4
12,000	13	522.6	96.8	1,258	174.8
11,000	14	512.3	92.3	1,292	76.9
10,000	15	502.9	88.2	1,324	121.1
9,000	16	494.4	84.5	1,352	283.9
8,000	17	486.5	81.1	1,378	546.4
7,000	19	472.5	75.0	1,425	312.5
6,000	21	460.5	69.8	1,465	327.7
5,000	24	445.3	63.2	1,516	185.6
1,000	64	364.2	27.9	1,786	12.4
100	220	320.2	8.8	1,933	0.3
10	713	306.4	2.8	1,979	0.0
1	2,272	302.0	0.9	1,993	0.0
0.1	7,200	300.6	0.3	1,998	0.0

Functions, variables, and parameters:

Cost function: $C_i(x_i) = f + c_i * x_i + d_i * x_i^2$

Inverse demand function: $p = a - b * X$, X = total industry output

f: see above
c_i: 300
d_i: 1
a: 900
b: 0.3

Sources: The demand function is based on industry production data for the period from 1985 to 1994 (VDMA Machine Tool Statistics, various years). Costs, prices, and profits are in thousand DM.

Table 3.5: Cournot Equilibrium for Various Fixed Costs and Levels of n for the Machining Center Market of the German Machine Tool Industry CASE 2: Flat Slope of the Demand Function

Fixed cost f	Max. no. of firms for $\pi_i \geq 0$ max n	Market price p	Output of each firm x_i	Industry output X	Profit of each firm π_i	
65,000	*-17*	*812.5*	*250.0*	*-4,250*	*625.0*	*Level of fixed costs leads in all these cases to a negative profit of an entering firm.*
50,000	*-14*	*755.6*	*222.2*	*-3,111*	*1,851.9*	
45,000	*-13*	*739.3*	*214.3*	*-2,786*	*3,214.3*	
40,000	*-11*	*710.0*	*200.0*	*-2,200*	*2,000.0*	
35,000	*-9*	*684.4*	*187.5*	*-1,688*	*1,914.1*	
30,000	*-6*	*651.4*	*171.4*	*-1,029*	*857.1*	
25,000	*-3*	*623.7*	*157.9*	*-474*	*1,177.3*	
21,000	1	592.9	142.9	143	428.6	
20,500	1	592.9	142.9	143	928.6	
20,000	2	586.0	139.5	279	443.5	
19,000	3	579.5	136.4	409	524.8	
18,000	4	573.3	133.3	533	666.7	
17,000	6	561.7	127.7	766	111.8	
16,000	7	556.3	125.0	875	406.2	
15,000	9	546.0	120.0	1,080	120.0	
14,000	10	541.2	117.6	1,176	532.9	
13,000	12	532.1	113.2	1,358	456.7	
12,000	15	519.6	107.1	1,607	53.6	
11,000	17	512.1	103.4	1,759	236.6	
10,000	20	501.6	98.4	1,967	158.6	
9,000	23	492.2	93.8	2,156	228.5	
8,000	27	480.9	88.2	2,382	174.7	
7,000	32	468.5	82.2	2,630	93.3	
6,000	38	455.7	75.9	2,886	56.7	
5,000	45	443.0	69.8	3,140	110.9	
1,000	153	363.4	30.9	4,732	4.4	
100	573	320.0	9.8	5,599	0.3	
10	1,903	306.3	3.1	5,873	0.0	
1	6,107	302.0	1.0	5,960	0.0	
0.1	19,392	300.6	0.3	5,987	0.0	

Functions, variables, and parameters:

Cost function: $C_i(x_i) = f + c_i * x_i + d_i * x_i^2$

Inverse demand function: $p = a - b * X$, X = total industry output

f: see above
c_i: 300
d_i: 1
a: 600
b: 0.05

Sources: The demand function is based on industry production data for the period from 1985 to 1994 (VDMA Machine Tool Statistics, various years). Costs, prices, and profits are in thousand DM.

A market with a reasonable size of 10 firms would be structured as follows. For the inelastic demand of case #1, fixed costs of 16 million can be covered by each firm selling 113 units at a market price of DM 560.4 thousand. For the more elastic demand of case #2, the fixed costs of DM 14 million for each firm are covered by delivering 118 units at a price of DM 541.2 thousand. Thus, a flatter demand function obviously leads to a more competitive outcome in a Cournot equilibrium for the market for machining centers.

3.3.2.5 Conclusion

To draw further conclusions, the following example should be considered. Assume that a medium-sized firm—that is "the median firm"—has 300 employees. With actual per capita sales of DM 200,000, the firm would have overall sales of DM 60 million. Based on the cost structure of the industry, it is safe to assume a fixed cost of DM 21 million, which the equivalent of a ratio of fixed cost on sales of 35 percent.

Under the demand and cost structure of our Cournot model, the fixed costs of DM 21 million would have the result of less elastic demand ("steep slope") for eight firms in equilibrium. However, elastic demand leads to only one firm. That is, the more elastic demand becomes, the less room is left in the market.

As table 3.2 shows, there are 22 German firms in the market (when including the very small ones). The estimated market share of the largest three firms is 56.5 percent.[44] In these cases, it is reasonable to believe that fixed costs are higher than the assumed DM 21 million of the median firm. Under the given demand and cost structure, only a maximum of DM 65 million in fixed costs could be used in the computation of the "steep slope" case. This computation results in only one firm in equilibrium.

The main conclusion to be drawn from these examples is that the firms in the German machine tool industry might enjoy (or at least have enjoyed until 1990) a certain extent of monopolistic power due to good customer relations. It seems that they were all, at least in part, monopolists. However, this monopolistic situation has been in danger since 1990.

The number of viable firms in a market depends to a large extent on the elasticity of demand and on the amount of fixed costs to be covered by revenue. Since fixed costs have to be covered in the machine tool industry, especially for the manufacturing of machining centers, the number of viable profit-making firms

---

44 It should be mentioned that the two largest firms, Maho AG and Deckel AG, went bankrupt. However, their machining center business has survived within the Gildemeister Group.

is limited. As the most recent development in the industry shows, the viable number might be very limited.

3.4 Product Differentiation and Market Structure

3.4.1 Introduction[45]

The most distinctive feature of product policies is the optimization of the firm's payoff with respect to the trade-off between product differentiation and cost efficiency (Albach 1990). Only recently, has the complementarity of these strategies been expressed and process innovation regarded as the complement of product innovation. From Porter's (1980) static articulation of "being stuck in the middle" (p. 41) as an inferior strategy, it took more than a decade to recognize that:

> "(C)ompetitive moves are generally prompted by moves of the customers along the competition front. A shift of demand from lower price products to higher price products may cause the firms with low prices and low costs to shift in the direction of products with higher target values, higher prices, and correspondingly higher target costs. If a product becomes a commodity, customers shift in the direction of the lower target value, lower target cost direction, and products are varied accordingly in the competitive process. Innovation, by contrast, tries to move the competition front to the right." (Albach 1996a, p. 192)

According to Albach's observation of the competitive process, three competitive strategies are of interest. The first one aims at offering a better product, which can be regarded as a strategy of vertical product differentiation. The second aims at offering a cheaper product, which usually is regarded as a strategy of process innovation or cost leadership. The third aims at offering a better and only slightly more expensive product, which might be characterized as a strategy combining horizontal and vertical product differentiation. If such a strategy includes process innovation it might well shift the competition front to the right.

Economic analysis has mainly provided single-characteristic models for horizontal and vertical product differentiation, but not for a combination of these strategies. To gain a better understanding of competition in capital goods markets, however, it is important to examine the case of a combined strategy of horizontal and vertical product differentiation. This is particularly important for

---

45 For a more detailed discussion of the empirical content of product differentiation see chapter 4.

this study because the combination of these separate strategies is the case in the machine tool industry, a primary supplier of capital goods.

Past research efforts have focused almost entirely on the separate analysis of either horizontal or vertical product differentiation (Eaton and Lipsey 1989). Exceptions are the works of Ireland (1987) and Rosenkranz (1995; 1996), who focused on the existence of equilibrium. Ireland studied a Nash equilibrium in a price-setting game played by duopolists, whereas Rosenkranz analyzed two duopolists who choose production technology and product differentiation through their R&D investment. These two models shed light on some of the important issues of product differentiation in capital goods markets. Their characteristics and results pertinent to this study will be discussed in the next section.

The next section will also discuss spatial models of imperfect competition[46] and the relevant results for machine tool markets. This is because there are many characteristics by which machine tools can be differentiated. Spatial models capture the most salient features of product differentiation and market structure. The classic model is the spatial differentiation model by Hotelling (1929).

As with Hotelling's model, any general model of product differentiation would have to specify four elements. On the supply-side, the first of these elements is the set of possible products. The second is the technology associated with each product—in economic terms, a specification of the fixed and variable costs associated with the production of any type of product. The third element concerns the demand-side, the tastes of consumers for the set of possible products and their income level—generally, a utility function defined for the set of products and budget constraints. The final element is an equilibrium concept. A general model of this kind seems to be intractable due to its complexity, that is the reason why the literature has focused on special cases.

3.4.2 Product Differentiation in Spatial Models

An important implication which product differentiation might hold for market structure is Hotelling's principle of minimum differentiation.[47] This special result says that two firms will locate as close to each other as possible. The result requires absolute inelastic demand for the product, and only two firms. If increased distance between a customer and a firm would result in substitution of

46 Since these models of product differentiation imply the consideration of interaction effects among competing products, they also fit (in a broader sense) into the framework of oligopoly models. The same is argued for models of monopolistic competition.

47 There was much debate in the literature on whether and under which conditions Hotelling's principle of minimum differentiation would hold. For a summary of this discussion see Beath and Katsoulacos (1991).

the product, then the firms would locate far away from each other with little interaction (shown in table 3.6 as "general version of model no. 1"). It should be noted that the consumer preferences in Hotelling's model are assumed to be asymmetric, that is a consumer would prefer the products that are the closest to his ideal product. The following assumptions are the most crucial in the Hotelling type of modeling product differentiation:

> "1. Each consumer buys a single unit of the commodity and has only one reservation price, which means that his demand function is rectangular. The consumers possess identical demand functions.
> 2. Marginal costs of production are constant (possibly zero). There are no fixed costs but there are a fixed number of sellers ...
> 3. Change in the location is costless ...
> 4. The customers are located uniformly along a straight line (or circle). To each unit of distance corresponds a one unit element of differentiation ... verifying the usual assumptions of symmetry. This assumption is fundamental to the spatial theory of horizontal product differentiation ...
> 5. The cost of transporting one unit of the commodity over one unit of distance is constant ...
> 6. Assumption 5 is crucial and implies that producers adopt f.o.b.-mill prices: it is the buyer who takes care of the transportation problem ...
> 7. ... each producer has only one location (sells one variety only).
>
> Given the above framework, spatial competition refers to the simple mechanism according to which firms try to capture the largest number of customers from their neighboring competitors, by choosing a certain position in the graphical space." (Phlips and Thisse 1982, pp. 3-4)

The characteristics and the results of the four main spatial models of product differentiation are summarized in table 3.6. To explore further the effect that product differentiation might have on market structure, Sutton's (1991) results need to be mentioned. His analysis of horizontal product differentiation is important since he refers to the multiproduct case and situations of multiple equilibria which are important for studying the machine tool industry. Sutton argues that both, fragmented and concentrated equilibria, can arise:

> "This case arises when a number of distinct varieties may be produced that are quite independent on the demand side (i.e., they are neither substitutes nor complements). If a setup cost of σ must be paid to produce any such variety (i.e., there are no economies or diseconomies of scope), then the market breaks down into a number of independent submarkets or segments. A firm's

Table 3.6: Market Equilibria and Social Optima in Selected Spatial Models of Product Differentiation

Model No.	Model type and decision variable(s)	Author(s)	Assumptions and characteristics	Results	Implications for equilibrium market structure	Remarks
1	*Spatial model, type: linear city,* horizontal product differentiation Decision variables: *location* of supply	Hotelling (1929)	Same physical goods, Bertrand competition, uniform distribution of consumers (density=1), each consumer buys one good, no entry, equal prices, linear transportation cost, asymmetric consumer preferences	Location on the same point in the middle of the line ($x = 0.5$), implies minimal product differentiation, a location outside of the middle leads to no equilibrium point, like the social optimal differentiation with $x_1 = 0.25$ and $x_2 = 0.75$ (minimizes transportation costs)	No explicit structural implication beyond location. Linear-cost model is not very tractable. It leads to discontinuous demand functions and to discontinuous and nonconcave profit functions. No pure-strategy price equilibrium exists but a mixed-strategy one.	Product differentiation introduced by transportation costs (t), differentiation increases with t, neighboring competition with strategic interaction, if $t = 0$, i.e. the absence of product differentiation leads to the Bertrand result
2	*Spatial model, type: linear city,* horizontal product differentiation General version of model 1 Decision variables: *location* of suppliers and *price*	d'Aspremont, Gabszewicz, and Thisse (1979)	Two-stage game: decisions on location in 1st stage, and on price in 2nd stage, quadratic transportation costs	Extreme polar case: $x_1 = 0$ and $x_2 = 1$, leads to maximal product differentiation		Results depend on modeling approach, two-stage game with quadratic transportation costs leads to opposite results than model 1, also plausible since suppliers want to avoid price competition

Table 3.6: continuation

3	*Spatial model, type: circular city,* horizontal product differentiation Decision variables: *entry and location* of supply	Salop (1979)	No barriers to entry other than fixed costs or entry costs (F), linear transportation cost (t), number of firms (n), there exists a large number of identical potential firms (i.e. equal constant marginal costs of c), circular city with a uniform distribution of consumers (density = 1), the product space is completely homogeneous (i.e. no location is a priori better than another)	The equilibrium price is: $p = c + \frac{t}{n}$ That is, price is above marginal costs and the lower the cost, the higher the number of firms in the market. The same is true for the profit margin (p - c) which decreases with increasing n. The maximal number of entering firms is: $n^* = \sqrt{\frac{t}{F}}$ The number of entering firms decreases with increasing fixed costs. With decreasing fixed cost entry, product differentiation increases. Minimizing the sum of fixed costs and the consumers transportation costs lead to the number of firms in the social optimum of $n^{**} = \frac{1}{2} n^*$ Thus, the optimal number of firms, n^{**}, is lower than the equilibrium number, n^*, and in equilibrium too many products are obtained.	When entry cost or fixed production cost F converges to zero, the number of entering firms tend to infinity and the market price tends towards marginal cost, i.e. the market is approximately competitive. When F increases, the number of firms decreases and both the distance between the firms and the prices increase. ************** *Continuation of previous column:* Market entry is endogenous and determined from the zero-profit condition of existing firms: $(p - c)\frac{1}{n} - F = 0$, that is, the profit margin times demand ($1/n$) minus fixed cost (F)	The model excludes the possibility of a firm producing more than one product, i.e. the firm can achieve only a certain degree of market power. A direct interdependence is only between the firm and its neighbor. In equilibrium, the firms make zero profits and from a social point of view there are too many firms. In this sense there is overcapacity in the industry as in the analysis introduced by Chamberlin. But, in Chamberlin's model there is no interdependence between neighbors.

Sources: See Tirole (1988, chapter 7); Eaton and Lipsey (1989); and Sutton (1991).

strategy now decomposes into a separate strategy for each segment. Given a large number of potential entrants, this model will have a range of equilibria. At the one extreme, the firms entering each submarket *are different, leading to a fragmented structure*; at the other extreme, *the same group of firms enters all segments, leading to a more concentrated structure* (emphasis by M. F.). In this special polar case, there is one equilibrium at which each firm produces only one product, and this single-product firm configuration is associated with the most fragmented equilibrium of the model. There are various other equilibria in which each firm occupies several niches, leading to a more concentrated structure." (Sutton 1991, p. 40)

Three features of the model are relevant for the range of equilibria: demand- and cost-side characteristics, and strategic asymmetry.

The two *demand-side effects* are: The *market expansion effect* which measures the extent to which the introduction of new products increases total industry sales, assuming fixed prices. And the *competition effect* which measures the extent to which, assuming the number of available products are fixed, prices are lower when each of these products is marketed by a different firm, as opposed to a supply of all products by a monopolist. According to Sutton (1991), "(A) stronger competition effect favors the appearance of concentrated outcomes, and the reason is ... tougher competition in the post-entry stage of the game makes the entry of rival producers less attractive." (Sutton 1991, p. 41) Sutton assumes that a monopolist has a stronger incentive to accrue sales from new customers than an entrant would capture from the incumbent's existing products. "Hence a stronger expansion effect favors the appearance of more concentrated equilibria, and vice versa." (Sutton 1991, p. 41)

The *cost-side characteristics* are related to the setup costs, which are due to the acquisition of a single plant of minimum efficient scale. In a case where part of these costs can be shared between several product lines (economies of scope), concentrated equilibria are favored.

Strategic asymmetry: "If some firms enjoy a strategic advantage (usually modeled in terms of a first mover advantage, by assuming sequential as opposed to simultaneous entry) then concentrated outcomes are favored. The first-mover may preempt the market by offering a range of products sufficiently broad to forestall further entry." (Sutton 1991, p. 41)

Sutton has generated robust results with these models for a range of horizontally differentiated products produced by multiproduct firms. The main general statement he makes is, "First ... the implied relaxation of price competition causes the concentration-size schedule to shift downward and to the left. Second, the appearance of multiple equilibria implies that this schedule now specifies only a *lower bound* to equilibrium concentration at any market size." (Sutton 1991, p. 42)

When firms compete with several product variants, the analysis has to capture horizontal as well as vertical product differentiation. Such analysis becomes more complex than the analysis of a single product differentiation strategy. One of the few microeconomic models for the study of combined product differentiation strategies was developed by Ireland (1987). The following section reviews his main conclusions.

3.4.3 Combining Horizontal and Vertical Product Differentiation

It is Ireland's (1987) intention to provide an analysis which allows for both horizontal markets and firms' choices over product quality. His main question is: whether the horizontal or vertical product characteristic has the dominant role in the market place? If the horizontal characteristic is the major difference between the products, one would expect little competition. Would this lead to a homogeneous quality?

A key aspect of Ireland's approach is to define two groups of consumers. In his model, Ireland indexes these two groups as $i = A, B$. These consumers are identical, except that they value products differently.

In Ireland's model, the consumers can be seen as varying according to a continuous, uniformly distributed parameter, x, where $0 \leq x \leq b$. An individual in group i with parameter x, purchases a quality u_j at a price p_j. He obtains a utility of:

$$U_j(x) = (x - p_j)\, V_{ij} \qquad i = A, B \tag{3.29}$$

where $V_{ij} = \lambda u_j$, $\lambda > 1$, if the product is horizontally preferred by consumers in group i. If the case is otherwise, the equation is $V_{ij} = u_j$. All products offered are preferred horizontally by exactly one of the two groups of consumers.

In Ireland's analysis, the market is characterized by horizontal dominance if $\lambda u_1 > u_2$ and $\lambda u_2 > u_1$. If $u_2 > u_1$ then both groups will prefer product 2 to product 1. If $u_2 > \lambda u_1$ then the market is characterized by vertical dominance. Ireland is not concerned about the case when one group of customers rates the two products as the same, that is, $\lambda u_1 = u_2$ or $\lambda u_2 = u_1$. The main result of this analysis is that the existence and nature of Nash equilibria depend on whether the market is characterized by horizontal or vertical dominance.

Ireland (1987) concludes for horizontal dominance:

"Nash equilibria with pure strategies may not exist if products are fairly vertically differentiated. Also, where they are of sufficiently similar quality two Nash equilibria will exist, with either firm taking the 'high-price' role. The 'low-price' firm will always obtain more revenue, and this need not to be the firm which supplies the higher quality product. In the 'vertical dominance' case … results are similar to those obtained by Shaked and Sutton, in that a unique Nash equilibrium will arise with the high-price, high-quality firm earning more revenue." (p. 110)

"The implication of the price-setting game for product selection has only been considered in terms of selecting quality … What appears to be clear from some numerical examples … is that a perfect equilibrium may be unlikely to involve vertical dominance as this produced a very skewed revenue distribution and so would be avoided by firms destined for the 'low-quality' role." (p. 111)

Obviously these results might lead to the question of whether a strategy of small quality differences is appropriate in capital goods markets since there is ambiguity caused by the dual equilibria in the pricing stage.

3.4.4 Product Differentiation and Cost Reduction

In order to study the efficiency of the supply of capital goods, it is important to determine whether price and/or quantity competition leads to an increase or decrease in economic efficiency, in other words, to find out whether the aggregate welfare of consumers and producers taken together is increased or reduced. In a recent paper, Bester and Petrakis (1993) have shown that both Cournot and Bertrand competition leads to *underinvestment in cost reduction* relative to the social optimum whenever firms enjoy a quasi-monopolistic position due to product differentiation and a low degree of substitutability. This result is reversed and competition leads to *overinvestment* in cases where competition is very high and goods become closely substitutable.

According to the analysis by Bester and Petrakis, Cournot competition provides stronger incentives to reduce cost through process innovation than Bertrand competition if the degree of substitutability is low, whereas the incentive may be weaker if the degree of substitutability is sufficiently high. This finding agrees with the work of Brander and Spencer (1983). They argue that a cost reduction by one firm lowers the Cournot equilibrium output of its competitors, however, they also find that the strategic use of such innovative effort may result in cost reductions beyond the point where total costs are minimized for the output chosen.

The crucial point for the analysis of the machine tool industry is the question of scale—whether the higher the output, the larger the total gain from a given reduction in the unit cost of production? Due to product differentiation, this might be somewhat less obvious, and as a result, competition may less directly influence cost reduction through the determination of equilibrium output. As will be shown later, this observation is closely related to excessive product differentiation in models of imperfect competition.

The analysis by Rosenkranz (1995; 1996) is of great interest and proves very useful for the evaluation of the performance of capital goods markets since it studies investments in cost reductions and in product differentiation. Rosenkranz has extended a previous analysis by Bester and Petrakis (1993), concerning the process innovation decisions of one firm, to the analysis of two identical duopolists who stress production technology and product differentiation with their R&D investments. This implies that firms can determine marginal costs and product substitutability simultaneously. Rosenkranz assumes heterogeneous Cournot competition and that the optimal division of R&D activities between process and product innovation varies with market size.

For the demand structure, Rosenkranz adopts the representative consumer's utility function developed by Dixit (1979). The utility is given as the utility of the two goods x_i and x_j plus the numeraire good m. Thus:

$$U(x_i, x_j) = a(x_i + x_j) - (x_i^2 + 2d\, x_i x_j + x_i^2)/2 \tag{3.30}$$

where $a > max[c_i, c_j]$ with c_i, c_j representing the firm's marginal production costs and $0 < d < 1$. The parameter d measures the degree of product substitutability. When d becomes zero, the firms are monopolists, and product differentiation is maximal. When $d = 1$, the two products are perfect substitutes.

The inverse demand function of firm i is given by:

$$P(a, x_i + dx_j) = a - (x_i + dx_j) \tag{3.31}$$

where a is the market potential—respectively the reservation price.

For the supply side, an oligopolistic industry with constant returns to scale is assumed. The degree of product differentiation is given by:

$$d := \bar{d} - d_i - d_j \tag{3.32}$$

of which d_i and d_j can be influenced through investment in R&D.

Furthermore, it is assumed that no technological spillover exists with process innovation.[48] For investment in product innovation the opposite is true—investment by one firm has a direct spillover concerning the profits of the rival.

The cost function for R&D is the same for both firms:

$$K(c_i) + G(d_i) \tag{3.33}$$

The higher the marginal costs chosen, the lower the needed R&D investment. Also, the higher the level of product differentiation, the higher the R&D investment.

In the first stage of the non-cooperative two-stage game, firms decide on their marginal costs by investing R&D in process innovation. Simultaneously, as they decide on R&D for product innovations, they are also deciding on the level of product differentiation. Quantities are chosen at the second stage. The two-stage game is solved by backward induction.

The following main findings of Rosenkranz (1995) concerning innovation decisions under R&D competition are of interest for a study of capital goods markets:

> "Firms do not necessarily specialize in one kind of innovative activity but rather allocate their R&D budget optimally among the two alternative forms of innovation, process and product innovation. Only if the R&D costs for one of the two innovations is such that investment would be inefficient, we find the extreme case of complete specialization ... Furthermore, the optimal division between the two kinds of innovative activity changes with the market size.
>
> Under R&D competition the business stealing effect induces firms to increase (reduce) their investment in process (product) innovation, compared to non-strategic decisions. As far as product innovations are concerned, investment is further reduced through the public good effect. The larger the market, the more firms invest in R&D and the more the investment is driven to product innovations provided that R&D efficiencies are similar.
>
> We therefore find that an increase in the market size affects the strength of competitive spillovers: 'Tough' investment becomes less 'tough'." (Rosenkranz 1995, p. 19)

Another interesting result relates to the coordination and cost sharing of R&D among firms. Firms do have a strong incentive to reduce marginal costs. Obviously, if firms are allowed to behave as joint profit maximizers they will

48 A somewhat reasonable assumption if one takes into account the adjustment cost of process innovations. It is not that much of an argument of the availabilty of information since these models do require complete information.

reduce costs and differentiate their products more than they would under more competitive conditions.[49]

3.4.5 Product Differentiation and Customer Reactions

In section 3.5 of this chapter we will develop the main hypothesis based on the above microeconomic analysis. At this point, however, it is appropriate to discuss the nonlinear duopoly model developed by Albach (1973; 1996b; 1996c). This model particularly applies to capital goods markets. because it allows the consideration of supplier switching costs and the cost of customer information acquisition. Albach has modeled the mobility of customers in a duopoly, with respect to the price differentials of the duopolists. The important issue in his model is that there is not only a reaction function with respect to the competitors but also one which relates to the demand. Using these reaction functions Albach was able to complete the Gutenberg oligopoly model in a consistent structural approach.

Gutenberg (1984) had developed and published in 1955 a model using a doubly kinked demand function. This demand function is particularly appropriate for the study of machine tool markets since it is based on a distribution of consumer preferences which result in a demand function with an inelastic range due to the firm's reputation/goodwill ("akquisitorisches Potential"). Gutenberg's argument is that the probability that customers in this market are going to switch their supplier increases with an increasing price differential. Their demand function possesses a range which allows for monopolistic pricing. This is actually the most reasonable description of pricing behavior in the German machine tool industry.

3.4.5.1 The Doubly Kinked Demand Function

Gutenberg (1984) developed his demand model to study non-price competition in imperfect markets. He argues that in the cases concerning atomistic supply and imperfect markets, monopolistic and competitive pricing needs to be integrated. This can be achieved with the demand function. Thus, the goal is to study product differentiation of the firm by analyzing the impact of marketing instruments on the shape of, and changes in, the demand function. Because Chamberlin used only the monopolistic demand function, and Robinson a slight

49 If the demand conditions allow firms to reach a maximal degree of product differentiation, then all market structures converge to a monopoly. The crucial issues which remain then are the cost for product differentiation and the stability of the demand conditions.

variation of Marshall's function, Gutenberg stressed the need to develop a more appropriate approach.

Gutenberg's starting point is that consumers think of quality norms as falling within a certain price range—they believe that for a certain product quality there exists a lower and an upper price limit. A reduction in price in the monopolistic region of the doubly kinked demand function will attract customers away from rivals only until the lower price limit is reached. An increase in price will chase customers to the rival firms until the upper ceiling is reached and the firm loses nearly all its demand. This behavior of the demand function is illustrated in figure 3.5. The own price elasticity of demand η in the monopolistic region is about one. Increasing the marketing effort would change the "preference structure" leading to a stretching of the monopolistic region of the demand function and thus increase the leverage for pricing policy.

The doubly kinked demand curve exhibits three parts, indicating that the marginal revenue function $E'(x)$ might be quasi-discontinuous. The demand curve in figure 3.5 is drawn in a way so that there are no discontinuities and so the elasticity in the monopolistic region is $\eta < 1$. In this figure, Gutenberg used first discontinuous demand functions. The figure also assumes constant marginal cost $K'(x)$.[50] As laid out by Gutenberg, the profit maximizing situation could be specific—one might get two profit maximizing outputs, expressed here at x_1 and x_3. There are two profit maxima—that is, the "maximum maximorum" must be found by comparison of the two profit maxima. Gutenberg argues that it is likely a firm would choose the higher "equilibrium" price, and also that the lower price would allow a higher profit. For a more detailed development of the model, see Kilger (1962) and Gutenberg (1965).

Gutenberg sees this form of price rigidity in firms as depending on the shape of the demand and cost function:

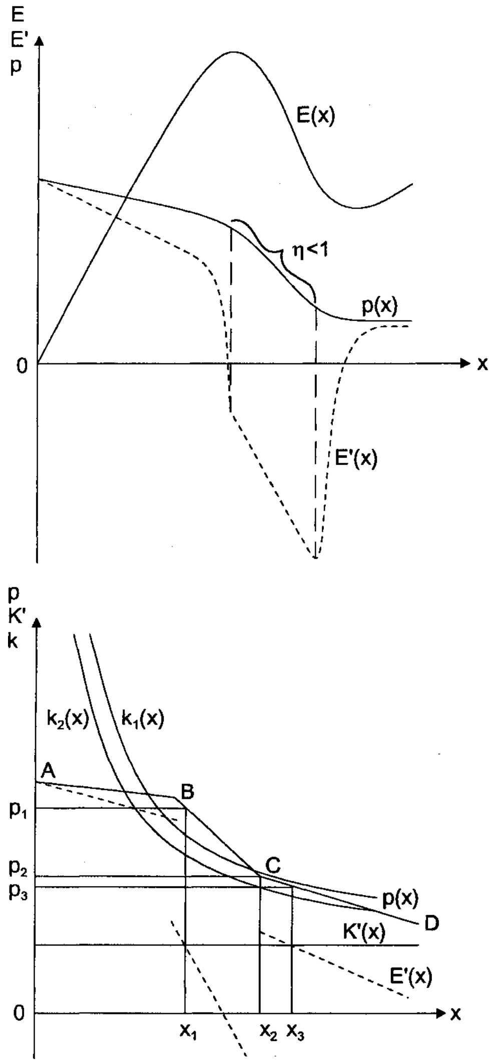
> "The more inelastic the demand function is in the monopolistic region, the greater the distance between the lower and the upper price ceiling is, and the higher the marginal costs, the more likely it is that the profit-maximizing price will be in the upper part of the monopolistic region of the demand function approaching the upper price-limit ceiling (and vice versa)." (Gutenberg 1984, p. 271; translated by M. F.)

Furthermore, a move towards the lower price (in the profit-maximizing "maximum maximorum") would first reduce profits in order to achieve the more profitable position. As such, it serves as a barrier and is a reason for the price rigidity of firms.

---

50 For the production of machining centers we have derived (in section 3.3.1.2) a similar cost function.

Figure 3.5: Gutenberg's Solution of Monopolistic Competition with a Doubly Kinked Demand Curve and Linear Marginal Costs



Source: Gutenberg (1984, pp. 259 and 261).

In the case of two local optima, the firm will choose the short-run price-output combination, which is located in the upper part of the demand function. In the short-run, firms have preferences to stay in the upper region. To move to the second local optimum—which is assumed to be the "maximum-maximorum"—is generally avoided by firms pursuing a strategy of product customization. Only if competitors move in this direction, will other firms follow due to competitive pressure. In this situation, however, it may be that not enough adjustment time is available.

3.4.5.2 Albach's Nonlinear Duopoly[51]

Albach (1996c) argues that the doubly kinked demand function may be regarded as a function of varying mobility of demand. The general market demand functions (as in the case of the machining centers described in equations 3.2 and 3.3) assume constant mobility of demand. For the duopoly, it is assumed that individual demand is linear with respect to the price differentials of the duopolists:

$$p_A = a - 2bx_A + c(p_B - p_A) \qquad a, b, c > 0 \tag{3.34}$$

with:

$p_{A,B}$ – prices of duopolists A, B

$x_{A,B}$ – sales volumes of A, B

a, b, c – parameters.

Customer reactions with respect to prices are given by:

$$\frac{\delta x_A}{\delta p_A} = -\left(\frac{1}{2b} + \frac{c}{2b}\right) = \sigma + \rho \tag{3.35}$$

Albach calls σ the reaction function of latent demand and ρ the customer reaction function of competitive demand. The parameter c measures the mobility of customers in the competitive market. For example, the customer faces only two opportunities as prices change in a market. He can continue to buy from his supplier or he can leave him. In case he leaves, he might switch to another

51 This section refers to Albach (1996c). The presentation of the formal model is based on the "Appendix B: Nonlinear Duopoly" of Albach's 1996 Göran and Luise Ehrnrooth-Lecture held at the Swedish School of Economics and Business Administration on May 14, 1996. For a summary of early work in this area see Brockhoff (1968).

supplier or may not buy at all (prices may have increased too much). On the other hand, if customers are unaffected by price changes, then c is small, and the market is effectively divided between the two duopolists. A perfect duopoly with one price is achieved if c approaches infinity.

Albach assumes that some customers are more price sensitive than others. His explanation is that customers face a cost of change when switching from one supplier to the other. Some customers have switching higher costs than others. Because of this, competitive mobility is variable. The assumption of different costs of change for different customers and a relatively high cost of change for most of them (in the case of machining centers) is expressed by applying the following function:

$$p_A = a - 2bx_A + c\,sin\,h(p_B - p_A) \tag{3.36}$$

For the case of machining centers, this demand function implies that if $c = 0$, then each customer is a regular customer. For $0 < c < \infty$ it is implied that the higher the price differential, the more likely it is that regular customers become occasional customers. In a case where c reaches infinity, each customer is an occasional customer of his supplier. The hyperbolic sine function implies that, the higher the price differential the more than proportionate the mobility of demand becomes. This is also expressed with the reaction coefficient of competitive demand:

$$\rho = \frac{c}{2b} cosh(p_B - p_A) \tag{3.37}$$

Again, the main result found is that the solution of the Gutenberg oligopoly consists of two monopoly points. Albach shows how the equilibrium area can be derived using the following cost and profit functions.

In Albach's nonlinear duopoly, equation 3.36 is the demand function, and equation 3.38 is the cost function:

$$K_A = k_A x_A + F_A \tag{3.38}$$

with

$K_{A,B}$ – total costs of the duopolists

$k_{A,B}$ – variable costs of the duopolists

$F_{A,B}$ – fixed costs of the duopolists

The profit function is then (with $g_{A,B}$-profit)

$$g_A = \frac{a+k_A}{2b} p_A - \frac{1}{2b} p_A^2 + \frac{c}{2b}\{sinh(p_B - p_A)\}(p_A - k_A) - \frac{ak_A}{2b} - F_A \quad (3.39)$$

Differentiating, Albach obtains the condition for optimal p_A

$$\frac{a+k_A}{c} = \frac{2}{c} p_A + \frac{1}{2}(p_A - k_A + 1)\frac{e^{p_A}}{e^{p_B}} + \frac{1}{2}(p_A - k_A - 1)\frac{e^{p_B}}{e^{p_A}} \quad (3.40)$$

The exit prices for $x_{A,B} = 0$ are derived from equation 3.36:

$$p_A^0 = a + \frac{c}{2}\left(\frac{e^{p_B}}{e^{p_A}} - \frac{e^{p_A}}{e^{p_B}}\right) \quad (3.41)$$

The solution space is bounded from below by either $k_{A,B}$ or by $g_{A,B} = 0$.

The lower bound of the price is limited by a zero-profit condition, and this limit (at least the variable cost, $k_{A,B}$) should be recovered.

Due to a lack of appropriate data for the machining center market, an estimation of Albach's model could not be undertaken in this study. However, the prisoners' dilemma situation which the model is based upon is typical for machine tool manufacturers. For this reason we would like to refer to the relevant result of Albach's analysis:

> "... the shaded 'triangles' are solutions also. They show price combinations which offer higher profits than the Cournot point. They are reached by significant price cuts by one competitor and stable prices by the other. These solutions can obviously only be reached by secret price cuts. Therefore, I have called them 'Chiseling Corners'. If secret chiseling is used by the duopolists, they will eventually end up ... where both of the competitors incur significant losses. Therefore, they will have to make a significant price increase together to get up to a level of profits from which they can start to 'chisel' again. These simultaneous price increases are sometimes taken as an indication of collusion. However, they are just the complement of the pricing strategy of secretly cutting prices. If the price level has come down so much that each duopolist faces severe losses, it does not take much insight to independently raise prices ... if one duopolist increases prices to the Cournot level and the other does not follow. The 'martyr' suffers very significant

losses and has to lower his prices immediately, thus rendering the competitor unprofitable immediately. He will learn quickly." (Albach 1996c, pp. 59-60)

3.4.5.3 Conclusion

The main conclusion for the market for machine tools derived from Gutenberg and Albach is that market structure depends on the mobility of demand. This happened in a similar (but not identical) situation when Japanese suppliers of machine tools entered the German market. The market area specifically targeted was CNC lathes and machining centers, where the Japanese suppliers were aiming at the latent demand of small and medium-sized firms of the metal-working industry. Although one would assume an oligopolistic market situation, German firms have not yet recognized that the Japanese competitors have taken-over a significant share of the overall market for these machine tools.

The following section will provide an explanation of the dynamics of competition in the German machine tool industry based on the above theoretical analysis. It will develop a hypothesis to be tested in chapters 4 and 5.

3.5 An Explanation: The Inefficiency Trap Hypothesis

The German machine tool industry evolved in such a way that led to an inefficiency trap. This was due to a number of reasons, the most important being the focus on a product differentiation strategy, in particular customizing products to individual customer specifications. The inefficiency trap is characterized by monopolistic competition and asset specificity which force the firms to continue pursuing the strategy of product differentiation, and thus to recognize decreasing efficiency when the mobility of demand increases due to switching customers. Thus, a positive relationship is expected between the extent to which monopolistic competition is maintained due to high product differentiation and low demand switching. Inefficiency would increase in the case where the mobility of demand increases. This is also because product differentiation has increased already to the point where the number of differentiated products exceeds the social optimum.[52]

52 This is the main conclusion which can be drawn from the literature on product differentiation as discussed above. A similar conclusion was achieved by Spence (1976). He used a partial equilibrium simulation model of monopolistic competition.

The most relevant economic effects concerning product characteristics in the German machine tool industry relate to the concepts of (and interaction between) product differentiation, asset specificity, design economies, and technological perfection[53]. The variables relating to these concepts, as observed in the German machine tool industry, have interacted in a manner that has resulted in the stagnation of competitiveness within the industry. The reason for this situation is the traditional engineering orientation of the industry. It has failed to pursue cost efficiency strategies aimed at volume market segments. In the few cases where large firms did try to implement a cost leadership strategy through volume, they failed due to their inexperience with asset parsimony and volume market-orientation.

For the period from 1950 to 1981, a significant increase in the degree of product differentiation was observed. Table 2.13 (in section 2.5) aptly illustrates this increase. The share of one-product group producers diminished from 65.5 percent to 37.3 percent. All other product groups exhibited significant increases.

In purely economic terms, the inefficiency trap has to do with inefficiencies in allocation. As shown in the theoretical analysis, these inefficiencies result from product differentiation in oligopolistic and monopolistic competitive market structures (including the conduct inherent in such a structure), and from inadequate management and use of resources. The latter efficiency concept is internal to the firm and called technical efficiency.[54] The hypothesis of the inefficiency trap is based on the concept of X-inefficiency, which means that management is unable to keep costs down to the minimum possible level.[55] The inefficiency trap

53 For similar arguments based on long-standing experience in the machine tool business, see Klingelnberg (1992) and Leibinger (1996).

54 Production is technically efficient when the goods are produced at a minimum input combination. Efficiency in machine tool production has to do with operating production plants that allow the industry to produce the machine tools at the lowest possible cost. In general economic terms: the allocation of production inputs is technically efficient if the output of one type of machine tool can not be increased without decreasing the output of some other good. All points of technical efficiency lie on the production contract curve and on the respective isoquants. Technical inefficiency in machine tool production can arise because the actual combination of inputs used lies above the isoquants corresponding to the observed output.

55 For the purpose of this study, the literature on X-efficiency is relevant since it deals with organizational and management efficiencies. Leibenstein (1966; 1987) has stressed similarities and differences between the concepts of X- and technical efficiency. Obviously, when it comes to the estimation of production functions, one efficiency coefficient is calculated which may still be decomposed. For the author of this study, the differences are more on a semantic level. See Leibenstein (1966) for the concept of X-efficiency, and Frantz (1988) for a recent review of studies concerning X-efficiency and the theoretical

hypothesis now posits that for the German machine tool industry, there is a systematic relationship between the degree of monopoly in the market (due to the strategy of product customization) and X-inefficiency.

It should be mentioned that the strategy of product differentiation observed in the German machine tool industry was successful in that it has helped to avoid (price) competition, and thus helped to avoid structural adjustments due to competition. On the other hand, the strategy of product differentiation and customization has prevented the adoption of future efficiency gains by blocking strategies of cost leadership (in the volume business) and product innovation (in breakthrough areas). Either strategy would have implied asset parsimony based on increasing capital intensity and investment of the gains in R&D for progressing in technological leadership. The product differentiation strategy has prevented the realization of economies of scale, and thus limited the industry to production at a suboptimal scale.

As argued in section 3.4.5, the low mobility of customer demand due to product differentiation was the main reason for the stability of this market structure. The market test for the market of machining centers has shown that a partial monopoly was in existence due to the demand and cost structure prevailing in the market. However, the mobility of demand for differentiated products is only low as long as the switching cost and the search cost are lower than the price differential between the rivals' price and the current supplier's price. For example, a price differential of 25 to 30 percent might lead to the switching of about a third of the suppliers (Simon 1990). In other words, Bertrand reactions can be assumed if the switching cost and cost for information on product quality are lower than the value of the price differential. In the long-run, the firm with the higher price may lose all its customers.

The inefficiency trap hypothesis relies on the analysis of industry and firm data, which indicates a considerable change in the structure of demand, a significant stability in the number of firms and in industry concentration, a significant increase in product differentiation, and an erosion and a sharp decline of industry profitability. Chapter 5 will show that nearly one-third of the twelve largest German machine tool firms have lost their price competitiveness. Chapters 4 and 5 clearly indicate how this can be explained by the inefficiency trap—a strategy of product customization which has resulted in increasing prices due to a low elasticity of demand. Because of significant barriers to entry, an imperfect competitive market exists. For several decades, these barriers were high. Due to increasing global competition and a strategy of cost leadership, serious rivals have been able to cross the barriers to entry.

---

debate regarding the concept of X-efficiency (and its differences with the concept of technical efficiency).

To summarize, the German machine tool industry clearly illustrates the trade-off between supplying more differentiated products at higher cost, and offering less product variety and consumer choice at the "expense" of lower cost and lower prices. It is reasonable to assume that there is a clear tendency for customer buying at the lowest price (including switching and search costs), especially in recessionary periods. In a case where the rival industry—e.g., the Japanese machine tool industry—is more volume-oriented, the German machine tool industry has to compete with lower prices. If the mobility of demand increases, firms have a higher risk of ending up in the inefficiency trap since they have an incentive to increase product differentiation to keep customers. This will be demonstrated in the following chapters for the German machine tool industry in the period of 1990-1993 (chapter 4) and 1990-1994 (chapter 5).

4. Hypothesis Test I: Analysis of Survey Data from the NIFA Panel

Surprisingly little empirical evidence has been published in the economics literature concerning competition in capital goods markets. Chapter 3 has attempted to fill part of this gap by developing the inefficiency trap hypothesis. The purpose of this chapter is to test the hypothesis by using a sample of machine tool plants from a larger panel data set covering the German mechanical engineering industry for the period of 1990 to 1993. The data set is the (so-called) NIFA Panel.[56] The data was collected primarily to study the problems and determinants of the organization of manufacturing in the mechanical engineering industries. Therefore, an important part of this study was the development of appropriate economic measures concerning the conduct and performance of these firms and plants.

Chapter 4 is organized as follows. In the introductory section, performance analysis in industrial organization is examined. The second section describes the main variables of the NIFA Panel, and discusses the measurement issues involved in testing the inefficiency trap hypothesis. The third section explores the variability of product differentiation in the data set. The fourth section models the relationships within the inefficiency trap hypothesis with a simultaneous equation approach. These equations explain product differentiation, efficiency, and profitability. The estimation results are discussed the fifth section, followed by a summary of the major findings.

4.1 Introduction

The testing of performance is one of the major concerns for empirical studies in industrial economics. It is important to know more about the impact of market structure, and to discover whether large firms in the more concentrated industries may be more profitable for reasons of their superior efficiency or because of

56 NIFA is the acronym for "Neue Informationstechnologien und Flexible Arbeitssysteme" (New Information Technologies and Flexible Work Systems) which is the name of the Sonderforschungsbereich 187 at the Ruhr-Universität Bochum supported by the German National Science Foundation (DFG) since 1989. The major characteristic of this source will be described in section 4.2.

collusion (see Scherer and Ross 1990, and Schmalensee 1989a; 1989b). A research methodology is needed that takes into account the complexity of the subject.

Early studies of the structure-performance relationship generally used ordinary least square (OLS) methods for their estimations. Although these studies have greatly broadened the understanding of the range of the major determinants of efficiency and profitability, they have a number drawbacks. Since the structure-performance relationship is determined by a multiplicity of causal links, the estimated coefficients were systematically biased. Furthermore, the impact of non-price competition could not be studied appropriately—their endogeneity was not recognized.

Recent simultaneous studies of the structure-performance relationship have attempted to endogenize the impact of advertising, research and development, and product differentiation (see Hay and Morris 1991, pp. 239-244 for a review of simultaneous studies of the structure-performance relation). These analyzes (concerning various forms of non-price competition) primarily used data from cross sections of industries. The standard procedure is to develop a set of simultaneous equations, in which each endogenous variable corresponds to one equation. The main difference between early simultaneous studies of competition and current work lies in the theoretical foundation of the equations. The earlier work was characterized by equilibrium conditions related to industry price-cost margins, whereas the "new IO" generally derives the equations by utilizing a game-theory model of the competitive situation being studied (Bresnahan 1989).

The modeling and the estimation procedures are sophisticated. Since the goal of these studies is to identify the impact of non-price competition variables, the OLS estimation bias has to be eliminated.[57] This is done by using instrumental variables, two-stage least squares (2SLS), and limited information maximum likelihood (LIML) procedures. The most recent and still more comprehensive techniques utilized to avoid such biased estimations are the full information maximum likelihood (FIML) method and the three-stage least squares (3SLS) method. The latter two methods are considered to be fully simultaneous methods that estimate the entire system of equations simultaneously.

---

57 See Greene (1993, chapter 20). It is the problem of identification which has to be solved. With OLS it might happen that the structure remains unidentified and therefore structural estimator would have to be used. But as Greene (1993, pp. 615-616) admits "Unfortunately, the issue is not so clear ... it is often found that the OLS estimator is surprisingly close to the structural estimator. It can be shown that at least in some cases, OLS has a smaller variance about its mean than does 2SLS about its mean, leading to the possibility that OLS might be more precise in a mean squared error sense."

However, there are no empirical studies which use this new methodology to analyze product differentiation in capital goods markets. There are studies that have used the advertising-sales ratio to capture the effect of product differentiation. But there are no studies which attempt to cope with the other main strategy of product differentiation—the design aspect. The design aspect requires one to customize the product to the needs of the individual customers. This is one extreme of product differentiation, and is called product customization.

A few recent empirical industrial organization studies test the impact of product differentiation on competitive outcomes with discrete choice models (see Berry 1994; Berry, Levinsohn, and Pakes 1995; and Goldberg 1995). The convincing methodology of these studies does require a significant amount of data for the estimation of the model parameters. Such data—particularly product-level data, such as prices and aggregate consumer-level data—is not available for the machine tool industry.[58]

When testing the inefficiency trap hypothesis, the concept of economic performance has to be further investigated. In short, there are at least three related concepts of economic performance. These have to do with efficiency, effectiveness, and productivity. In terms of practical measurement these categories are related since they approach the performance issue from different angles. Effectiveness is associated with the achievement of goals—what is achieved compared with what is possible. Or it can simply be a measure of the degree to which goals are attained. Efficiency is an important category in microeconomic analysis. Measures of efficiency show how effectively resources are used to generate useful output—useful in the sense of social welfare. Productivity is a special measure of efficiency since it is the relationship between the output generated by a system and the input used to create the output. Thus, productivity also measures the efficient use of resources in the production of goods and services.

Efficiency for economists implies not only consideration of the relationship between outputs and inputs, but also how the market evaluates the productive output. That is, economic efficiency is related to the aggregated welfare of both consumers and producers taken together. Welfare considerations are the major difference between efficiency and productivity.

To understand how one might test the inefficiency trap hypothesis within a specific market structure-conduct-performance setting, the major empirical approaches are outlined below. This is important because it is necessary to

58 Ireland (1987) discussed earlier empirical studies of product differentiation. He makes the point that a large discrepancy exists between theoretical models of product differentiation and empirical analysis of market performance, which is among others due to the limited data available.

understand the specific methodology that is used to test the determinants of economic performance in the German machine tool industry, especially the impact of product differentiation.

From the methodological viewpoint, the use of the Salter (1966) curve (which models the distribution of labor productivity) is one way to measure the overall performance of a market. Other possibilities are the use of measures from the traditional structure-conduct-performance paradigm or from the "new empirical industrial organization" (NEIO) paradigm conceptualized by Bresnahan (1989).

In the new empirical industrial organization paradigm, Bresnahan (1989, p. 1012) takes the firms' price-cost margins (and not the price-cost margins of the industries) as unobservables. Individual industries are regarded as important, therefore new empirical industrial organization is skeptical about using comparatively static variations across industries. Firm and industry conduct (through which firms set price and quantity) are viewed as parameters to be estimated in the behavioral equations. In general, new empirical industrial organization attempts to test propositions about the strategic choices of firms in duopoly market situations. Usually in non-NEIO studies, only static consumer surplus is used as the criterion to evaluate competition in the specific market.

The measurement of efficiency requires comparison of the different results of the allocation of resources. A misallocation might occur and cause a loss in allocative efficiency. The usual case is the loss of allocative efficiency due to market power. A general measure of comparison is the measure of social welfare as introduced by Dupuit (1844). Dupuit made the suggestion to use the surface below the demand function minus market price times output. This measure was developed further to comprise the Lerner index of monopoly power.[59] It measures the extent to which price exceeds marginal costs. If demand is more elastic and the marginal cost curve is steeply sloped, then the Lerner index is low. Thus one would need to know the elasticity of demand or, respectively, price and marginal cost.

The estimation of efficiency using price-cost margins and concentration ratios on an industry-wide basis has led to numerous studies (a summary of these studies is contained in Schmalensee 1989a). Usually, the following statistical model is used:

59 Another measure of the amount of consumer and producer surplus generated in an industry is the Dansby-Willig performance index. It measures how much social welfare would improve if firms in an industry expanded output in a socially efficient manner. Social welfare is defined as the sum of consumer and producer surplus. If the index is zero, no gains can be made by output expansion, but if it is greater than zero, welfare would improve (see Dansby and Willig 1979).

$$\pi_i = f(s_i, C_j, B_j, X_{ij}, OS_{ij}, D_j, \varepsilon_i)$$

where π_i is a measure of firm profitability correlated with firm i unobserved. Lerner index s_i is the firm's market share, C_j is a measure of seller concentration in the industry, B_j represents the set of entry barrier measures, X_{ij} represents measures (firm or industry) regarding the conjectural variation, OS_{ij} is the term for structural characteristics that explain the discrepancy between π_i and the Lerner index. D_j measures the demand and ε_i is an error term for the unmeasured factors.

The above equation is generally used for cross-section industry studies and for firm effect studies. In cases involving aggregated cross-section industry studies, the single firms are aggregated at the industry level, thus s_i disappears, as do the firms indexed by i.

There are two major explanations of industry performance in the industrial organization literature. They are the differential collusion hypothesis and the differential efficiency hypothesis:

> "*Differential Collusion Hypothesis*: Industries differ in the effectiveness with which sellers are able to limit competition by tacit or explicit collusion. Collusion is more likely to be effective, and profitability is more likely to be above competitive levels, the higher the seller concentration.
> *Differential Efficiency Hypothesis*: Effective collusion is rare or nonexistent. In some industries, long-lived efficiency differences are unimportant, and both concentration and accounting profitability are generally low. Where efficiency differences are important, efficient firms obtain large market shares and earn rents, and both concentration and industry-level profitability are thus high." (Schmalensee 1987, pp. 399-400)

The German machine tool industry is a special case in the sense that there was high profitability and low concentration. That was probably due to an optimal degree of product differentiation and considerable productive efficiency. This has now changed toward a very high degree of product differentiation and a low level of profitability.

An interesting question is raised: how much monopoly power do firms have because of product differentiation? Does the level of monopoly power change with an increasing degree of product differentiation? Using the Gutenberg demand curve, it was shown that firms move along the demand curve until they reach the point where the demand elasticity becomes very elastic. Further price increases at this point reduce output. On the other hand, increasing product differentiation is confronted with the changing preferences of the machine tool buyers, and with decreasing switching costs on their part. This leads to the earlier mentioned trap situation.

One approach to handling this problem empirically is to measure demand elasticities. But even under the constant elasticity and symmetry assumption, an N-product industry has N own-price elasticities, N income elasticities, and $(N\text{-}1)N/2$ cross-price elasticities. For the German machine tool industry, with its more than 1,000 products, the data requirement issue is not manageable.

The major approach to handle this problem is to aggregate similar products until there are only a few left.[60] In this study, the degree of product differentiation is attributed to each single firm. Thus, an attempt is made to shed some light on the issue of market power in a differentiated capital goods industry.

This study argues that in the case of the German machine tool industry, product differentiation has helped to establish partial monopolies which have led to less thorough price competition, thus leading firms to pursue cost driven price increases and avoid cost and efficiency control. In other words, *the central hypothesis to be tested in this chapter is that the German machine tool industry has evolved in a way which has led it into an inefficiency trap.*

The next four sections cover the empirical analysis of product differentiation and performance.[61] The purpose is to make specific the hypothesis to be tested with data derived from the sample of plants found in the NIFA Panel. The machine tool industry is one important branch in this panel data set (which is characterized in the following section).

4.2 Measurement Issues

4.2.1 The NIFA Panel[62]

The NIFA data is a panel database including a large sample of plants and firms from the German mechanical engineering industry. The first wave of data collection was undertaken in 1991—collecting data for the year 1990, as well as for the time of the data collection. The underlying paradigm of the NIFA Panel is

60 Bresnahan (1989, p. 1045). A recent paper which has applied this approach to the Spanish banking market was presented by Jaumandreu and Lorences (1996) at the 23rd Annual E.A.R.I.E. Conference in Vienna.

61 Performance analysis has to distinguish between two major types of performance: the productive performance (of which the concept of technical efficiency is quite familiar), and the market performance (the concept of allocative efficiency).

62 For more details of the NIFA Panel see Flimm and Saurwein (1992). The methodology of the NIFA Panel is also reported in Hauptmanns and Seitz (1992).

in the tradition of German industrial sociology. The questions that the survey primarily focuses on are related to issues of production at the shop floor level. Nevertheless, the NIFA Panel contains a significant amount of "basic data" which relates to the economic functioning of the plant, and correspondingly to the firm. The firm is important because the majority of the plants in the panel are independent, single-plant firms. Although accounting profits are not available, the available data can be transformed into economic performance measures such as value added per capita, and a non-accounting based profitability measure. Therefore, a profitability index was developed by using data of 1991 and 1992.

The analysis itself focuses on data for 1992, the beginning of a down swing in the business cycle.

The classification of the main area of the product program follows the classification of the German mechanical engineering industry (where the segments are called "Fachzweige"). Table 4.1 shows the distribution of plants in the panel according to the Fachzweige and the panel mortality over the four periods. The Fachzweig classification might be regarded as a way of measuring the production program between a three- and four-digit industry classification.

The sample size of the West German mechanical engineering industry at the time of the first wave of data collection contained 5,487 plants. The level of response was high. Of the gross sample, 1,682 questionnaires could be used. The large sample size achieved thus permits an accurate representation of the specific segments of the West German mechanical engineering industry (and beginning with the third wave, of the German mechanical engineering industry as a whole).

4.2.2 Product Differentiation

If a market is to be regarded as competitively imperfect, and if it has more than one supplier, there must be a sufficiently significant degree of product differentiation. In the capital goods market, product differentiation has much to do with product customization, and the establishment of reputation (whereas the situation in the consumer goods market is quite different). Although the idea of product differentiation is very general, its measurement depends, to a large extent, on the specific product.

Table 4.1: The NIFA Panel: Plants Participating in all Four Waves (penultimate column) (the plants were surveyed from 1991-1994 in the respective years)

Value label (HI1_1)	VDMA Code	NIFA Code	Plants in wave				Panel mortality rate (%)
			1	1&2	1&2&3	1&2&3&4	
Information technology	24	1	5	3	2	2	-60.0
Machine tools and manufacturing systems	1	2	163	101	63	48	-70.6
Printing and paper equipment	23	3	38	26	14	11	-71.1
Power transmission engineering	34	4	77	55	42	31	-59.7
Mechanical handling	22	5	151	97	59	48	-68.2
Air handling	9	6	28	18	16	12	-57.1
Food processing and packaging mach.	18	7	112	68	48	39	-65.2
Agricultural machines and tractors	16	8	38	22	16	11	-71.1
Construction equip. & build. mat. mach.	13	9	47	32	22	17	-63.8
Precision tools	7	10	138	83	51	38	-72.5
Textile machinery	25	11	55	34	22	20	-63.6
Valves and fittings	31	12	59	42	32	29	-50.8
Machinery for rubber and plastics	14	13	43	21	13	8	-81.4
Prime movers	10	14	9	6	4	2	-77.8
Fluid power equipment I (pumps)	11	15	32	21	15	14	-56.3
Fluid power equipment II (hydraulics)	36	16	46	33	24	22	-52.2
Processing machinery and equipment	19	17	115	68	47	36	-68.7
Woodworking machinery	6	18	41	24	18	17	-58.5
Compressors and vacuum pumps	12	19	13	5	5	3	-76.9
Mining machinery	15	20	15	11	6	4	-73.3
Total			1,225	770	519	412	-66.4

Depending on the literature one is dealing with—either the economics or the marketing literature—an inconsistent concept of product differentiation emerges. Therefore, it is useful to draw attention to the original idea as it was used by Chamberlin.[63] Chamberlin maintains that a buyer's preferences are dynamic and decisive. They are dynamic because they are affected by the interplay of monopolistic and competitive forces in the market. They are decisive because demand is a function of the buyers preferences, among others.

Economists have stressed the distinction between two types of product differentiation—horizontal and vertical.[64] The marketing profession, however, has neglected the concept of product differentiation, and instead developed the concept of market segmentation. Market segmentation is understood as segmenting markets according to customer needs.[65] Marketing people have stressed that product variations due to product differentiation are not based on an analysis of natural market segments (Kotler 1997, p. 249). It assumes that product differentiation in general is based on artificial product differences. Thus, one might come to the conclusion that the differences in the understanding of product differentiation in the two disciplines are due to differences in the intended goals of the two approaches. That is, the marketing discipline deals with activities directed at satisfying needs and wants through exchange processes whereas industrial economics deals with the aggregate of the exchange process, that is, with the analysis of competitive and imperfectly competitive markets.

In markets such as those for machine tools, capital goods are mainly customized products. Thus, product differentiation in these capital goods markets

63 "A general class of product is differentiated if any significant basis exists for distinguishing the goods (or services) of one seller from those of another. Such a basis may be real or fancied, so long as it is of any importance whatever to buyers, and it leads to a preference for one variety of the producer over another. Where such differences exist, even though it be slight, buyers will be paired with sellers, not by chance or at random (as under pure competition), but according to their preferences. Differentiation may be based upon certain characteristics of the product itself, such as exclusive patented features; trade-marks; trade names; peculiarities of the packages or container, if any; or singularity in quality, design, color, or style." (Chamberlin 1962, p. 56)

64 "Differentiation is said to be *horizontal* when ... between two products the level of some characteristics is augmented while it is lowered for some others, as in the cases of different versions ... of a car. [A consumer] will buy the 'closest' product in terms of a certain *distance* ... Differentiation is called *vertical* when ... between two products the level of all characteristics is augmented or lowered, as in the case of cars of different *series* ... There is unanimity to rank the products according to a certain *order*." (Phlips and Thisse 1982, p. 2) Also see the introductory definition of product differentiation given in section 1.1 of this study.

65 *Market segmentation* is the process of identifying groups of buyers with different buying desires or requirements, see Kotler (1997, p. 249).

has much to do with product customization and the establishment of reputation. According to normal understanding of marketing, product customization comes closer to the idea of market segmentation since the products are custom-made in order to penetrate highly specific market segments. For the purposes of this study, however, the concept of product differentiation is only relevant insofar as it describes the conditions necessary for competition in imperfect markets.

As mentioned, there are a number of approaches one can use to measure product differentiation, especially in the marketing literature. The usual economic approach—to proxy it by advertising expenditures—is not suitable for the capital goods market since this market does not involve significant advertising efforts. The measurement of sales force effort would be more appropriate. Usually, however, sufficient data for such measurement is not available. Hedonic functions, which measure the value of product characteristics, are often applied to quality changes of products, and as such are appropriate for measuring product differentiation.[66] Unfortunately, the above situation also applies to the data requirements of hedonic regression analysis, which requires price information and data on product characteristics.

In his major publications, Porter (1985; see also Caves and Williamson 1985). covers strategies of product differentiation extensively. The components of his concept of product differentiation strategy are:

1. *product characteristics and quality*, and their scope for differentiation based on the bundle of product characteristics (this includes quality and product design aspects),
2. *image and reputation*, which allows for product promotion,
3. *distribution*, i.e. the scope of product distribution and sales force effort,
4. *support*, i.e. the scope of after-sales and technical support, and
5. *price*, since appropriate pricing is crucial for the success of product differentiation strategies.

Although there is no uniform definition of product differentiation in the literature, the above mentioned five components are adequate to encompass the phenomenon of product differentiation as is required in this study. The importance of single components can only be evaluated for specific market situations. In the marketing literature, attempts have been made to derive the optimal bundle of characteristics for a specific product(-market).[67]

66 See e.g. Gordon (1989) and Trajetenberg (1990) for an application of hedonic functions to computers, and to computed tomography scanners, respectively.

67 See the most recent publications on models of optimal product characteristics and market segmentation in the Journal of Marketing Research. Cooper and Inoue (1996)

The informational basis for product differentiation measurements in this study are:

- the share of total sales of products which were made according to customer specification ("Erzeugnisse nach Kundenspezifikation und -bestellung"),
- the share of total sales represented by products manufactured only once ("Unikatfertigung/Einmalfertigung"),
- the share of the type of production structure "workshop manufacturing," ("Werkstattfertigung") which means that there are specialized workshops according to types of machines (e.g. milling-shop), and
- the share of the type of production structure "workbench manufacturing," ("Werkbankfertigung") which means that specialized machines are put together in one workshop.

The above variables include both the preferences of consumers for a specific product, and the manufacturing structure given in the plant. Thus, it is important to remember that product differentiation arises out of a taste for diversity in individual consumption. Therefore, as shown in chapter 2, product differentiation may simply be regarded as the number of variants in a specific product group.

As the evidence presented so far suggests, it is difficult for the firm to decide what degree of product differentiation is most profitable in a given situation. As was demonstrated in chapter 3, the optimal degree of product differentiation depends on the structure of the demand and cost function. Thus, the relevant empirical question is: what degree of product differentiation can be observed at the plant level? The above mentioned variables of the NIFA Panel allow one to construct three measures of product differentiation. These three measures capture two dimensions of product differentiation. First, the dimension of product customization, and second, variety within the production program.

The first measure is a natural measure of product differentiation. It refers to the cause of product differentiation, and answers the question: how many variants of a single product group will a buyer choose? The answer depends on the supply of these variants, and the buyer's preferences. Therefore, it is reasonable to view the degree of the customer-tailored production of goods as a natural measure of product differentiation.

The information gathered with the NIFA questionnaire provides a good basis to capture this basic dimension of product differentiation. At the plant level, the distribution of sales is measured according to three types of product policies:

---

provide a review of the recent literature on market structure analysis and preference structure analysis.

- products produced according to the specifications of the customers (share of custom-tailored sales),
- products produced according to a standardized program with variants provided by the customer, and
- standardized products that the customer can choose from the available production program "out of the catalog."

The first measure of product differentiation, labeled as PDIFF1 variable, is simply the share of item 1 product sales. The second measure combines the weight of all three types of product strategies (PDIFF2). The third measure, labeled PDIFF3, measures the depth of specialization with respect to the equality of product variety as measured by the sales shares of the three largest product groups.

The correlation coefficients for the three product differentiation measures are high, and the intercorrelation between the single product differentiation measures is highly significant. The correlation coefficients for the single years regarding PDIFF1 and PDIFF2 are 0.86. For this reason, the following estimations are based on the continuous product differentiation measure PDIFF1.

4.2.3 Productive Performance

4.2.3.1 Capacity Utilization

The capacity of a plant represents the rate of operation that will yield the minimum average total cost. Capacity in this sense is not fixed, but will vary with changes in the costs of the factors of production. Thus, capacity is an important strategic instrument in competition. It is assumed that the intensity of competition increases the more excess capacity is available in the industry. And, if all plants in the industry were to be used to capacity, excess capacity might exist when industry profitability is below normal.

In the questionnaire of the NIFA Panel, information was gathered as to what extent the capacity of the existing machinery and the available labor was utilized. Thus, the questionnaire measures the degree of used capacity in a plant in terms of the existing machinery and labor over a given period—the past year. This is a generalized measurement that relates to the maximum physical capacity of the machinery and the physical input capacity in numbers of employees or man hours.[68]

68 Widmaier, Niggemann, and Merz (1994) argue that the productive capacity is an important measure of performance in the mechanical engineering industry. They find a significant relationship between capacity utilization and five independent variables. They

4.2.3.2 Value Added

The concept of value added is useful in measuring the productivity of plants, firms, and economic agents in general. In the national income and product accounts, total factor productivity measures are based on the valued added concept of output. Although there are some reservations regarding the use of this concept on an aggregated level—due to the crucial role that intermediate inputs such as energy can play in production costs and inflation—its use at lower levels of aggregation as an appropriate measure of productivity is unquestionable (Norsworthy and Jang 1992). Since no better indicator of economic performance is available from the NIFA Panel data, it was decided to apply this measure for the test of the inefficiency trap hypothesis.

4.2.3.3 Technical Efficiency

The production of goods and services is technically efficient when they are produced with the minimum value of inputs. This is obtained by minimizing the cost of each product-related activity. Technical efficiency has to be distinguished from allocative efficiency, which is related to market performance.[69] Business practice shows that improvements in technical efficiency are achieved by utilizing existing inputs more efficiently. To express this idea, Leibenstein (1966) introduced the socio-economic notion of X-efficiency and, correspondingly, X-inefficiency. X-inefficiency is utilized in cases where there seems to be the possibility of increasing efficiency by a new combination of inputs or more intensive use of inputs. For the purposes of this study, the meaning of X-efficiency and technical efficiency coincide. As argued in section 3.5, the term technical efficiency will be used the way it is in the comparable literature.

This study considered the following variables as appropriate indicators for technical efficiency (based on the NIFA Panel data):

- value added per capita,
- the degree of value added,

---

conclude that complex strategies are more often successful than unidimensional ones. Widmaier et al. used the method of static microsimulation, the so-called MICSIM program. This very innovative methodology is not dependent on the type of distribution of the variables.

69 This study uses the distinction between productive and market performance due to its empirical character and the related measurement issues. In microeconomic theory the distinction is usually allocative—specifically price efficiency. Price efficiency concerns the best allocation of scarce resources among alternative activities and uses. Allocative inefficiency might be due to distorted relations of input prices or of output prices.

- the percentage of the sales of the main product in relation to the total sales of the firm,
- the degree of capacity utilization of machinery, and
- the degree of capacity utilization of man-power.

The measurement of technical efficiency requires some sort of standard of optimal or best practice efficiency. For this requirement, economic theory has provides the concept of the production function. For the purpose of empirical testing, one needs a well-defined and specified production function for each product-related activity. Based on the typical production technology in plants in the mechanical engineering industry, some preliminary estimations of the Cobb-Douglas production function were made.

The empirically relevant properties of the Cobb-Douglas production function are:

1. the input factors are almost completely substitutional, that is asymptotically substitutional (except for the cases $K = 0$ and $L = 0$),
2. the input factors in partial variation exhibit diminishing returns of scale,
3. the marginal rate of substitution decreases with increasing substitution,
4. the Cobb-Douglas production function is linear homogeneous. If each of the inputs is multiplied by k, then the output also increases by k. The returns to scale are 1,
5. with total factor variation the marginal returns are constant, that is, a production function with constant returns to scale. The returns to scale are measured by the sum of the coefficients, which is in the given case 1,
6. the elasticity of substitution is 1, and
7. the Cobb-Douglas production function allows for the direct measurement of efficiency. The "base coefficient" of the more efficient firm is larger than of the less efficient firm since it produces more output with the same input and technology.

There are a number of critical points to be addressed. The most crucial one is the assumption that the input factors are nearly perfectly substitutable. In the long-run, this can be realistically assumed.

The most convincing measurement specification was one using—as inputs—the number of skilled workers, and the number of machine tools used. Value added was used to measure the output. Thus, a practically classical production function with two variable inputs—capital K and labor L—was estimated using a frontier production function approach. Since the input factor "skilled workers" did not capture the structure of overall employment, a different procedure was chosen. Labor productivity per employee was used and scaled at 100 percent efficiency at a value added level of DM 400,000 per employee.[70]

Table 4.2: Correlation Coefficients for the Intercorrelations of Various Efficiency Measures for 359 Plants in the NIFA Panel, 1990-1993

Variables	Labor productivity measures (simple input efficiency measure)				DEA efficiency measures						
					1990		1991		1992		1993
	1990	1991	1992	1993	CRS	VRS	CRS	VRS	CRS	VRS	CRS
Labor productivity measures											
1991	0.48										
1992	0.39	0.43									
1993	0.40	0.42	0.63								
DEA measures											
1990 CRS	0.87	0.39	0.33	0.35							
VRS	0.56	0.28	0.22	0.19	0.68						
1991 CRS	0.38	0.72	0.33	0.34	0.41	0.36					
VRS	0.25	0.55	0.30	0.24	0.32	0.41	0.75				
1992 CRS	0.31	0.37	0.85	0.52	0.33	0.26	0.40	0.37			
VRS	0.15	0.23	0.56	0.31	0.24	0.54	0.38	0.61	0.73		
1993 CRS	0.37	0.36	0.59	0.94	0.39	0.22	0.42	0.31	0.56	0.37	
VRS	0.18	0.22	0.39	0.61	0.24	0.59	0.32	0.59	0.43	0.65	0.65

Note: All correlations are significant at the 0.1% level.

To validate the results of the simple productivity measurement, data envelopment analysis (DEA),[71] the non-parametric method of efficiency analysis was used. Two models of measuring the input efficiency were applied, the constant returns model (CRS) and the variable returns model (VRS). Complete data from all waves was available for the 359 plants that were included in the analysis. Table 4.2 shows the correlation coefficients for the various efficiency measures observed over the four year period. All correlations are highly significant. The intercorrelations between the labor productivity measure and the DEA constants' returns efficiency is high and ranges between 0.72 (for 1991) and 0.94 (for 1993). The correlations for the variable returns model are 0.55 (for 1991) and 0.61 (for 1993). It was decided to use the simple efficiency measure based on

70 DM 400,000 is quite a high value, but it was used to include the most efficient plants as well.

71 See Charnes and Cooper (1985) for an overview on issues and methods of DEA.

labor productivity in the analysis since there is a strong impact of labor on efficiency for mechanical engineering plants.

4.2.4 Market Performance

Few economists have made the issue of product strategy as clear as Henry Ford in his famous quote: "My customers can have a car of any color they want as long as it is black." Obviously, this strategy reflects a specific position towards product adjustment efficiency. Ford's ability to choose to produce what the customer was willing to buy, and serve the market with a minimum of effort, was certainly dependent on the conditions of the automobile market of that time. But it is a timeless strategy insofar as it points to product-market performance in a general sense—a firm must be efficient in choosing a product to offer in a marketplace where buyers have an adequate range of choice.[72]

An ideal measure of product-market efficiency is the market-share in the long-run. Indicators from the NIFA Panel which might approximate this market performance are:

- the market share of the sales per plant as compared to the overall sales of the mechanical engineering industry, expecting the same share at the level of the single segments of the industry,
- the volume of orders considered in an appropriate time-period (only available for 1992 and 1993),
- past earnings, and
- the growth rate of sales over a longer period.

Accounting profits were not measured in the NIFA Panel. It was therefore decided to estimate a profitability measure using an indicator of the development of returns as measured on a rating scale.[73] For the purpose of constructing a scale, past returns as reported by the firms were used. Data for 1991 and 1992 were matched (see table 4.3). Where the reply of the firms was either a "strong increase" or an "increase" in returns in 1991 and 1992, the plants were classified

72 For a comparable distinction see Downie (1958). He distinguishes between technical efficiency and market efficiency. Market efficiency for him is "the skill in choosing what the customer will be willing to buy." (Downie 1958, p. 44)

73 This scale was used for the first time in the second wave (called "Maschinenbau 1992") which covers the year 1991. The question reads as follows: "Please evaluate on a scale ranking from +2 (= significant increase) to -2 (= significant decrease) the following developments: (a) 'development of returns in the past three years' and (b) 'development of returns in the next three years'."

as "(3) profitable." When they reported (for 1991 and 1992) a "strong decrease" or a "decrease" for the past returns, they were classified as plants with "(1) low profitability." The remaining plants were assigned a "(2) mid-range profitability."[74]

Table 4.3: Definition of the Profitability Measure PROFIT1 Using the Evaluation of the Development of Returns in 1991 and 1992

	Past returns in 1992				
Past returns in 1991	strong increase	increase	no change	decrease	strong decrease
strong increase	36	42	20	13	10
increase	26	162	106	65	55
no change	4	47	75	71	43
decrease	3	17	23	47	56
strong decrease	0	1	6	18	67

Definitions:

Low/not profitable plants (in the right-hand bottom corner; PROFIT1 = 1) $N_1 = 188$

Mid-range profitable plants (diagonal area; PROFIT1 = 2) $N_2 = 559$

Profitable plants (in the left-hand top corner; PROFIT1 = 3) $N_3 = 266$

In order to capture the growth dimension of profitability, the measure PROFIT1 was multiplied by the growth of value added over the period 1991 to 1992. For this, the growth rates had to be transformed so as to fix the highest negative value at zero. The profitability measure PROFIT4 was then calculated:

$$\text{PROFIT4} = [(\text{Growth of value added 1992/1991}) + 100] * \text{PROFIT1}.$$

4.2.5 Intensity of Competition

The intensity of competition is a concept designed to capture the degree of competitive pressure. Since competition is a timely and dynamic process, the intensity of competition is one important property in this process. What form

74 There is a reservation to be made regarding the measurement. Because there is no baseline to which one could refer there are problems of interpretation. Then there remains the question of "intersubjective" comparability. This is partly solved by using data for two years. Nevertheless, the data can at least be intepreted as an ordinal scale.

such a process will take is partly determined by factors related to the activities of rival firms. Competitive conduct might take the form of price competition, advertising and promotion, research and development, vertical integration, and diversification.

There is a huge amount of empirical literature on competition in the tradition of the structure-conduct-performance paradigm.[75] In short, competition is a dynamic process in which the convergence towards perfect competition creates the competitive pressure, and defines the degree of the intensity of competition. Simple measures of the character of competition relate to the properties of market structure, such as the size and number of sellers and buyers. Since there is no conclusive evidence that as market concentration increases there is a monotonic decrease in competition, empirical studies of competition are left to develop further indicators to test for competition. One possible way to develop an index of the intensity of competition is to use a survey instrument with competitive methods that constitute the building blocks of competitive strategies.[76] This is the approach which currently prevails in strategic management literature. Such an index is based on questions regarding the perceived intensity of each form of competition.

For the purpose of this study, questions of the NIFA Panel regarding the following dimensions are used to measure the intensity of competition. Each question was asked twice in order to relate development: (a) in the past three years, and (b) in the next three years. The answers were measured on a five-point scale ranging from "significant increase" (+2) to "significant decrease" (-2):

- the intensity of competition (this information is only available for the first "wave," which was conducted in 1991),
- the development of demand,
- the development of sales,
- the development of profits, and
- the development of employment.

75 For example, Scherer and Ross (1990, p. 16) provide an overview of this literature. They briefly state, that "(I)n modern economic theory, a market is said to be competitive (or more precisely, purely competitive) when the number of firms selling a homogeneous commodity is so large, and each individual firm's share of the market is so small, that no individual firm finds itself able to influence appreciably the commodity's price by varying the quantity of output it sells."

76 See e.g. Robinson and Pearce (1988) for the recently standardized instrument containing an overall of 22 items for measuring the competitive strategy of firms.

The observations for the first item were used in the econometric analysis since it seemed that this variable best captured the competitive situation of the plant (labelled COMP_INT).

4.3 Variation of Product Differentiation in the NIFA Panel

Table 4.4 examines the relationship between product differentiation, efficiency, and profitability for segments of the German mechanical engineering industry in the period 1990-1992. To obtain more general values for product differentiation, the means for the segments of the large sample were used. For wave 1 those collected for 1990 (in the year 1991) are included in this table. The values for the degree of product differentiation, based on the data of plants included in three waves, are also shown. For wave 1, observations of 1,145 plants are used, whereas for the three waves, only data from 348 plants could be used.

This table includes the degrees of product differentiation, a profitability measure, and an efficiency measure. It also includes the coefficient of variation, that is, the ratio of the standard deviation to the mean multiplied by 100 (column five).

Four segments from the NIFA Panel were excluded due to their small sample size. There are eight segments of the industry with high efficiency scores ranging from means of 31.2 to 35.6, and eight segments with low efficiency scores ranging from 26.8 to 30.7. The mean for the high efficiency group is 33.8, and for the low efficiency group 28.4. Comparing the mean values, the absolute difference is 5.4 percent, which is a relative advantage of 18.7 percent for the high efficiency group.

The industrial segments with the high efficiency values show a low degree of product differentiation, with a mean over the group and three periods of 36.6; whereas the low efficiency group has a mean of 47.5. The difference between the high and the low efficiency group with regard to the degree of product differentiation is -23.0 percent. The more efficient plants thus exhibit a lower degree of product differentiation.

The high efficiency group has an average value on the profitability index of 2.20 (whereby the profitability measure—PROFIT1—measures low profitability with values of 1 and high profitability with values of 3). The profitability mean of the low efficiency group is 1.94. Thus, the high efficiency group exhibits on average 13.6 percent higher profitability than the low efficiency group.

Overall, the analysis of table 4.4 clearly indicates a significant difference in product differentiation, efficiency, and profitability between the segments of the

Table 4.4: Product Differentiation, Profitability, and Efficiency in Segments of the German Mechanical Engineering Industry, 1990-1992

Segments of the mechanical engineering industry	No. of plants in 3 waves	Product Differentiation PDFF1 mean (%) wave1 only N = 1,145	Product Differentiation PDFF1 mean (%) 3 waves	Product Differentiation PDFF1 CV (%) coefficient of variation	Profitability PROFIT1 mean overall measure	Efficiency EFF1 mean (%) 3 waves
Segments with HIGH Efficiency Scores:	N = 153	N = 530	N = 153			
Woodworking machinery	12	40.1	41.9	93.9	2.33	35.6
Machinery for rubber and plastics	8	51.0	35.3	83.9	1.63	35.4
Valves and fittings	23	33.0	34.0	103.7	2.35	34.3
Construction equip. & building material mach.	17	39.3	39.5	92.4	2.65	34.0
Textile machinery	12	42.0	42.9	88.7	1.83	34.0
Mechanical handling	44	51.4	50.3	67.4	2.32	33.8
Food processing and packaging mach.	30	43.3	42.2	90.5	2.20	31.8
Agricultural machines and tractors	7	17.2	6.7	141.8	2.29	31.2
Segments with LOW Efficiency Scores:	N = 195	N = 615	N = 195			
Fluid power equipment I (pumps)	12	18.5	21.0	114.5	2.17	30.7
Printing and paper equipment	11	44.0	53.9	67.1	1.91	28.8
Power transmission engineering	28	48.5	52.0	66.4	1.82	28.7
Air handling	14	50.3	31.4	89.1	2.36	28.4
Machine tools and manufacturing systems	47	51.2	49.4	73.8	1.89	28.2
Processing machinery and equipment	32	61.3	61.2	54.3	2.09	28.1
Precision tools	35	68.6	72.5	47.5	1.69	27.8
Fluid power equipment II (hydraulics)	16	42.8	38.8	68.6	1.56	26.8
Means of HIGH Efficiency Group:		39.7	36.6	95.3	2.20	33.8
Means of LOW Efficiency Group:		48.2	47.5	72.6	1.94	28.4
Difference: HIGH-LOW Group (in percent):		-17.6	-23.0		13.6	18.7

Note: The segments are sorted in decreasing order of their mean efficiency value (last column). Efficiency estimations are based on labor productivity (value added per employee). The variable product differentiation is based on the NIFA-Variable "Sales share of customized products" from three waves. The estimations for three periods have reduced the number of originally available observations in the panel. The group mean values are based on the mean of the branches.

German mechanical engineering industry. The next sections (4.4 and 4.5) focus specifically on the machine tool industry and on the tentative generalization that product differentiation decreases efficiency, and that efficiency increases profitability. One intuitive explanation is that plants which pursue an intensive strategy of product differentiation take any business order which increases the utilization of the existing capacity, at the expense of profitability. Therefore, the next section is devoted to modeling these relationships by laying the basis for the estimation of a system of simultaneous equations, in order to test for the significance of the tentative generalization and the hypothesis of the inefficiency trap.

4.4 Development of a Simultaneous Equation Model

As shown in chapter 3, the economic impact of the degree of product differentiation in a market depends on the substitutability of the products as seen by the buyers. The smaller the elasticity of substitution between the products, the higher the degree of product differentiation. *The steeper the slope of the firms' demand curves, the higher the price-cost margin (i.e. the margin of price over marginal cost), and the smaller the equilibrium output relative to minimum average cost, thus the greater the number of firms and products.*

An important determinant of product differentiation is the extent of economies of scale. The smaller the economies of scale, the smaller is the minimum average cost output, and the larger is the number of firms, and the number of products in equilibrium. Thus, an increase in scale economies would reduce the degree of product differentiation if the preference of the buyers towards product variety are not too strong. If buyers view the differences between similar products as important, product differentiation will remain high. It will be lower if they view similar products as acceptable substitutes.

In order to study the efficiency of the supply of capital goods, it is important to determine whether price and/or quantity competition leads to an increase or decrease in economic efficiency. In other words, to find out whether the aggregate welfare of consumers and producers taken together is increased or reduced. In a recent publication, Bester and Petrakis (1993) have shown that both Cournot and Bertrand competition lead to *underinvestment in cost reduction* relative to the social optimum whenever firms enjoy a quasi-monopolistic position due to product differentiation and a low degree of substitutability. This result is reversed and competition leads to *overinvestment* in cases where competition is very high and goods become closely substitutable.

According to the analysis by Bester and Petrakis, Cournot competition provides stronger incentives to reduce cost through process innovation than Bertrand competition if the degree of substitutability is low, whereas the incentive may be weaker if the degree of substitutability is sufficiently high. Brander and Spencer (1983) argue that a cost reduction by one firm lowers the Cournot equilibrium output of its competitors. However, they also find that the strategic use of such innovative effort may result in cost reductions beyond the point where total costs are minimized for the output chosen.

The crucial point for the analysis of the machine tool industry is the question of scale—whether the higher the output, the larger the total gain from a given reduction in the unit cost of production? Due to product differentiation, this might be somewhat less pronounced, and as a result, competition may less directly influence cost reduction through the determination of equilibrium output. Therefore, in the following sections a set of three equations is developed to examine the relationships among product differentiation, efficiency, and profitability. Each of the equations is discussed in turn.

4.4.1 The Product Differentiation Equation

The question addressed by much of the economic literature concerning product differentiation is: whether interindustry variations in advertising activity, as a proxy for product differentiation, can be explained by interindustry variation in concentration? This study applies a different perspective since it analyzes an intraindustry variation of product differentiation. The line of argument holds for concentrated industries in general, however, since many researchers have found a positive relationship between concentration and advertising (product differentiation) activity (see Scherer and Ross 1990). It has to be recognized that the proxy which measures product differentiation has implications for the analysis. It may well be that product differentiation due to advertising is related to concentration and unrelated to product differentiation due to product customization. Product differentiation due to product customization is tentatively unrelated or negatively related to concentration. Thus, in the sense of this study, product differentiation is expected to decrease with economies of scale and concentration. To proxy economies of scale at the plant level, the estimated stock of machine tools will be used (see the variable KAP in Table 4.5).

The effects of scale economies and concentration might also be captured with a proxy measuring market share. Since the plants of the NIFA Panel offer quite a good representation of the German mechanical engineering industry, the market share (SHARE_ME) is measured as the share each single plant has of the overall sales of the plants in the sample.

From information on the industry, it is assumed that competition in the markets of the mechanical engineering industry primarily takes the form of intensive product rivalry. The firms try to capture a share of the stable market by offering ever-improving machine performance. This might give rise to the argument that competition has a positive effect on the degree of product differentiation. But, if in course of competition so much process innovation takes place, then quite the contrary might happen, that is a reduction in the degree of product differentiation. To test which mechanism is working, a measure of the competitive intensity is used. This is the perceived change of the intensity of competition in the past three years (COMP_INT).[77]

Table 4.5: Variable Definitions for Simultaneous Equation Model

Dependent variables	
PDIFF1	Degree of product differentiation as measured by the the sales share of customized products (type 1 measure)
EFF	Measure of technical efficiency based on labor productivity
PROFIT4	Profit index measured as changes in profitability as indicated by successive changes over two periods
Independent variables	
KAP	Capital intensity measured by the number of machine tools used in the production process (measured for 1992 and equalized to a standard machine) and taken as the log-form (ln)
BATCH1	The production structure is such that the products can be made to single/special orders ("Anteil_Einmalfertigung")
COMP_INT	Degree of competitive intensity in product markets as measured by the perceived change of competitive intensity in the past three years (5 = sign. increase; 1 = sign. decrease)
SHARE_ME	Plant's market share of the total mechanical engineering industry's sales
SIZE_LG	Plant size measured as the log of the number of employees
CU_MACH	Degree of capacity utilization of machines
CU_PERS	Degree of capacity utilization of personnel
LINEPROD	Share of the production which is organized/produced according to the assembly line production ("Anteil_Fließfertigung")
DEMAND_F	Expected development of demand in the next three years as measured in terms of expected change (5 = sign. increase; 1 = sign. decrease)

77 The original scale of the NIFA Panel is reversed for the purpose of estimation. The original scale assigns to a significant increase the value one, and to a significant decrease the value five. Thus, a reservation should be mentioned—that this five-point scale implies no information on the level of the intensity of competition at which the change occurs. It is nevertheless a good indicator of the competitive intensity.

Work in economic theory suggests that there is an important effect which comes from the type of capital employed. The so-called "asset specificity" implies that the employed assets allow only the manufacturing and distribution of a certain range of products.[78] Thus, the degree of asset specificity regarding product differentiation is captured by the variable share of production structure appropriate to special orders (BATCH1). Obviously, this variable is expected to have a positive and highly significant effect on the degree of product differentiation.

As a final remark regarding the specification of the product differentiation equation, it should be mentioned that no information on the degree of the substitutability of products or product groups is available. Hence, the above discussion suggests the following specification for product differentiation:

$$\begin{aligned} \text{PDIFF1} = \alpha_0 + \alpha_1 \,\text{KAP} + \alpha_2 \,\text{BATCH1} + \alpha_3 \,\text{COMP\_INT} + \\ \alpha_4 \,\text{SHARE\_ME} + \varepsilon_1 \end{aligned} \tag{4.1}$$

4.4.2 The Efficiency Equation

An analysis of product differentiation must treat efficiency as an endogenous variable. Firms that pursue a strategy of product differentiation (Porter 1980; 1985) are expected to be profitable, resulting in higher profit margins due to their differentiation advantage. In recent years, strategy research has challenged this position (see e.g. Reitsperger, Daniel, Tallman, and Chismar 1993). It is argued that only firms with a strategy aiming at both—product differentiation and cost leadership—have the potential to be profitable. However, the crucial variable in this relationship is efficiency, and the question is: to what extent does product differentiation affect efficiency (and how do both interact to affect profitability)? According to the inefficiency trap hypothesis, it is expected that product differentiation (PDIFF1) has a negative impact on efficiency. This has to do with the impact of the organizational structure of production on efficiency (among other reasons). Significant amounts of the input factors are used to pursue product differentiation. *Transaction costs related to product differentiation are higher than those related to homogeneous products.*

A separate issue of the organizational structure of production relates to specific technologies. Thus, the variable share of production that is organized according to the assembly line principle (LINEPROD) is assumed to have an

78 As Williamson (1981, p. 1546) argues "The reason why asset specificity is critical is that, once the investment has been made, buyer and seller are effectively operating in a bilateral exchange relation for a considerable period thereafter."

impact on efficiency. Since this principle might either support the efficiency of the production process or be in conflict with it, it is an open question to state the direction of the affect in advance.

It is assumed that the degree of capacity utilization has an influence on efficiency. Again, the measurement of efficiency has to be separated from its determinants. This is because a production function can be modeled in such a way that the degree of capacity utilization is a parameter. Such a model would directly model the impact of capacity utilization on efficiency. On empirical grounds, it is reasonable to test for the impact of capacity utilization on efficiency. Usually, the physical capacity to produce manufactured output is viewed as fixed in the short term.[79] An affect of the capacity utilization of machines (CU_MACH) and an affect of the capacity utilization of labor (CU_PERS) on efficiency is assumed. Efficiency might also be affected by plant size. Thus, the variable plant size (SIZE_LG) is also included in the efficiency equation.

$$\begin{aligned} \text{EFF1} = \beta_0 + \beta_1\,\text{PDIFF1} + \beta_2\,\text{LINEPROD} + \beta_3\,\text{CU\_MACH} + \\ \beta_4\,\text{CU\_PERS} + \beta_5\,\text{SIZE\_LG} + \varepsilon_2 \end{aligned} \tag{4.2}$$

4.4.3 The Profitability Equation

Profitability must be treated as an endogenous variable since it implies the possibility of a simultaneous optimization of product differentiation and efficiency. The profitability equation in this analysis is not intended to capture the classical profit-maximizing behavior with product differentiation at the firm level due to limitations of the available data. Such modeling would require that the tastes of the buyers in the product characteristics space are given. Furthermore, one would have to include pricing data and selling expenditures in the analysis, as well as the production costs. This is not feasible due to the lack of appropriate data in the NIFA Panel.

A considerable number of empirical studies have revealed the importance of market share for profitability (for an overview see Schmalensee 1989a). Hence, the market share variable is to be included in the profitability equation. It is nevertheless recognized that market share and concentration effects cannot be precisely and unambiguously distinguished in empirical work.

To test whether there are divergent effects of product differentiation (PDIFF1) and efficiency (EFF), both variables are included in the profitability equation. *To*

79 For the development of production functions including time and intensity adjustment see Albach (1980).

test for decreasing returns to scale of product differentiation, a quadratic term of PDIFF1 is introduced into the equation.

Finally, the influence of the demand has to be considered in the profitability equation. Again, data is only available on the expected development of demand in the next three years as measured on a five-point scale (attributing five to a significant increase and one to a significant decrease).[80]

Thus, the following relationship describing profitability across the plants is obtained:

$$\begin{aligned}\text{PROFIT4} = \gamma_0 + \gamma_1\,\text{SHARE\_ME} + \gamma_2\,\text{PDIFF1} + \gamma_3\,(\text{PDIFF1})^2 + \\ \gamma_4\,\text{EFF} + \gamma_5\,\text{DEMAND\_F} + \varepsilon_3 \qquad (4.3)\end{aligned}$$

4.5 Estimation Results

Table 4.6 presents two-stage least squares (2SLS) estimates of equations (4.1) to (4.3) for the machine tool industry and the mechanical engineering industry as represented in the NIFA Panel in 1992. All equations are at least significant at the 1 percent level, except the estimation of the profit equation for the machine tool industry, which is significant at the 10 percent level. In equation (4.1) the estimated influence of capital intensity KAP is positive and significant on product differentiation for the mechanical engineering industry. Thus, we found the opposite of what was expected. It was expected that KAP as a proxy for scale economies would reduce the degree of product differentiation. This might have to do with the measurement of KAP. Remember that the number of machine tools was used to proxy for capital intensity. A second attempt to proxy capital intensity using average investment figures per employee (derived from investment statistics) plus the value of the machine tools employed, showed comparable results. Thus, at least for the mechanical engineering industry as a whole, capital intensity has a positive influence of on product differentiation for this sample. For the machine tool industry, the effect is negative but not significant.

Highly significant is the effect of BATCH1—the share of the production structure which is aimed at customized production. This somewhat obvious result emphasizes the importance of the existing production structure for product policy. Again, this might imply a structural component which is also related to capital intensity and its positive impact on product differentiation. It was argued that this is an result of asset specificity, i.e. production structure and capital intensity are important determinants of product differentiation.

80 The original data has a reversed order of values.

Table 4.6: Estimated Regression Coefficients Using the NIFA Panel Data for 1992 for the German Mechanical Engineering and the Machine Tool Industries (2SLS Estimations with t-Statistics in brackets)

VARIABLE:	PDIFF1		EFF (Lab. Prod.)		PROFIT4	
	Mech. eng. industry	Mach. tool industry	Mech. eng. industry	Mach. tool industry	Mech. eng. industry	Mach. tool industry
Intercept	34.726***	85.802**	17.751***	7.921	-234.109*	5.135
	(3.593)	(2.808)	(3.308)	(0.662)	(-2.179)	(0.060)
KAP	3.674*	-0.322				
	(2.101)	(-0.49)				
BATCH1	0.526***	0.451**				
	(11.711)	(3.180)				
COMP_INT	-2.923	-12.891*				
	(-1.450)	(-2.491)				
SHARE_ME	-40.442**	10.260			-161.468*	-189.361°
	(-3.030)	(0.229)			(-2.207)	(-1.674)
PDIFF1			-0.037*	-0.154*	1.844°	0.652
			(-2.141)	(-2.652)	(1.759)	(0.398)
$(PDIFF1)^2$					-0.016°	-0.006
					(1.691)	(-0.377)
EFF					13.155***	4.567*
					(4.354)	(2.575)
DEMAND_F					3.908	14.103
					(0.505)	(1.128)
LINEPROD			0.077*	-0.097		
			(2.103)	(-0.582)		
CU_MACH			0.084*	0.342**		
			(2.147)	(2.765)		
CU_PERS			0.083	0.076		
			(1.448)	(0.551)		
SIZE_LG			0.871	-1.214		
			(0.617)	(-0.291)		
N obs.	464	45	464	45	464	45
F	38.635***	4.948**	4.979***	4.027**	4.619***	2.224°
R^2	0.252	0.331	0.052	0.341	0.048	0.222
R^2 adj.	0.245	0.264	0.041	0.256	0.038	0.122

Significance levels are: ° 10%, * 5%, ** 1%, *** 0.1%.

The proposition that increasing competition intensifies product rivalry, and thereby increases product differentiation is not supported since the coefficient of the variable COMP_INT is negative. It is only significant at the 5 percent level for the machine tool industry, and it is negative and not significant for the mechanical engineering industry. Thus, it is reasonable to believe that *increasing competition decreases the degree of product differentiation in capital goods industries.* A negative effect on the market share of the degree of product differentiation was expected. This effect is significant at the 1 percent level for the mechanical engineering industry.

In the efficiency equation, the effect of product differentiation is inverse on efficiency. For both industries, the coefficient is negative and significant at the 5 percent level. Product differentiation reduces the efficiency as measured by the labor productivity. Assembly line production increases the efficiency in the mechanical engineering industry with a significance at the 5 percent level. In the machine tool industry the sign is negative, but the effect is not significant. The degree of machine capacity utilization increases the efficiency. This is significant, at least at the 5 percent level. The impact of the degree of capacity utilization of personnel is not significant, which might have something to do with measurement problems. There is also no significant impact of size on efficiency in both industries.

In the profit equation, the effect of product differentiation is reflected in the linear and the quadratic term. The coefficients are significant at the 10 percent level for the mechanical engineering industry. The signs are the same for the machine tool industry, the linear term is positive and the quadratic term is negative. *There is certainly a weak effect of decreasing returns of product differentiation on profitability.* A plot of the functions shows that at between 50 and 60 percent product differentiation, profitability begins to decrease. The profitability enhancing effect of efficiency is significant at the 0.1 percent level for the mechanical engineering industry and at the 5 percent level for the machine tool industry. What is interesting is the effect of market share on profitability. The coefficients are negative and significant at the 5 percent and 10 percent levels. This is a clear indication that in the mechanical engineering industry the usual profitability increasing effect of an increasing market share does not exist. In both estimates the result of the expected demand is not significant.

4.6 Conclusion

The German machine tool industry exhibits a clear trade-off between the supply of more differentiated products (at higher cost and price) versus less product variety (consumer choice) at the "expense" of lower cost and price. This analysis has treated product differentiation, efficiency, and profitability as endogenous in order to test for this trade-off. The study found decreasing returns of product differentiation in the German machine tool industry for the early 1990s. This is not in line with the commonly held view, which expects that firms that pursue a strategy of product differentiation are more profitable (for recent empirical work see Kekre and Srinivasan 1990).

For the plants in the NIFA Panel, product differentiation had a negative influence on efficiency. The industrial segments with the high efficiency values show a significantly lower degree of product differentiation when compared with the low efficiency group. In short, the more efficient plants exhibit a lower degree of product differentiation. The high efficiency group also has a higher average profitability index. The profitability mean of the low efficiency group is significantly lower than the index of the high efficiency group.

The analysis using descriptive statistics to analyze a low and high efficiency group is supported by the results of the simultaneous equation analysis. The profitability enhancing effect of efficiency is significant. The impact of product differentiation on profitabilty follows a pattern of decreasing returns to product differentiation. But this influence is weak. The proposition that increasing competition intensifies product rivalry, and thereby increases product differentiation, is not supported. Thus, it is reasonable to believe that increasing competition decreases the degree of product differentiation in capital goods industries.

5. Hypothesis Test II: Analysis of Published Accounts from the Bonn Databank

5.1 Methodological Issues

5.1.1 Product Differentiation in Strategy Research

5.1.1.1 Introduction

There are many factors involved in the recent decline of the German machine tool industry. Unfortunately, the study of all of these factors is much too broad to be dealt with in a single analysis.[81] Therefore, chapter 4 concentrated on analyzing product differentiation in the form of product customization as a major factor relating to the deteriorating competitive position of the machine tool companies listed in the NIFA Panel. The overemphasis on product customization has led to inefficiencies. The high costs of product differentiation have not resulted in the expected returns. However, it should be noted that the data of the NIFA Panel lacks exact accounting information. Chapter 5 compensates for this deficiency by utilizing sources that include profitability data which is based on actual accounting information. This allows a more precise examination of the microeconomic functioning of machine tool firms. In addition, it offers a further test of the inefficiency trap hypothesis, and presents a clearer view concerning the economic foundation of the strategies used by large German machine tool firms.

Success factor research (known simply as strategy research) is an important approach in the study of performance. Success factor research tries to identify a small number of key factors which vitally affect the performance of firms. The assumption is that the resulting impact of these key factors contributes a significant portion of the enterprise's performance. The determination of the relevant performance factors involved requires an analysis of the cause and effect relationships between these factors and at least one performance criteria. Keeping in mind the theoretical foundations of chapter 3, this chapter utilizes success factor research and an extended version of the Bonn Databank to further

81 For more information concerning the diversity of causes see the strategy paper of the VDW (1993a).

explore the relationship between product differentiation and the performance of firms in the German machine tool industry.

Product differentiation, as a major instrument of a firm's product policy, is a relevant performance factor because of its impact on the firm's demand function. The central question, however, is the evaluation of how product differentiation effects are felt under specific demand and supply conditions. Recent controversies surrounding the influence of product differentiation (measured as product variety) on the profitability of firms illustrate how important the effects are (see Coenenberg and Prillmann 1995; Thießen 1996). The isolation of these effects is important for this analysis. With an increasing number of success factors, the possibilities of interdependence create problems for correct analysis and interpretation. A compromise must be made between completeness and manageability. The analysis in this chapter thus focuses on product differentiation (measured as the degree of product group specialization), and on the main strategies utilized by large German machine tool firms.

The primary task of success factor research is to answer the question: what degree of influence does a specific factor have on a certain performance criterion? Its end goal is the clarification of an effect's impact on the chosen success factors. It is also important to establish whether (or in what way) the effect depends on other parameters. Success factor research is not exclusively about the clarification of causal coherence, but also about the indirect factors influencing the analysis. Previous success factor research has shown that there can be considerable problems in the identification and measurement of success factors. It should also be mentioned that the main approaches of empirical analysis used in this type of research—multiple regression analysis and cluster analysis—provide only a few insights (if any at all) into the underlying causality. Researchers have encountered considerable difficulties with the complexity of their examined issues. This is an essential reason why the analysis here is focused only on product differentiation as a decisive part of the product policy utilized by machine tool firms.

To illustrate potential problem areas in the field, it is useful to refer to two representative papers that focus empirically on issues of product policy. Kekre and Srinivasan (1990) used the PIMS database (utilizing a sample containing more than 1,400 business units of U.S. companies) to study the influence of the breadth of the product program. Their main finding was that both market share advantages and increases in the performance of business units were due to broad product lines. They did not find any support for the assumption that production costs rose with a broader product program. In other words, business units practiced product variety with favorable results.

Completely opposite results were found in a more recent study undertaken by Coenenberg and Prillmann (1995). Using an international sample derived from the electronics industry (98 business units from Asia, the U.S.A., and Europe), and covering the five year period of 1987 to 1991, led them to conclude that a clear and negative relationship exists between product variety and firm profitability. Firms with high product variety were found to be less successful with respect to profitability. They found that a low degree of product variety was a basic condition for widespread standardization and simplification of the manufacturing processes—thus allowing firms to exploit economies of scale at all levels.

A major difference in the focus of the two studies was the overall variety of the firms involved. Kekre and Srinivasan referred to the complete range of business units for the entire U.S. manufacturing sector, whereas Coenenberg and Prillmann derived their results explicitly from the electronics industry. Perhaps, industry specific effects are partly responsible for the discrepancy in the results? To help answer this question, it is useful to refer to a few other studies exploring success factors in the capital goods industry.[82]

5.1.1.2 Prior Strategy Measurement Studies in the Machine Tool Industry

An important result of this study's analysis of the structure of the German machine tool market (in chapters 2 and 3) was the conclusion that suppliers were partly monopolists in their markets, and that monopolistic competition was the dominant type of competition. Today, this is changing. Increasing global competition seems to be creating an almost perfectly competitive market. There are now enough sellers and buyers of machine tools so that no single seller or buyer can control prices. Several questions arise from this new situation. What actions can a producer of machine tools take to gain advantage in a competitive market? How might a German firm deter entry by Japanese machine tool firms? Should firms invest in large-scale production plants, as Maho did? Should they aggressively enter the most important Asian markets, as suggested by the German industry association VDW (1993a)?

Obviously, firms differ in their strategies and strategic moves. However, some theorists argue that the firms within an industry form groups according to the similarity of their competitive strategies (Newman 1978). It is assumed that these strategic groups are a stable element of the market structure and that they

82 See Hambrick (1983); Vasconellos and Hambrick (1989); Welge and Hüttemann (1993); and Homburg (1995a; 1995b). Additional references can be found in Backhaus (1992).

influence a firm's short-term decision-making. It is also assumed that these groups show persistent performance differences.

There is empirical evidence concerning the existence of strategic groups within a number of industries (for a review see McGee and Thomas 1986), and specifically within the West German machine tool industry (Zörgiebel 1983). However, the analysis raises doubts as to whether such groups persist over time. In a manner similar to Marshall's concept of industry, the concept of strategic groups is merely an analytical convenience to group the economic activities of firms. The basic question regarding the German machine tool industry is: whether there are groups of firms which choose to react to competitors' strategic initiatives in different manners? If this is not the case, then the entire industry would have to be considered as a single actor, and there would be no differences within the concept of industry at all (Caves and Porter 1977).

Acting strategically can be defined as aiming for some sort of advantage over actual or potential rivals. In the machine tool industry it relates to business variables such as capital investment, R&D, product differentiation, manufacturing, and marketing (among others). Four strategic concepts have influenced the thinking concerning strategic choices in the machine tool industry: Porter's (1980) concept of competitive strategies, Zörgiebel's (1983) technology based strategies, the Boston Consulting Group's (1985) strategic concept, and Ehrnberg and Jacobsson's (1993) model of competitive strategies for flexible manufacturing systems (FMS). These studies define the nature of competition in the industry, and the competitive strategies that respective strategic groups utilize. The approaches can be summarized as the following concepts and measures:

Porter:
- strategic advantage (unique product or low costs)
- strategic target (specific market segments or whole industry)

Boston Consulting Group (BCG):
- number of approaches to achieve advantage (few or many)
- potential size of advantage (small or large)

Zörgiebel:
- product complexity (conventional machines, NC stand alone, MC, FMS)
- problem solving vicinity (near or distant)

Ehrnberg and Jacobsson:
- strategic advantage (differentiation or cost leadership according to Porter, measured as annual production volume of NC machine tools)
- strategic orientation (machine centered or systems centered)

No detailed analytical study of the machine tool industry applying Porter's concept of competitive strategies is known, although his strategies of overall cost leadership, differentiation, and focus have been used for conceptual convenience in the studies by Zörgiebel (1983), and Ehrnberg and Jacobsson (1993). A similar and more often used strategic approach in the machine tool industry is the concept of the Boston Consulting Group (BCG 1985; Maschke 1987; and the CEC Report 1990). As with Porter, BCG's concept is based on the market volume and the opportunities for product differentiation. They define four competitive environments related to: product characteristics, economies of scale, market, and competition.

BCG's four competitive environments are labeled: stalemate, volume, fragmented, and specialized businesses. Stalemate and volume capture standard products—stalemate with a mature technology, and volume with a dynamic one. Product differentiation is implied by fragmentation and specialization. Fragmentation is assumed to use a mature technology, and specialization operates with a dynamic technology.

Based on 51 percent of the West German machine tool production in 1989, the CEC Report (1990) illustrates changes in the competitive position of the West German machine tool industry from 1983 to 1989. According to the CEC Report, West German manufacturers moved out of stalemate, fragmented, and volume environments. Most of them have become specialists. The report maintains that this move took place primarily through the switch from conventional to NC machine tool technologies. The companies interviewed adopted the following strategies:

"– upgrading products to CNC and introducing peripheral components into the product range,
– introducing cost reduction strategies such as the standardization of components, automation of production, and increased sub-contracting, and
– expanding distribution networks.

In reality, manufacturers tend to operate in more than one competitive environment. Specialist producers offer standard products and a high degree of customization. On the other hand, volume producers have their own areas of specialization. Most manufacturers offer conventional machines in their product portfolios. Offering a wide product portfolio which includes a conventional machine is also considered to be a strategic advantage in cultivating and maintaining a client base ... by offering a low cost machine to regular clients (the producer) ... prevents new suppliers from undermining his customer base." (CEC Report 1990, p. 83)

The assumptions and conclusions of the BCG model are primarily based on the supply structure of the industry—with technology distinguishing between successful (volume, specialization) and less successful (stalemate, fragmentation) suppliers. The demand structure is not captured by the model. As in Porter's model, the distinction between fragmentation and specialization is arbitrary and disappears in cases where appropriate industrial market segmentation is applied. Thus, the main purpose of the model is to compare the advantages and disadvantages of various aspects of the machine tool business. It by-no-means captures the analytical dimensions of strategic moves—since it defines them. For example, stalemate businesses have a low potential for pricing and exploiting economies of scale, whereas for specialization the definition is the exact opposite. Nothing is said about how firms should make price decisions or decisions concerning how much to invest in R&D, human capital, advertising, or new plants and equipment. The same dimensions are assumed true for firms, even when demand or cost conditions are changing and new competitors are entering the market.

Two important studies remain to be mentioned when analyzing strategic aspects of the German machine tool industry. First, there is the analysis of strategic groups by Zörgiebel (1983). Second, the study by Ehrnberg and Jacobsson (1993). The latter study is interesting since the authors focus on the most dynamic product segment of the global market—machining centers and FMS based on machining centers.

In figure 5.1, we find on the horizontal axis Ehrnberg and Jacobsson's (1993) machine-centered and systems-centered firms (measured as the accumulated number of FMSs sold by 1988). Porter's strategies of differentiation and cost leadership (measured as the annual production volume of NC machine tools) lie on the vertical axis.

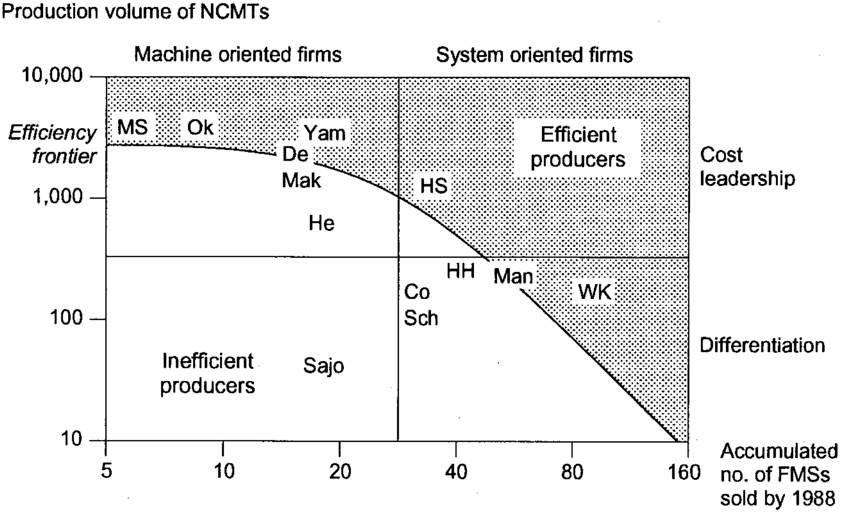
The FMS industry primarily consists of large machine tool producers. German firms are found in two of the four squares in the figure (if one would include the entire industry, certainly three squares would be covered—northwest, southwest, and southeast). The producers of intelligent systems are located in the southeast square. This is where the highest concentration of German firms is found (Werner and Kolb, Scharmann, and Hüller Hille). The competitive strength of these firms is mainly based on transfer lines. Werner and Kolb is regarded as the leader in this strategic group.

Among the cost leaders of the northwest square are two German firms: Deckel[83] and Heller. To some extent, they both follow the same strategy—based on milling machines and machining centers. "Heller is the largest non-Japanese firm of machining centers and seems to be the only European machining center

83 In the meantime the Deckel AG, and its successor the Deckel Maho AG, went bankrupt.

firm which directly competes with the Japanese." (Ehrnberg and Jacobsson 1993, p. 10)

Figure 5.1: Strategic Map of the International Industry Supplying Machining Centers and FMSs Based on Machining Centers



MS = Mori Seiki; Ok = Okuma; Yam = Yamazaki; De = Deckel; Mak = Makino; HS = Hitachi Seiki; He = Heller; HH = Hüller Hille; Man = Mandelli; WK = Werner und Kolb; Co = Comau; Sch = Scharmann

Source: Based on Ehrnberg and Jacobsson (1993, p. 36).

The most interesting strategic group is the system-centered cost leadership group, where Hitachi Seiki is in the forefront. Interesting, because global competition has pushed the bulk of efforts towards developing low-cost intelligent systems. Also, Hüller Hille and Werner and Kolb are moving in this direction. This strategic group aims at high product utility with low price, a typical case for global industries. Based on industry expertise, Ehrnberg and Jacobsson (1993) judge:

"... that it is highly plausible that this decade will see a race by companies into the northeast square ... where they will supply (PC based) smaller and lower cost systems to smaller and medium-sized firms on a large scale" (p. 16), and

> "... that the system centered differentiators will be under very considerable pressure in the years to come ... (since) basing company strategy purely on leading the new technological discontinuity, implies going for a position around which it is difficult to build significant and sustainable entry and mobility barriers" (p. 17).
>
> Ehrnberg and Jacobsson argue that due to the cumulative nature of technological change in the FMS industry "... it is less likely that one or few firms can gain decisive first mover advantages" (p. 20).

But, this depends on the rate of diffusion for the FMS. With a quick rate of diffusion, first movers can more easily build barriers to entry and sustain them. *If the diffusion rate is slow, late-comers have time to perceive the opportunities and to react strategically.* The point worth noting here is that one or another advance in strategy is not definite. The possibilities of strategic advance change over time with the dynamics of global competition. Therefore, it is equally important to see whether improvement in strategy measurement might help to increase the empirical evidence concerning the impact of strategy on the performance of the German machine tool industry.

5.1.1.3 An Index of Product Group Specialization

The basic unit used to measure the extent of product differentiation in section 2.5.1 was a single product, called the "product item." The composite of products offered by a firm can be regarded as the degree of product differentiation or product group specialization—assuming that the firm is operating in a single industry only. The width and depth of the product mix are the basic dimensions used to measure the patterns of product differentiation. When measuring the degree of product differentiation, differentiation has to be distinguished from the degree of product diversification, as well as from the product differentiation measure which was used in chapter 4. In chapter 4, product differentiation was measured as the sales share of customized products that a firm produced.

The usual methods applied to product diversification cannot be used in this study because machine tool firms generally operate in only one four-digit SIC industry (the basic unit in the measurement of product diversification). Usually, machine tool firms practice only product group specialization since they manufacture products in only one of the two broad classes of the types of machine tools (machine tools, forming type, SYPRO 3211 or machine tools, forming type, SYPRO 3212). Because of this, the product classification scheme of the industry association as expressed in the VDW's Directory of Machine Tool Suppliers (also called the VDW Red Book) was used to measure the variety of product differentiation. To provide a better understanding of this variety table 5.1 shows the size of 85 firms and the length of their product mix.

Table 5.1: Sales, Employment, and the Length of the Product Mix of 85 of the Largest West German Machine Tool Firms in 1990

	Firm	Sales in DM	Employment	Per capita sales in DM	Length of product mix (total no. of items)	First major product group	Second major product group
1	Siempelkamp	50,000,000	100	500,000	1	fly presses	
2	Heidenreich & Harbeck	100,030,400	230	434,915	1	transfer, MC, FMS	
3	Graessner	32,966,400	240	137,360	2	honing mach.	
4	Feinm. M. Deckel	40,000,000	260	153,846	2	grinding mach.	
5	Dreistern-Werk	44,000,000	230	191,304	2	oth. met. form.	
6	E. Jäger	117,160,000	392	298,878	2	oth. met. form.	
7	F. Werner (W&K, Bln.)	160,000,000	600	266,667	2	transfer, MC, FMS	
8	Jaespa K. Jäger	14,500,000	85	170,588	3	sawing mach.	
9	Walther Trowal	30,000,000	250	120,000	3	honing mach.	
10	Bohle	39,000,000	115	339,130	3	transfer, MC, FMS	milling mach.
11	EHT Eisen-u. Hammerw.	45,000,000	225	200,000	3	shears f. sheet	
12	F. Kuhlmann	15,000,000	100	150,000	4	milling mach.	grinding mach.
13	Ingersoll	88,000,000	490	179,592	4	spark eros., EDM	lathes & autom.
14	Traub AG	453,000,000	2,632	172,112	4	lathes & autom.	
15	Ziersch & Baltrusch	22,000,000	80	275,000	5	grinding mach.	
16	K. Hoffmann	22,000,000	270	81,481	5	planing mach.	grinding mach.
17	Felss	25,000,000	160	156,250	5	oth. met. form.	hammers
18	Arnz "Flott"	30,000,000	150	200,000	5	drilling & bor.	
19	Bahmüller	30,000,000	400	75,000	5	grinding mach.	
20	Boley	30,000,000	170	176,471	5	lathes & autom.	
21	Stama	95,020,800	328	289,698	5	transfer, MC, FMS	drilling & bor.
22	Hoesch Mafa	104,878,400	465	225,545	5	lathes & autom.	special presses
23	Gehring	115,059,200	630	182,634	5	honing mach.	
24	Fortuna	121,038,400	719	168,343	5	grinding mach.	
25	Liebherr-Verzahnt.	123,139,200	700	175,913	5	gear cutting m.	industr. plants
26	Index	350,000,000	2,000	175,000	5	lathes & autom.	
27	Göckel	30,000,000	200	150,000	6	grinding mach.	
28	Ixion	30,000,000	150	200,000	6	lathes & autom.	
29	P. Wolters	31,027,200	248	125,110	6	honing mach.	
30	Diskus Werke AG	45,000,000	170	264,706	6	grinding mach.	honing mach.
31	Hurth	80,000,000	560	142,857	6	gear cutting m.	grinding mach.
32	SHW	90,000,000	340	264,706	6	milling mach.	transfer, MC, FMS
33	Chiron	215,000,000	590	364,407	6	units f. m. cutt.	transfer, MC, FMS
34	Grob	275,043,200	1,700	161,790	6	transfer, MC, FMS	spec. purp. cutt.
35	Maho AG	714,000,000	3,679	194,074	6	milling mach.	transfer, MC, FMS
36	H. Kolb AG (W&K, Kö)	73,000,000	221	330,317	7	drilling & bor.	transfer, MC, FMS
37	Monforts	119,000,000	400	297,500	7	lathes & autom.	
38	Gildemeister AG	716,200,000	3,742	191,395	7	lathes & autom.	industr. plants
39	K. E. Fischer	30,000,000	200	150,000	8	bending mach.	shears f. sheet

Table 5.1: continuation

40	Bohner & Köhle	64,963,200	350	185,609	8	milling mach.	rolling mills
41	Hessapp	69,972,800	330	212,039	8	lathes & autom.	milling mach.
42	Pittler GmbH	88,000,000	700	125,714	8	lathes & autom.	
43	Diedesheim	100,000,000	650	153,846	8	lathes & autom.	drilling & bor.
44	Waldrich Siegen	140,000,000	750	186,667	8	lathes & autom.	milling mach.
45	Schiess AG	194,000,000	1,464	132,514	8	grinding mach.	gear cutting m.
46	Schütte	216,000,000	1,150	187,826	8	grinding mach.	lathes & autom.
47	Trumpf	548,955,200	2,874	191,007	8	combined punch.	laser separ. m.
48	Lindenmaier Prä. AG	56,000,000	180	311,111	9	units f. m. cutt.	transfer, MC, FMS
49	Leifeld	62,054,400	450	137,899	9	rolling mills	oth.met. form.
50	GMN G. Müller AG	212,019,200	1,700	124,717	9	grinding mach.	units f. m. cutt.
51	Buderus	30,000,000	230	130,435	10	grinding mach.	transfer, MC, FMS
52	Reinecker	33,000,000	240	137,500	10	grinding mach.	lathes & autom.
53	Hegenscheidt	87,264,000	511	170,771	10	lathes & autom.	drilling & bor.
54	G. Wagner	100,000,000	690	144,928	10	sawing mach.	grinding mach.
55	Schaudt	140,000,000	625	224,000	10	grinding mach.	
56	Pfauter	200,000,000	1,000	200,000	10	gear cutting m.	
57	Deckel AG	636,000,000	2,470	257,490	10	milling mach.	spark eros., EDM
58	Kapp	90,011,200	530	169,832	11	grinding mach.	gear cutting m.
59	Blohm	101,000,000	400	252,500	11	grinding mach.	
60	Emag	120,000,000	500	240,000	11	lathes & autom.	spec. purp. cutt.
61	Boehringer	201,192,000	1,356	148,372	11	lathes & autom.	milling mach.
62	Hilgeland	32,000,000	200	160,000	12	rolling mills	oth. met. form.
63	Naxos-Union AG	91,950,400	532	172,839	12	grinding mach.	spec. purp. cutt.
64	Bihler	130,000,000	860	151,163	13	oth. met. form.	bending mach.
65	Wafios	148,025,600	560	264,331	13	oth.met.form.	bending mach.
66	Witzig & Frank	74,982,400	310	241,879	14	milling mach.	lathes & autom.
67	TBF Tiefbohrtechnik	95,990,400	500	191,981	14	units f. m. cutt.	drilling & bor.
68	Weisser	110,000,000	560	196,429	14	lathes & autom.	units f. m. cutt.
69	Dörries Scharmann	250,000,000	1,100	227,273	14	lathes & autom.	grinding mach.
70	Reinhardt	39,000,000	270	144,444	15	oth. met. form.	shears f. sheet
71	SMS Hasenclever	164,993,600	463	356,358	16	hydraul. presses	fly presses
72	Alzmetall	50,000,000	334	149,701	17	drilling & bor.	units f. m. cutt.
73	Hüller Hille	370,000,000	2,000	185,000	17	units f. m. cutt.	transfer, MC, FMS
74	Steinel	100,000,000	500	200,000	18	units f. m. cutt.	transfer, MC, FMS
75	SMG Pressen	107,464,000	461	233,111	18	hydraul. presses	special presses
76	Ex-Cell-O	181,000,000	900	201,111	18	units f. m. cutt.	transfer, MC, FMS
77	Klingelnberg	319,968,000	1,700	188,216	18	gear cutting m.	grinding mach.
78	Heller	345,000,000	1,700	202,941	18	milling mach.	transfer, MC, FMS
79	Eumuco AG	82,000,000	460	178,261	20	shears f. profil	crank presses
80	Elha	26,000,000	140	185,714	22	drilling & bor.	transfer, MC, FMS
81	Schuler	750,147,200	4,000	187,537	22	eccentr. presses	oth. mech. press.
82	Honsberg	90,000,000	500	180,000	25	units f. m. cutt.	drilling & bor.
83	Lasco	43,000,000	280	153,571	26	hydraul. presses	hammers
84	Alfing Kessler	200,000,000	950	210,526	27	units f. m. cutt.	transfer, MC, FMS
85	Müller-Weingarten AG	408,000,000	2,250	181,333	34	hydraul. presses	oth. mech. press.
Averages:		146,411,962	764	201,189			

Sources: VDW Red Book (1989); American Machinist Blue Bulletin (1991); Tecnologie Meccaniche (1990; 1991; 1992).

However, the width and the depth of the product mix was combined to compute an index for product group specialization. It should be emphasized that this is a particular measure of product differentiation of the firm. The index measures the extent to which the firm is specialized into one product group as compared to the overall number of product items. For this purpose, the maximal number of product items produced by a firm in a product class were counted.

For example, the degree of product group specialization for the Trumpf Group (the largest firm in the industry) is computed as follows. The VDW Red Book (1993) lists the following product item code numbers for Trumpf: 23.02, 23.03, 23.04, 23.05, 24.01, 25.01, 27.05, 28.01, 28;02, 36.01, and 42.10. The length of the product mix, that is the total number of product items is 11. The maximal number of items in one product group is 4 (in group number 23, "thermal beam separating machines, plasma, and laser"). Since Trumpf produces 11 items, the percentage of the specialized items is 36.4 percent. This percentage is taken as the measure of product group specialization, "the index of product differentiation number four (PDIFF4)."[84] In order to widen the scale—and to measure the size of product differentiation—this percentage is multiplied by "the maximal number of items in one product group," in this case, by 4. 4 multiplied by 36.4 leads to a product differentiation index number 5 (PDIFF5) for Trumpf of 145.6. It should be mentioned that one could think of other measurement concepts, such as the ones applied in diversification research. Diversification research utilizes a weighting procedure using sales shares of product items and similar factors. Since information of this type is not available for the firms in this study, the suggested measures of product group specialization seem to be reasonable.

However, one reservation has to be made which holds for any measure based on empirical product classifications. Since these classifications generally are pragmatic, they do not allow a very precise measurement. This is the case with the German Machine Tool Builders Association classifications published in their Red Book. The overall number of items and the size of the product groups remain arbitrary. This, however, is true for each product related measurement. It can only be avoided when measuring the technical dimensions of a product, such as the speed and precision of a machine tool.

Table 5.2 shows the degree of product group specialization for 12 German machine tool firms as measured by the two described indexes, PDIFF4 and PDIFF5. The index PDIFF4 ranges from 22.7 for Schuler to 100 for Pittler. The index PDIFF5 ranges from 94 for Schumag to 900 for Pittler. This means that Schuler and Schumag have a low index since they produce 22 and 17 product

84 In the analysis of the NIFA Panel data (chapter 4) three indexes of product differentiation were used. They are adjusted to that particular data set.

Table 5.2: Indexes of Product Group Specialization (PDIFF4 and PDIFF5) Based on the VDW Classification for a Sample of 12 German Machine Tool Firms

Firm	Count of product items (1)	(2)	Index PDIFF4	Index PDIFF5
	Maximum number of product items in a single product group	Total number of product items the firm is producing	Share of the product items of the largest product group (1) as of the total (2)	Weighted index PDIFF5 = (1) * PDIFF4
Schuler Group	5	22	22.7	113.5
Schumag AG	4	17	23.5	94.0
Eumuco AG	5	21	23.8	119.0
Müller-Weingarten AG	9	31	29.0	261.0
Dörries Scharmann/Schiess AG	4	12	33.3	133.2
Trumpf Group	4	11	36.4	145.6
Ex-Cell-O Group	9	18	50.0	450.0
Schütte GmbH	5	8	62.5	312.5
Traub Group	4	5	80.0	320.0
Gildemeister Group	5	6	83.3	416.5
Walter Group	8	8	100.0	800.0
Pittler Combine	9	9	100.0	900.0

Note: The indexes are computed only for the parent company. The large Groups Thyssen Industrie AG and IWKA AG are excluded. The Rothenberger AG is excluded due to its particular product-mix. The data is based on VDW's Directory of Machine Tool Suppliers (VDW Red Book 1993).

items respectively; but only 5 and 4 respectively in one product group. Pittler produces 9 product items overall in only one product group. This means that Pittler exhibits a significant degree of product group specialization. It should be mentioned that these measurements were only applied to the parent firms. The indexes do not include the product items of the subsidiaries.

5.1.2 Choice of Performance Criteria

5.1.2.1 Limitations of Unidimensional Criteria

There are several problems that must be addressed when choosing performance criteria. With respect to the unit of analysis, a decision must be made as to whether performance should be measured on the level of the business unit, the firm, or the industry. It should then be decided which type of performance criteria to accept. Are measures based on accounting data appropriate? Or is information concerning capacity utilization and productivity more appropriate? Finally, one has to fix the reference point and the time period for the measurement.

The explanatory power of a single one-dimensional performance criterion is limited. Accounting criteria might be biased. One has a certain amount of leverage in drawing up a balance sheet for instance, there are possibilities to choose among various rules for the valuation and depreciation of assets. Criteria like capacity utilization or productivity are restricted to just one element of production—be it the capacity of machines or the available labor. The important market share criteria are generally missing, as are the accumulated resources invested in its achievement. The same is true for quality criteria. The weaknesses of using a single criterion, suggest adoption of a measurement approach based on multidimensional criteria.

Two criteria which have proven their validation in numerous empirical studies are the hexagon criterion of Albach, and the Z value of Altman. The choice of the dimensions of the hexagon criterion are based on a systematic analysis of excellent firms. The Z value is based on a multifactor model developed by Altman for the purpose of bankruptcy prediction.

5.1.2.2 The Hexagon Criterion of Albach

The hexagon criterion of Albach uses six measures. These six measures are similar to those used by Peters and Waterman (1982) in their comprehensive empirical field work on excellent firms.[85] The overall criteria was designed by Albach as a model hexagon, where the surface of each of the six measures defines one coordinate of the hexagon (as with the surface of a radar chart). For the selection of the excellent firms, the performance measures (averaged over a long period) are used to define the hexagon. The surface for each single firm is then used to get the ranking of the firms in the whole sample. The greater the surface, the better the performance of the firm. The six measures defining the hexagon are:

1. the growth rate of fixed assets,
2. the growth rate of equity capital,
3. the ratio of market to book value of the firm,
4. return on total capital,
5. return on equity, and
6. return on sales.[86]

This combined criteria measures profitability, the achieved growth, and the intangible assets of the firms. The scaling of the single measures has an impact on the surface of the hexagon. It defines—jointly with the formula for the surface of the hexagon—the value of the overall criteria. The scaling and surface definition express the implicit weighting procedure of the single criterion. As such is the case, they remain arbitrary, and it is reasonable to keep this reservation in mind.

Reservations concerning particular single criteria are to be taken seriously. As Davis and Kay (1990) note, capital intensity and gearing interfere with the ranking of firms, and while the usual profitability measures capture some aspect of the success of firms, none gives the whole picture. While Davis and Kay are in search of a single measure,[87] however, this study rests on two combined

85 Peters and Waterman (1982, p. 12) define in their popular book excellent firms as firms "especially adroit at continually responding to change of any sort in their environments." That is an excellent firm is a well adapted firm able to match its strength with the opportunities in its environment. They measured the financial and innovative performance of their sample of firms for the period 1961 to 1980.

86 See Albach (1987) for the definition. A discussion of the performance criteria can be found in Albach (1988).

87 Davis and Kay propose to measure added value as a means of valuating the intangible assets of a firm. They assess the amount of capital employed by the firm. Then they calculate the capital costs using a normal rate of return. Finally, they deduct this from the operating profit of the firm. This measure recognizes the cost of capital, which is an important issue in the proper measurement of performance. This relates to the ongoing discussion of shareholder value. This study assumes that the hexagon criterion and the Z

measures—the hexagon criterion of Albach and the Z value of Altman. Albach (1987), Altman (1968; 1971), and Peters and Waterman (1982) among others have shown that these two criteria are capable of discriminating excellently performing firms from poorly performing ones. It should be noted, however, that new measures, such as the added value measure by Davis and Kay (1990) will certainly enrich the field of performance measurement.

Figure 5.2: Hexagon Criterion for German Machine Tool Firms, 1991-1994

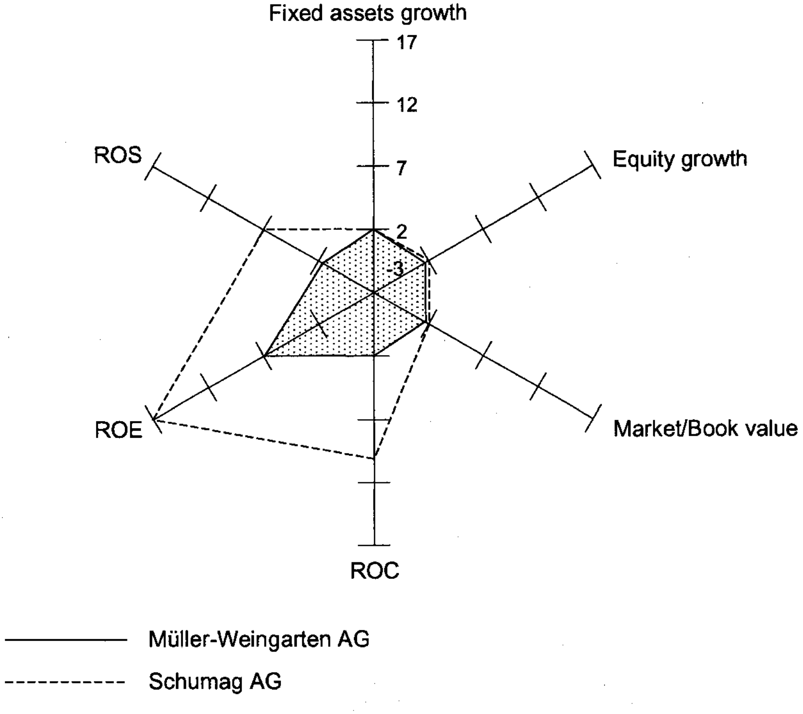


Figure 5.2 illustrates the hexagonal criteria for two firms (from a sample of 15 German machine tool firms). In order to obtain a more equal scaling of the axis, the ratio "market value to book value" was multiplied by 0.01 for the purpose of

value are appropriate to capture the intangible assets by using the ratio of market to book value.

presentation. For the computation of the proper hexagonal values, the formula for the hexagon was applied. The graphic representation of the hexagon's criteria has also to be adjusted for cases in which a single variable becomes negative. For this situation, computation rules have to be applied. In cases where two values are negative, they result in a negative expression and are subtracted (contrary to arithmetic where the product would be positive and it would have to be added). For more detail concerning the computation of the variables see Albach and Moerke (1996). A further multidimensional criterion deserving attention is the Z value developed by Altman. This is discussed in the following section.

5.1.2.3 The Z Value of Altman

The Z value based on Altman's discriminant function might be regarded as an index to discriminate between bankrupt and healthy companies—it is essentially an index of the company's overall well-being.

The literature of business economics contains numerous studies regarding the possible causes of firms' failures. Usually, these studies are related to the factors of insolvency and bankruptcy. One method with considerable validity is the discriminant function, modeled and estimated by Altman. Altman (1968) has compiled 22 indicators which were previously used for insolvency predictions. He reduced them to the five most meaningful ones. Using data from 33 solvent and 33 insolvent industrial, joint-stock companies he estimated the following discriminant function (Altman 1968) in which the Z value is defined as follows:

$$Z = 0.012x_1 + 0.014x_2 + 0.033x_3 + 0.006x_4 + 0.010x_5 \tag{5.1}$$

The five variables Altman used are:

x_1 = working capital/total assets,

x_2 = retained earnings/total assets,

x_3 = earnings before interests and taxes/total assets,

x_4 = market value of equity/book value of total debt, and

x_5 = sales/total assets.

Using the Z function, Altman was able to classify companies as to their solvency (as bankrupt endangered or as healthy enterprises). A bankruptcy is probable if the Z value is smaller than 1.8. The probability for a bankruptcy is low if the Z value is more than 3.0 (Argenti 1976, p. 57).

Altman could obtain a considerable classification quality. 72 percent of the cases with joint-stock companies became insolvent two years after Altman's time-series ended. Altman has further obtained a classification quality of 94 percent for the group of solvent enterprises.

Since Altman's publication in 1968, numerous papers on the prediction of firm bankruptcy have been published. These have primarily focused on the predictive power of the predictor variables (Schönbrodt 1981).

Perlitz (1979) evaluated eighteen studies of insolvency prediction. A strong predictive power is attributed by Perlitz' study to the ratios of equity capital/debt capital, current assets/short-term debt, and cash flow/debt capital. These ratios do not compare directly to Altman's predictor variables. However, for the purpose of this study, the application of Altman's discriminant function (in an adjusted version) to a sample of firms in German manufacturing industries was utilized (see Hänchen 1983). The samples show that the Z function of Altman is suitable for insolvency forecasts and distinguishing between healthy firms and firms near bankruptcy.

Hänchen (1983) used the Bonn Database to adjust the Altman discriminant function for a representative sample of 18 solvent and insolvent German firms. He estimated the following parameters:

$$Z = 0.1345x_1 + 0.1996x_2 + 0.3067x_3 + 0.0123x_4 - 0.0261x_5 \tag{5.2}$$

The variables are defined in the same way as Altman's (1968). Hänchen made a particular adjustment which is important for this study. It is an adjustment which allows one to analyze firms which are not quoted on a stock exchange. In our sample, these are generally large companies with limited liability. Hänchen used the firm value as a substitute for the market value. The assumption of this procedure is that the net income for the past five years can be used as a proxy for the firm value. Then, the annual average from the five year period is taken and multiplied by sixteen, so that a price-earnings ratio of sixteen is applied to achieve the value of the firm as a substitute for the market value.

5.1.2.4 Efficiency Measures

Method

The test of the inefficiency trap hypothesis in the previous chapter is based on labor productivity as a proxy for technical efficiency. This was due to the very limited data on capital input available. Nevertheless, this input data was used to test two methods of efficiency measurement for their appropriateness. The first was an OLS estimation of a Cobb-Douglas production function, the second was the application of Data Envelopment Analysis (DEA). Since a high correlation between these measures of technical efficiency and labor productivity was found, the latter measure was used due to its appropriateness with the available data. The basic concept of efficiency is described in section 4.1. Details of the measurement can be found in section 4.2.3.3, Technical Efficiency.

Average and frontier production functions for German industries are reviewed in Albach (1980). New estimations for the major German industries are reported in Albach (1996a). A survey of the recent literature is included in Greene (1996). No attempt is made in this study to estimate a vintage model to capture technical progress since the information on capital inputs of machine tool firms in the sample is limited—for a significant number of firms, data concerning investment is only available for four years. Thus, two simple versions of the following methods of estimating the frontier production function were used: The linear programming model approach[88], and the fixed effects approach using the least squares dummy variable (LSDV) estimator to estimate a set of firm specific constants (see Greene 1996, pp. 45-47).

Both approaches are based on the Cobb-Douglas production function. The goal function of the linear programming model includes a Cobb-Douglas term as well as the LSDV model specification.

Input and Output Definitions

The data are based on the extended version of the Bonn Databank. As the output measure X real value added was used, at the conceptual level this is comparable to the value added measure in chapter 4.

The output as real value added then is defined as:

	Sales
+/–	Increase or decrease of the inventories of finished goods and work-in progress
+	Other own cost capitalized
=	Total output
–	Expenses for raw materials, supplies, and purchased merchandise
–	Other operating expenses
–	Cost of purchases services
–	Depreciation and adjustment on plant, equipment, and intangible assets
=	Value added (real net output)

88 See Albach (1980, pp. 59-60). For a detailed discussion of the estimation of production functions and efficiency for the German chemical industry see von Maltzan (1978).

Capital K was defined as the stock of machinery and equipment (including office equipment) deflated by a price index for capital goods. Due to the short observation period, no particular capital measurement, such as the perpetual inventory method, could be applied.[89] Instead, capital was defined as the average of the stocks of machinery and equipment, minus depreciation at a rate of 14.5 percent a year, plus the annual average of two years investment. The average of the investment was taken to adjust for the fluctuation in investment in short periods of observation. Capital in period t is then defined as follows:

$$K_t = (1 - \rho)\, K_{t-1} + 0.5\, (I_t + I_{t-1}) \tag{5.3}$$

with ρ as the depreciation rate and I_t as the new investment in period t minus reductions in machinery and equipment (disinvestment) plus transfer.

Labor L is defined as salaries and wages plus the employer's share of social security contributions, payments into old age pension funds, and other benefit costs. These labor cost then are deflated by a labor cost index.

5.1.3 Implications for the Test of the Inefficiency Trap Hypothesis

A systematic review of empirical studies concerning success factor research clearly indicates that there is not only a lack in the theoretical base, but that there are also problems in an appropriate research design, and in implementation. This limits the use of this type of research. For a discussion of this argument see Dellmann (1991) and Jacobs (1992).

In chapter 4 of this study the inefficiency trap hypothesis was tested using a sample of machine tool firms drawn from the NIFA Panel. One limitation of the NIFA Panel database has to do with the small and varying share of large firms participating in the NIFA Panel. Further, the panel is entirely based on anonymous survey data. As such, there is no possibility to enrich the data with complementary data sources in order to get more information for the interpretation of results. However, this disadvantage is compensated by the fact that the NIFA Panel includes numerous small- and medium-sized firms. These firms contribute a considerable amount to the competitiveness of the machine tool industry. The above mentioned disadvantage can further be overcome when using the annual reports of medium-sized and large firms—including their published accounts.

89 See von Maltzan (1978, pp. 85-100) for a detailed discussion of appropriate methods for measuring the capital stock of German industrial companies.

This chapter complements chapter 4 by using an extended version of the Bonn Databank. The aim is to test the inefficiency trap hypothesis from a broader microeconomic perspective and with a smaller sample. The approach can be called an intra-industry study of competition.

The importance of such an intra-industry analysis was emphasized by a number of authors. They found that there is suffcient intra-industry heterogeneity so that performance differences between firms can fruitfully be approached by industrial organization studies. A few publications should be mentioned which have already undertaken this type of analysis for the German manufacturing sector—although they are primarily inter-industry studies: Albach (1984); Neumann, Böbel, and Haid (1983); Schwalbach and Mahmood (1990); Fritsch (1990); and Schohl (1992).

5.2 Sample and Data

5.2.1 Structure of the International Machine Tool Industry

Considerable structural changes occurred in the 1970s and 1980s in the international machine tool industry. There are four characteristics of this development (see Carlsson 1990). During the 1980s, distribution of the world production of machine tools has moved from the traditional suppliers in the U.S.A. and Western Europe to firms in Japan. The Japanese gains are partly related to resulting losses for West German and U.S. machine tool firms, as well as for firms in some East European countries. This change is a result of increasing international trade and its specialization. This is particularly true for Japan, where the globalization of the automotive industry has played a decisive role for the development of the machine tool industry. During this process, conventional machine tools were replaced by numerically controlled machine tools. This development is still reflected in the most recent statistics of the world machine tool industry. Japanese firms were the largest in 1995 (the last year for which statistics are available). These statistics (from the so-called "Blue Bulletin") are only partially official since they are edited by Ashburn[90] of the

90 The 1995 "Blue Bulletin" is the 31st annual collection of data on major machine tool firms. Initially covering only U.S. companies, it has been enlarged to include companies from other countries. This year it includes only companies with sales of more than U.S.$ 10 million. The number of firms included is 214, of which 72 are German firms. Thus, it covers a quite complete list of German machine tool firms. The Blue Bulletin includes sales, profit, and employment figures. The profit figures are very incomplete. It is not entirely clear which figures and which exchange rates were used. It is said that

Association for Manufacturing Technology for the American machine tool industry. Five Japanese firms are the world's largest machine tools manufacturers. This structure has seen very little change within the past ten years.

Worldwide, the largest machine tools manufacturer in 1995 was Fanuc. Fanuc has U.S.$ 1.138 billion (USD) in annual sales. This is primarily due to the sale of machine tools and computerized numerical control equipment. Second is Amada, primarily an engineering and marketing firm, with sales of U.S.$ 1.104 billion. The family-owned firm, Yamazaki Mazak, is third with sales of U.S.$ 1.021 billion. Fourth place is held by Fuji Machine (U.S.$ 893 million) and coming in fifth is Okuma with U.S.$ 722.7 million. The U.S. firm of Gidding & Lewis is ranked sixth (U.S.$ 659.4 million). Only one German machine tool manufacturer is among the largest 10 firms—seventh place Trumpf with U.S.$ 645.7 million in annual sales in 1995. Number eight is the Japanese Mori Seiki (U.S.$ 622.2 million). The final two are the U.S. firm, Western Atlas Inc., (U.S.$ 558 million) and the Fiat-owned, Comau Group in Italy, with sales of U.S.$ 547.2 million.

5.2.2 The Sample: German Machine Tool Firms with Published Accounts

The 20 largest German machine tool firms in 1994 were listed in table 2.4.[91] In order to include nearly all of the largest firms in the analysis, nonquoted companies are also included in the sample.

Table 5.3 includes half of the firms listed in table 2.4, along with a few other important machine tool companies. The above list includes eight of the ten largest machine tool firms in 1994 (see table 2.4). Ninth-ranking Grob-Werke is not included, nor is tenth-ranking Heller. These are both family-owned firms.[92] Thus, it is reasonable to say that the sample includes nearly all large German machine tool producers.

"Foreign currencies are translated to dollars at the average daily market rates for the period covered." (p. 1)

91 As mentioned, there are some uncertainties about the ranking in the Blue Bulletin. That might have—as mentioned—to do with the conversion of original sales figures into sales in U.S.$ as well as with the reporting. Therefore, and for the purpose of a comparison with the 1990 data, table 2.4 is based on the German figures as published by the weekly journal, Produktion.

92 Both firms ought to publish their balance sheet and profit and loss statement according to the compulsory disclosure of the Disclosure Law of 1969. One reason for keeping their accounts private might be that they fear disadvantages in competition.

Table 5.3: List of the 15 German Machine Tools Firms in the Sample (in alphabetical order)

1. *Dörries Scharmann AG* (Merged with Schiess AG.)
2. *Eumuco AG*
3. *Ex-Cell-O AG*
4. *Gildemeister AG* (Now includes three Deckel Maho plants.)
5. *IWKA AG* (A large group with 7,826 employees in 1995; most important is the 100% share in Boehringer; holds a 41% participation in Ex-Cell-O AG; has participation in firms producing machines for modern manufacturing technologies, such as KUKA (100%), with its welding and assembling robots.)
6. *Müller-Weingarten AG*
7. *Pittler AG* (Partial participation by the Rothenberger family; details see table A.4.)
8. *Rothenberger Werkzeuge AG* (The "core" company of the Rothenberger family.)
9. *Schütte GmbH* (Non-quoted.)
10. *Schuler GmbH* (Non-quoted.)
11. *Schumag AG*
12. *Thyssen Industrie AG* (This group is included because its subsidiary, Thyssen Maschinenbau, has significant participation in machine tool firms. Daughters are: Maschinenfabrik Diedesheim, Hüller Hille, Wagner Dortmund, and Krause Maschinenfabrik Bremen.)
13. *Traub AG*
14. *Trumpf GmbH* (Non-quoted.)
15. *Walter AG*

5.2.3 The Data

The data used are from the published accounts of German quoted companies included in the Bonn Databank. The Bonn Databank ("Bonner Stichprobe")[93] covers the German industrial stock companies. This database contains financial

93 This database was developed at University of Bonn at the Institut für Gesellschafts- und Wirtschaftswissenschaften, Betriebswirtschaftliche Abteilung I, headed by Horst Albach. For a detailed description of the database see Albach, Brandt, Konitz, Schmidt, and Willud (1994). The database is now at the Research Area "Market Processes and Corporate Development" of the Wissenschaftszentrum Berlin für Sozialforschung (WZB).

information about the German industrial corporations quoted on the German stock exchange. The database is constructed from the annual business reports of the stock corporations (called "Aktiengesellschaften" and designated "AG"). The use of this database allows this study to continue the research of one of the very few studies (Albach and Held 1983)[94] on profitability for German firms in the metal-working industry.[95] Albach and Held used the Bonn Databank to analyze 27 firms in the German mechanical engineering industry. For the purpose of this analysis, the database had to be extended since a few of the large German machine tool manufacturers (including the largest—the Trumpf GmbH & Co—and others, such as Schuler GmbH) are limited companies. These GmbHs provide a large amount of significant financial information in their annual business reports.

Finally, it should be noted that a number of companies have changed their accounting systematics due to legal and tax considerations. In the new system, the former core of the company (the AG) becomes a Holding. This implies that they no longer report the realistic sales and employment figures for the AG.[96] These figures are only available using the consolidated financial statements. This means that the unit of analysis has to be changed from the AG to the Group ("Konzern") using information from the consolidated balance sheets and income statements. There is no longer a choice of using unconsolidated or consolidated accounts for the purpose of an empirical analysis. However, it is analytically more appropriate to use the approach utilizing the unconsolidated accounts of individual companies. Thus, one has to recognize the disadvantage of using consolidated accounts since the accounts can be changed by the acquisition or disposition of a subsidiary company. This has to be made apparent when interpreting the data.

---

94 For a comparison of Finnish, German, and Swedish firms of the metal-working industry see Artto (1982; 1996).

95 The production of machines—and in particular of machine tools—and the manufacturing of iron and steel define the so-called metal or metal-working industry.

96 This is the case with IWKA AG since 1981, with Gildemeister AG since 1988, with Pittler AG since 1986, with Thyssen Industrie AG since 1960, and with Traub since 1995.

5.3 Empirical Results

5.3.1 Profitability

It has been argued that high profits can be regarded as a major criterion of good performance in capital goods industries. But what if these are subject to measurement errors? Some have argued that reported profit rates provide a limited understanding of "real" economic profitability. For example, Fisher and McGowan (1983), and later Benston (1985), have questioned whether accounting profits can be used to draw conclusions about economic performance. In this study it is argued that this can be compensated for by using multidimensional measures, such as the hexagon criterion or the Z value. However, it is recognized that accounting practices tend to distort meaningful comparisons. These distortions might then obscure the true relationships between profitability and other variables (see Mueller 1990 for a discussion of the arguments concerning "accounting returns versus economic returns"). Although the measures used here are far from perfect, they do offer interesting insights into the performance of the major German machine tool firms.

Table A.8 shows the return on capital after tax (ROC) and the Z values for the overall sample in the period 1986 to 1994. The table includes 19 firms with an overall of 31 units of analysis, (however the observations are incomplete for the first five years). It includes the ROC for the unconsolidated AGs and the consolidated Groups. The firms which went bankrupt are also included—such as Deckel, Maho, and the Deckel Maho AG. Their decline is clearly indicated by the highly negative ROC measures for 1991/1992.[97] Table A.8 emphasizes that all the firms were profitable from 1986 to 1990.

The next tables focus on the core of the sample, the 15 firms mentioned in table 5.3. The tables in the appendix, tables A.9 to A.13, provide an overview for the shorter list over the entire period of 1986 to 1994. The summary in table 5.4 (to be discussed in detail later in this chapter) compares the average profitability for 1991 to 1994, and provides a single and an overall ranking of the firms according to these measures.

The return on equity capital after tax (ROE) is shown in table A.10. Only Schumag shows a considerable persistence in ROE for the firms for which observations are available over the whole period. Müller-Weingarten shows a comparable persistence in ROE. With the exception of 1989, Thyssen Industrie

97 An exception is the positive value for the Deckel AG in 1991. This, however cannot be used for the purpose of interpretation since it is a holding AG. It cannot be interpreted in any meaningful way due to the holding status on which the published profit and loss statement is based.

Table 5.4: Four-Year Averages for Profitability after Tax and Value Added, 1991-1994, and Multiple Rankings for 15 German Machine Tool Firms

Firm	Return on total capital (ROC)		Return on equity (ROE)		Return on sales (ROS)		Value added per employee		Average ranking according to 4 profitability measures	Final rank no.
	Percent	Rank	Percent	Rank	Percent	Rank	Thousand DM	Rank	1991-1994	1991-1994
Schuler Group	4.48	3	19.16	1	4.26	3	105,000	1	2.0	1
Schumag AG	9.59	1	16.82	2	7.64	1	79,411	7	2.8	2
Trumpf Group	4.56	2	-7.52	8	3.66	4	93,538	2	4.0	3
IWKA Group	4.02	4	8.30	4	3.25	5	93,189	3	4.0	4
Eumuco AG	3.92	5	-1.77	6	4.29	2	80,567	6	4.8	5
Thyssen Industrie Group	3.46	7	12.32	3	3.04	6	69,529	9	6.1	6
Ex-Cell-O Group	3.56	6	-6.66	7	2.69	7	88,519	5	6.3	7
Müller-Weingarten AG	2.27	8	7.04	5	1.65	9	91,343	4	6.5	8
Schütte GmbH	0.62	10	-12.64	9	-5.02	12	68,054	10	10.3	9
Dörries Scharmann/Schiess AG	1.76	9	-20.30	10	2.13	8	-3,498	15	10.5	10
Rothenberger Group	-0.53	11	-23.94	11	-0.26	10	62,730	11	10.8	11
Walter Group	-1.54	12	-24.96	12	-2.04	11	77,411	8	10.8	12
Pittler Combine	-5.11	13	-46.84	13	-6.92	13	41,733	14	13.3	13
Traub Group	-5.48	14	-86.50	14	-8.59	15	56,700	13	14.0	14
Gildemeister Group	-7.51	15	-151.76	15	-8.20	14	60,468	12	14.0	15

Note: In case of equal average ranking the final ranking is adjusted to the ranking of "return on total capital."

does as well. Focusing on the period of 1991 to 1994, offers a complete picture comparable persistence in ROE. With the exception of 1989, Thyssen Industrie does as well. Focusing on the period of 1991 to 1994, offers a complete picture based on averages. A good performance is shown by Schuler, Schumag, Thyssen Industrie, IWKA, and Müller-Weingarten. The ROE measures of the followers are immediately negative.

Table A.11 shows the development of the ratio of shareholder equity (or the equity ratio—the ratio of equity to total capital in percent). Schumag has (with 50.3) the highest equity ratio, with an increase over time, and has the second highest ROE with 16.8 percent. Surprisingly, Schuler has the lowest equity ratio (9.5 percent), but high ROE and ROC values. This seems to be an exception since the other firms with low equity ratios also show lower ROE and ROC values.

Table A.12 illustrates return on sales after tax (ROS). Interestingly, the ROS of Schumag (ranked highest with 7.64), is nearly twice as large as the 4.29 of the second firm, Eumuco. Table A.13 summarizes the figures of value added per employee. The values of Dörries Scharmann are highly negative with DM -28,702 in 1993, and DM -99,207 in 1994. This has to do with the very high cost of "other operating expenses" for the group in 1993 and 1994.[98]

Table 5.4 summarizes the averages of the profitability measures from 1991 to 1994. The table also includes the rankings according to each of the four profitability measures, as well as the average over all four ranks. This results in the "final rank," which is shown in the last column. There is a significant performance difference between the good performers and the poor performers. Thus, the four criteria are quite consistent in discriminating between the first eight and the second seven firms. This came as a surprise given the arguments and examples provided by Davis and Kay (1990) against the conventional profitability measures.

The criticism regarding accounting profitability measures has led to the application of the Z value of Altman/Hänchen and the hexagon criterion of Albach. Albach's hexagon criterion includes the ratio of market to book value. Since a number of the firms in our sample are nonquoted companies, it was decided to compute the hexagon criterion using the ratio of the firm value related to book value. A comparison was made using firms for which the market value was available. This is shown in table 5.5 and allows the comparison of the firms according to all four sets of criteria. The hexagon criterion based on the market

---

98 The annual reports of 1993 and 1994 are not very explicit. They say these are administrative expenses and losses due to devaluations in current assets as well as expected losses due to particular orders ("Zuführungen aus auftragsbezogenen Rückstellungen").

Table 5.5: Multiple Rankings According to Profitability, Z Values, and Hexagon Criterion for a Sample of German Machine Tool Firms over the Period 1991-1994

Firm	Profitability		Z values		Hexagon criterion			Overall ranking	
	Average ranking according to 4 profitability measures	Ranking according to 4 profitability measures	Z values according to Altman/ Hänchen	Ranking by Z values	Hexagon criterion (1) based on market value	Hexagon criterion (2) based on firm value	Ranking by hexagon criterion (2)	Ranking according to profitability, Z values and hexagon criterion (2), Averages	Rank
Schuler Group	2.0	1	8.4	5	14.4	20.6	2	2.7	2
Schumag AG	2.8	2	14.6	1	46.7	126.4	1	1.3	1
Trumpf Group	4.0	3	2.6	9	-5.4	-1.3	8	6.7	7
IWKA Group	4.0	4	10.4	3	10.8	15.0	3	3.3	3
Eumuco AG	4.8	5	2.8	8	-0.5	-0.2	7	6.7	8
Thyssen Industrie Group	6.1	6	8.8	4	11.3	9.7	4	4.7	4
Ex-Cell-O Group	6.3	7	3.2	7	0.8	4.9	5	6.3	6
Müller-Weingarten AG	6.5	8	12.0	2	5.5	4.9	6	5.3	5
Schütte GmbH	10.3	9	6.0	6	3.2	-17.4	9	8.0	9
Dörries Scharmann/Schiess AG	10.5	10	0.9	10	-39.5	-42.9	11	10.3	10
Rothenberger Group	10.8	11	-1.9	12	-20.2	-22.6	10	11.0	11
Walter Group	10.8	12	-1.2	11	-30.5	-33.8	12	11.7	12
Pittler Combine	13.3	13	-1.9	13	-96.5	-109.7	13	13.0	13
Traub Group	14.0	14	-3.0	15	-196.5	-206.2	14	14.3	14
Gildemeister Group	14.0	15	-2.2	14	-357.5	-370.0	15	14.7	15

Note: The ratio "market value/book value" cannot be computed for nonstock companies. For these companies the market value was substituted by the firm value. The firm value was computed by using a price-earnings-ratio relationship, that is, the net income was averaged over the four years and multiplied by a price-earnings factor of 16. In the column "Hexagon criterion (1)" all values are computed for the purpose of "comparison." In cases where the market value is missing the ratio was not included in the computation. The values for the non-stock companies Schuler, Trumpf, and Schütte should be excluded since they are based on only five of the six criterion variables which define the hexagon criterion.

value corresponds to the one which is based on the firm value. For details on computation of the criteria see the note in table 5.5.

The Z value and the hexagon criterion show a comparable pattern. The Z value deviates from the previous ranking according profitability for Schuler, Trumpf, and Eumuco. For Schuler this might be due to the high debt ratio. For Trumpf it is probably due to losses in 1992 and 1993, which had a strong impact on the computation of the firm value. Regarding the ranking by the hexagon criterion only, Trumpf and Eumuco deviate from their profitability ranking. Again, the main reason lays in the computation of the firm value.

Certainly, the overall result provides a very clear pattern of difference in performance. Table 5.5 shows a significant difference in performance according to the overall ranking between a group of good performing firms and a group of poor performers. This boundary can be drawn between the number nine performer, Schütte, and the number ten performer, Dörries Scharmann. All three sets of criteria show a nearly consistent pattern beginning with rank number nine.

5.3.2 Technical Efficiency

The efficiency measures for the sample of 15 machine tool firms are shown in table 5.6. Their calculation is based on two estimations: a least square dummy variable estimation,[99] and a linear programming[100] approach (as described in section 5.1.2.4). A progress coefficient was not estimated due to data limitations. The coefficient of the firm dummy is a simple measure of the difference in the technical efficiency of the firms. For the 121 observations in the period from 1986 to 1994 we get the following results for the Cobb-Douglas production function (see table 5.6):

$$x = 1.030\, K^{0.053} L^{0.847} \quad \text{(OLS estimation)} \tag{5.4}$$

and

$$x = 1.309\, K^{0.076} L^{0.850} \quad \text{(LP estimation)} \tag{5.5}$$

The output elasticity of labor in the machine tool firms is 0.85 for both estimations. This means that the firms made considerable investment in human capital. The output elasticity of capital is 0.05 in the OLS case and 0.08 in the LP case. This implies that the firms tried to keep investment in capital low. This

99 See Greene (1996, pp. 45-47) for this type of OLS "fixed effects" efficiency estimation model—particularly equation 4.57 on page 45.

100 See Greene (1996, p. 14), equation 3.16.

Table 5.6: Technical Efficiency for 15 German Machine Tool Firms: Averages over the Period 1986-1994

Firm		OLS Estimation (LSDV)		LP Estimation		
	Number of observations (T)	Coefficient of firm dummy	Technical efficiency (%) (EFF_OLS)	Technical efficiency (%) (EFF_LP)	Average of efficiency (%) (mean of the two estimations)	Final rank according to average efficiency
Rothenberger Group	8	1.2137	99.43	86.13	62.26	1
Schuler Group	5	1.2194	100.00	84.46	61.89	2
Trumpf Group	8	1.2146	99.52	81.78	60.84	3
IWKA Group	9	1.2111	99.17	80.76	60.38	4
Schütte GmbH	9	1.1176	90.32	79.81	57.08	5
Thyssen Industrie Group	9	1.2044	98.51	76.77	58.83	6
Müller-Weingarten AG	9	1.0465	84.12	71.73	52.30	7
Ex-Cell-O Group	6	0.9871	79.27	68.19	49.48	8
Schumag AG	9	0.9897	79.47	67.72	49.39	9
Walter Group	7	0.9611	77.24	64.87	47.69	10
Traub Group	8	0.9534	76.65	64.21	47.27	11
Gildemeister Group	9	0.9225	74.31	63.09	46.11	12
Pittler Combine	9	0.8989	72.58	61.96	45.15	13
Dörries Scharmann/Schiess AG	7	0.8185	66.98	57.34	41.71	14
Eumuco AG	9	0.7542	62.80	55.14	39.56	15

Estimated Functions (Method: OLS and LP Estimation of a Cobb-Douglas Production Function)

OLS Estimation: $x = 1.030 * K^{0.0526} * L^{0.8474}$
LP Estimation: $x = 1.309 * K^{0.0756} * L^{0.8498}$

x: Output
K: Capital
L: Labor

might express a tendency to overinvest in human capital. This is also a typical feature of the mechanical engineering industries.

Due to data limitations production functions for individual firms are not estimated, but rather the technical efficiency for each firm. The LP estimations are lower since they are averaged over the nine years. However, the two estimations produce nearly the same results. And, with two exceptions, the ranking of the firms according to their efficiency is expected when compared to their profitability measures. The exceptions are Rothenberger and Eumuco. Rothenberger is (on average) the most efficient firm, although the firm has a final profitability rank of 11. Eumuco held the eigth lowest position in profitability, but is shown here to be the least efficient firm. Obviously, Rothenberger has achieved its value added with the least inputs. This might be explained by the fact that their core output is not machine tool manufacturing, that is, some of their sales are also based on retail business in tools and related products. This may allow them to create higher value added than a typical machine tool firm. As for Eumuco, Rothenberger has an average equity ratio and a value added per employee near the average, so an obvious explanation is not at hand.

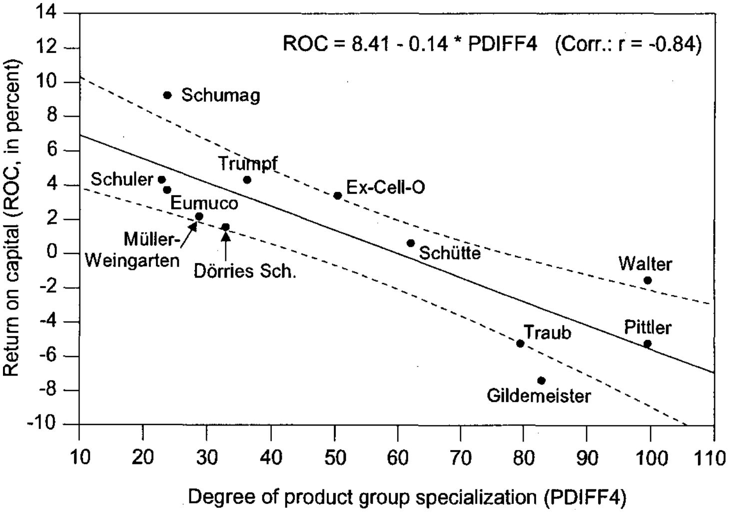
Schuler (in the second position) and IWKA (in fourth place) rank as expected. Trumpf and Schütte are actually more efficient than their profitability rates indicate. The middle group is as expected. This is also the case for the poor performers. To summarize, the efficiency measures provide (with the above mentioned two exceptions) a good indicator to distinguish between the performances of German machine tool firms.

5.3.3 Strategy Analysis: Cost Leadership versus Product Differentiation

Although some important studies (among these are the studies cited in section 5.1.1.2) have provided provisional answers to the question, "which strategies should firms pursue to gain competitive advantage?," knowledge about the situation in capital goods industries remains limited. Thus, the purpose of this section is to show a simple test for the inefficiency trap hypothesis by clarifying the issue of cost leadership versus product differentiation for our sample of machine tool firms. Considering the results of the efficiency analysis, we can further reduce our sample in order to enhance its homogeneity. This implies eliminating the large firms that participate in the machine tool business from the sample (IWKA, Rothenberger, and Thyssen Industrie). Twelve firms then remain. This is still enough to clarify the issue for the German machine tool industry, since they are the largest competitors.

We have shown in section 5.1.1.2 that a relative limited number of generic strategies capture the essence of most ways of competing in capital goods markets. Zörgiebel (1983) and Ehrnberg and Jacobsson (1993) have demonstrated, that an adjustment of Porter's (1980) typology of generic strategies seems useful to study the strategic behavior of machine tool firms. Although Porter has constructed his typology two-dimensionally, it seems that each type is defined on three dimensions: efficiency, differentiation, and scale/scope. We will show that efficiency and differentiation are not incompatible in the case of machine tool firms, and they are not opposite ends of a single continuum. The excellent firms of the German machine tool industry can excel at both.

Figure 5.3: Impact of Product Group Specialization on Return on Capital for a Sample of 12 German Machine Tool Firms, 1991-1994



Certainly, whether a strategy is considered a cost leadership strategy or a differentiation strategy depends on the frame of reference. In empirical survey research firms are usually asked which strategy they pursue and to which extent. Rühlmann (1992) undertook such a survey using a large sample of German machine tool firms. Although these German firms do perceive international cost disadvantages they are inclined to pursue also a cost leadership strategy. In fact, it was difficult to discriminate the firms on this dimension using their response to the question on cost leadership strategy. Therefore, this study tried to avoid such problems of a questionnaire-type of strategy measurement, that is, new measures were applied to test for the impact of strategy on performance.

The next portion of this study uses two measures already discussed—the efficiency measure and the indexes of product group specialization. Both measures are objective—they are not based on survey questions. Figure 5.3 illustrates the impact of product group specialization on the return on capital of twelve German machine tool firms. Pursuing the strategy of cost leadership is defined as having an above average efficiency ("strong cost leadership"). Below average efficiency is defined as a "weak cost leadership" strategy. It could be argued that efficiency is not a strategy. However, to use efficiency as measure of cost leadership strategy is reasonable. The firms were also classified as differentiators or non-differentiators. The firms with a higher than above average index of product group specialization are differentiators ("high product group specialization"). Those below average are non-differentiators ("low product group specialization"). The firms can now be classified according to four mixed strategies. Table 5.7 shows how the firms are grouped.

Table 5.7: Cost Leadership and Product Group Specialization Strategies in the German Machine Tool Industry, 1991 to 1994 (criterion: return on capital after tax in percent)

Strategy orientation	*Weak cost leadership*	*Strong cost leadership*
Low product group specialization	2.84 (Dörries Scharmann, Eumuco)	5.23 (Müller-Weingarten, Schuler, Schumag, Trumpf)
High product group specialization	-4.91 (Gildemeister, Pittler, Traub, Walter)	-2.09 (Ex-Cell-O, Schütte)

The differences in return on capital are obvious. Cost leadership strategies clearly dominate differentiation strategies with respect to profitability (ROC). However, it should be kept in mind that differentiation is proxied using a measure of product group specialization.

5.3.4 A Second Test of the Inefficiency Trap Hypothesis

The goal of the second test of the inefficiency trap hypothesis is to test whether product differentiation (measured as product group specialization) has an impact on profitability, and whether it interacts with efficiency. A simple plot of the ROC and the product group specialization indexes indicates a linear relationship.

To test for the statistical relationships, this study estimates an equation using the simple index of product differentiation PDIFF4. Since there are so few observations, a simultaneous equation model (as utilized in chapter 4) cannot be applied. Our main goal is to provide a statistical test of the relationship between profitability, product group specialization, equity, and efficiency. The equation reads as follows:

$$ROC = \alpha_0 + \alpha_1 \text{ PDIFF} + \alpha_2 \text{ EFF} + \alpha_3 \text{ EQUITY\_R} + \varepsilon_1 \tag{5.6}$$

The efficiency measure based on the OLS estimation is included in the equation. The OLS estimation of the above equation with PDIFF4 leads to the following results (n = 12, t-values in parenthesis):

$$\underset{(0.02)}{ROC = 0.08} - \underset{(-6.85)}{0.13 \text{ PDIFF4}} + \underset{(0.89)}{0.05 \text{ EFF}} + \underset{(3.60)}{0.18 \text{ EQUITY\_R}} \tag{5.7}$$

$$R^2_{adj.} = 0.86; \; F = 22.7; \; p < 0.0003$$

This estimation explains 86 percent of the variance. Highly significant is the effect of the degree of product group specialization PDIFF4 on the profitability measure, ROC. The p-level is 0.0001, that is there is a very low probability that the negative impact of product group specialization on profitability is a purely random effect. This result is important because the sample size is very small.

The equity ratio is also significant at the 0.01 p-level. There is a positive relationship between the ratio of shareholder equity capital to the return on total capital.

Efficiency has the correct sign, indicating a positive relationship between efficiency and profitability in the above equation. However, the relationship is not significant.

Thus, the results from this chapter confirm the key role that product differentiation plays in the performance of machine tool firms. The findings suggest that the inefficiency trap hypothesis is a reasonable explanation for the development of the large German machine tool firms.

6. Conclusions

This study provides a contribution to the theoretical and empirical foundation of product differentiation in capital goods markets. The analysis emphasizes many important questions related to increasing competition in medium-sized industries like the German machine tool industry. In addition, a case is put forward suggesting an inefficiency trap in this industry. Below is a summary of the major results and suggestions for further research.

The methodological core of this study is rooted in the field of industrial organization: just as market structure conditions influence product differentiation, product differentiation also affects market structure. We look specifically at the German machine tool industry. This is an industry where producers became internationally competitive in a number of market segments at the turn of this century. This competitive position was achieved by imitating successful American machine tool designs (Frick 1991). Strong reconstruction and engineering efforts in the post World War II period resulted in a dominant position in the 1960's in those markets. However, a decade later Japanese suppliers captured (due to an aggressive market penetration strategy) large market shares for CNC machine tools in the U.S. The same trend has now continued in Europe (as shown in table A.5). These recent and significant market share gains by Japanese producers signal the beginning of a challenge to the market position of German machine tool manufacturers (VDW 1993a). The resulting adjustments in employment and bankruptcies over the past five years have led to a labor force reduction of nearly one-third.[101]

Based on a descriptive analysis of the dynamics of the industry since the early 1950s (chapter 2), six stylized facts were derived. These can be easily summarized as follows: considerable change in demand, stability of concentration, limited economies of scale, increasing product differentiation, increasing foreign competition, and decreasing industry profitability. The most important of these observations concern the significant increase in product differentiation and the limitations of scale economies found in the German machine tool industry.

The third chapter developed the theoretical and empirical foundations for the explanation of the observed market dynamics. Since size distributions provide a good picture of the overall structure of a market, this traditional analysis of

101 A decline from 98,000 employees in 1991 to 68,300 in 1995 (VDMA Machine Tool Statistics 1995; see also table 2.18).

structure was undertaken (see also Sutton 1995; 1996 for a recent attempt to capture statistical regularities of market structure). The firm size distributions observed for the German machine tool industry are highly skewed. The most important result (derived from the estimation of Pareto coefficients) is that the German machine tool industry has a structure comparable to manufacturing industries as a whole. This result is consistent with the study's probability chart analysis. However, this type of structural analysis provided no detailed insight into the competitive reaction of firms, and in particular into product differentiation strategies. Therefore, the demand and supply structure of a typical machine tool market was analyzed, the very important market for machining centers.

For this second test of market structure a Cournot model was used (assuming that each firm in the machining center market treats the output of its rivals as fixed and then decides on the quantity to produce). In the Cournot model, the number of viable firms depends to a large extent on the elasticity of demand, and on the amount of fixed costs to be covered by revenue. Since fixed costs have to be covered in the machine tool industry, especially for the manufacturing of machining centers, the number of viable profit-making firms is limited. The main conclusion drawn from the analysis was that there is room for only one firm. Thus, the study concluded that the firms in the German machine tool industry enjoy—or at least enjoyed until 1990—some monopoly power due to tight customer relationships.

One of the crucial questions for this study relates to the efficiency of the supply of capital goods. Thus, it is important to determine whether price and/or quantity competition leads to an increase or decrease in economic efficiency. It is reasonable to conclude that both Cournot and Bertrand competition lead to underinvestment in cost reduction relative to the social optimum whenever firms enjoy a quasimonopolistic position due to product differentiation and a low degree of substitutability. This is exactly what happened in the German machine tool industry before the mid-1980's. There was an underinvestment in cost reduction. This result is reversed in theory and competition leads to overinvestment in cases where competition is very high and goods become closely substitutable.[102] Whether increasing competition in the German maschine tool industry in the past decade has led to overinvestment in cost reduction is still an open question.[103]

Another crucial point for the analysis of the machine tool industry is the question of scale—whether the higher the output, the larger the total gain from a

102 This type of result was among others derived by Brander and Spencer (1983); Bester and Petrakis (1993); and Rosenkranz (1995; 1996).

103 One example for such an overinvestment might be the new Maho plant in Kempten for the production of machining centers.

given reduction in the unit cost of production? Due to product differentiation, competition may less directly influence cost reduction. To shed more light on this phenomenon, the study uses a model which particularly applies to capital goods markets because it incorporates the customers' cost of information acquisition and supplier switching. This model is the nonlinear duopoly model developed by Albach (1996c). Albach has modeled the mobility of customers in a duopoly with respect to the price differentials of the duopolists. The important issue in his model is that there is not only a reaction function with respect to the competitors but also one which relates to the demand.

Based on the models discussed above, the study was able to posit its main hypothesis: the German machine tool industry evolved in a way which led to an inefficiency trap. This was due to a number of reasons. The most important reason is that the industry focused on a strategy of product differentiation, especially a strategy of customizing products to individual customer specifications and to practice to much of a strategy of product group specialization.

To test this hypothesis the study used two data sources: 1) the NIFA Panel, and 2) the Bonn Databank.

Using data from the NIFA Panel in a simultaneous equations model, it was found that extensive product differentiation in capital goods markets leads to inefficiencies that reduce the profitability of plants and firms. Our hypothesis is further supported by the fact that the prevailing manufacturing technology of single batch production restrains the firms supplying more differentiated products at higher cost and price. This inhibits a structural change towards less product variety and consumer choice. The direct effect of product differentiation on profitability follows a pattern of decreasing returns to scale, but this effect is weak.

Since the NIFA Panel data lacks exact accounting information, the study undertook a second test of the inefficiency trap hypothesis. This was possible for the twelve largest German machine tool firms by utilizing an extended version of the Bonn Databank (which includes profitability data based on annual business reports). Overall, the inefficiency trap hypothesis is supported by the sample of the twelve largest firms. Another interesting finding is that cost leadership strategies clearly dominate differentiation strategies based on product group specialization with respect to profitability.

One further way to increase understanding and possibly to find relevant qualifications for the inefficiency trap hypothesis would be to study product differentiation on the product and customer levels. This would imply studies of particular product characteristics and identification of the preference structure of customer segments. For a sophisticated type of analysis, this requires data on switching probabilities and attribute ratings in order to understand the market structure.

As previously mentioned, this study has chosen a methodology which takes into account the restrictions of the available data sets. Thus, the estimations in chapters 4 and 5 could be further improved by using panel data analysis (estimation of fixed and random effects models). This would require that the data sets cover quite a long period of time. This particularly applies to the efficiency estimation in chapter 5. The production function could then include a parameter for technical progress. It would be desirable to get better data, in order to take greater advantage of the fruits of modern computing technology. Unfortunately, this was beyond the parameters of this specific project.

To remain competitive, it is evident that the German machine tool industry must find the optimum level of product differentiation, product innovation, and efficiency in today's highly competitive global environment. Therefore, the analysis in this study focused on the strategic relevance of these factors to the competitiveness of the German machine tool industry.

7. Appendix

Table A.1: Orders, Production, Exports, Imports, and Consumption of the West German Machine Tool Industry since 1954 (current prices)

Year	Incoming orders Home mill. DM	Incoming orders Abroad mill. DM	Incoming orders Total mill. DM	Orders to production ratio	Production mill. DM	Exports mill. DM	Exports/ Production ratio	Imports mill. DM	Imports/ Consumpt. ratio	Mach. tool consumpt. mill. DM	Producer price index (1991=100)	GEI bill. DM	Consum./ GEI ratio
1954	776	538	1,314	1.23	1,069	543	50.8%	66	11.1%	592	16.2		
1955	1,259	674	1,933	1.40	1,382	577	41.8%	117	12.7%	922	16.7		
1956	919	763	1,682	1.00	1,681	699	41.6%	132	11.8%	1,114	17.8		
1957	815	734	1,549	0.85	1,813	880	48.5%	125	11.8%	1,058	18.6		
1958	992	731	1,723	0.98	1,752	939	53.6%	136	14.3%	949	19.1		
1959	1,362	884	2,246	1.20	1,876	966	51.5%	175	16.1%	1,085	19.1		
1960	2,264	1,604	3,868	1.71	2,262	1,074	47.5%	308	20.6%	1,496	19.9	27.14	5.51%
1961	1,716	1,377	3,093	1.12	2,766	1,405	50.8%	406	23.0%	1,767	21.3	31.32	5.64%
1962	1,299	1,114	2,413	0.76	3,184	1,545	48.5%	466	22.1%	2,105	22.8	34.98	6.02%
1963	1,157	1,075	2,232	0.76	2,945	1,627	55.2%	275	17.3%	1,593	23.1	35.64	4.47%
1964	1,779	1,350	3,129	1.06	2,940	1,560	53.1%	305	18.1%	1,685	23.7	39.21	4.30%
1965	1,994	1,497	3,491	1.06	3,302	1,601	48.5%	388	18.6%	2,089	24.7	43.35	4.82%
1966	1,527	1,867	3,394	0.99	3,442	1,947	56.6%	351	19.0%	1,846	25.6	43.98	4.20%
1967	1,310	1,979	3,289	0.97	3,398	2,205	64.9%	255	17.6%	1,448	26.0	41.07	3.53%
1968	2,207	2,618	4,825	1.36	3,550	2,423	68.3%	306	21.4%	1,433	26.3	43.14	3.32%
1969	3,797	2,990	6,787	1.58	4,308	2,545	59.1%	525	22.9%	2,288	28.2	53.59	4.27%
1970	3,676	2,529	6,205	1.16	5,366	2,929	54.6%	777	24.2%	3,214	31.8	65.88	4.88%
1971	2,484	2,068	4,552	0.76	6,027	3,057	50.7%	820	21.6%	3,790	35.6	72.66	5.22%
1972	2,253	2,703	4,956	0.87	5,712	3,255	57.0%	696	22.1%	3,153	37.1	72.74	4.33%
1973	3,130	3,600	6,730	1.16	5,807	3,639	62.7%	587	21.3%	2,755	39.2	75.27	3.66%
1974	2,800	4,500	7,300	1.08	6,766	4,780	70.6%	618	23.7%	2,604	43.6	72.36	3.60%
1975	3,150	3,950	7,100	1.05	6,770	5,113	75.5%	668	28.7%	2,325	47.9	78.05	2.98%
1976	2,700	4,050	6,750	0.97	6,966	5,014	72.0%	747	27.7%	2,700	50.7	86.08	3.14%
1977	3,755	3,857	7,612	1.07	7,085	4,944	69.8%	923	30.1%	3,064	53.8	95.32	3.21%
1978	4,507	4,652	9,159	1.19	7,679	4,991	65.0%	1,145	29.9%	3,833	56.2	105.75	3.62%

Table A.1: continuation

1979	4,311	4,288	8,599	1.00	8,598	5,324	61.9%	1,387	29.8%	4,661	59.0	118.97	3.92%
1980	4,916	5,870	10,786	1.09	9,888	6,165	62.3%	1,807	32.7%	5,530	62.8	126.84	4.36%
1981	4,220	5,224	9,444	0.92	10,272	6,741	65.6%	1,751	33.2%	5,282	66.4	126.96	4.16%
1982	4,513	4,638	9,151	0.93	9,789	6,280	64.2%	1,512	30.1%	5,021	70.3	123.61	4.06%
1983	3,611	4,618	8,229	0.91	9,041	5,829	64.5%	1,497	29.5%	5,069	72.8	134.95	3.76%
1984	5,278	5,762	11,040	1.17	9,431	6,048	64.1%	1,704	33.5%	5,087	75.3	137.13	3.71%
1985	6,832	7,641	14,473	1.32	10,929	6,817	62.4%	2,311	36.0%	6,423	78.4	153.03	4.20%
1986	6,927	7,811	14,738	1.13	13,014	7,891	60.6%	2,904	36.2%	8,027	82.7	160.87	4.99%
1987	5,661	5,775	11,436	0.86	13,272	7,642	57.6%	2,825	33.4%	8,455	86.8	169.43	4.99%
1988	6,232	7,435	13,667	1.03	13,321	8,241	61.9%	2,822	35.7%	7,902	88.9	182.46	4.33%
1989	9,089	8,897	17,986	1.21	14,908	9,177	61.6%	3,475	37.7%	9,206	91.1	203.47	4.52%
1990	9,308	8,175	17,483	1.06	16,425	9,447	57.5%	4,397	38.7%	11,375	95.5	234.57	4.85%
1991	8,385	6,945	15,330	0.89	17,235	9,828	57.0%	4,866	39.6%	12,273	100.0	264.94	4.63%
1992	5,878	5,747	11,622	0.82	14,159	8,507	60.1%	3,834	40.4%	9,486	103.0	255.17	3.72%
1993	4,146	5,112	9,258	0.86	10,706	6,946	64.9%	2,607	40.9%	6,367	104.2	211.28	3.01%
1994	5,245	6,518	11,763	1.13	10,398	7,057	67.9%	2,647	44.2%	5,988	104.0	204.00	2.94%
1995	6,304	7,626	13,930	1.13	12,310	8,045	65.4%	3,362	44.1%	7,627	105.8		

	Orders/Production avg. ratio		Export ratio (Export/Production)	Import ratio (Import/Consumption)	MT Consumption/GEI ratio
1954-70:	1.13	max. value	75.5%	38.7%	6.02%
		min. value	41.6%	11.1%	2.94%
1971-95:	1.02	avg. value	58.4%	24.7%	4.20%

Note: Since 1991 East-Germany is included; Consumption = Production + Imports - Exports; GEI: Gross Equipment Investment; MT: Machine Tool.

Sources: VDMA Machine Tool Statistics (various years); Jahresgutachten 1995/96 des Sachverständigenrates zur Begutachtung der gesamtwirtschaftlichen Lage (p. 392).

Table A.2: User Industries of Machine Tools for Metal Working in Germany, 1995
(percentage of the total units of machine tools supplied to particular user industries)

User Industries / Machines	Steel constr.	Mach. tools	Other mach.	Auto. parts	Auto-mobil.	Air-craft	Ship build.	Electr. engi-neering	Instru-ments, optics	Tools for presses	Electric utilities	Metal work. industr.	Other industr.	Mach. distrib.	Training, research	Total
Machining centers	0.3	5.4	39.5	14.3	23.3	1.2	0.9	1.5	5.5	3.6	0.3	1.5	1.0		1.6	100.0
Lathes	2.9	8.8	37.6	12.5	7.0	1.1	0.3	5.7	8.9	5.4	0.7	6.4	0.4	0.2	2.3	100.0
Turning centers	1.3	2.0	32.5	16.6	11.3	5.3	1.3	7.9	10.6	0.7		10.6				100.0
Drilling & boring mach.	0.9	1.6	4.5	0.5	1.4	0.2	0.1	1.7	0.3	0.5	1.2	48.6		38.4		100.0
Milling machines	2.9	5.1	15.4	7.2	4.3	3.8	0.1	1.7	10.9	23.7	0.3	24.4	0.2			100.0
Sawing machines	37.5	0.3	26.1	9.4	6.1	0.3	1.3	0.3		1.3	0.3			17.5		100.0
Cyl. grinding machines	1.1	4.5	22.7	19.3	17.6	0.3		2.0	1.7	15.0	0.6	10.8	3.1		1.4	100.0
Other grinding machines		5.7	41.2	12.9	8.6	2.5		1.8	1.8	17.9		3.6	1.8	1.8	0.4	100.0
Gear cutting machines		7.1	12.3	26.5	33.8	0.8		2.1	0.4		1.3	3.8	6.7	3.1	2.3	100.0
EDM, laser			9.3	9.3	2.8					74.1		0.9		0.9	2.8	100.0
Special purpose machines		14.5	3.5	11.0	55.5			5.8			1.2	4.6	4.0			100.0
Other metal work. mach.		28.4	1.1	40.9	20.5	1.1		1.1	5.7		1.1					100.0
Bending machines	11.8	5.2	72.1	6.0	1.4	0.2	0.2	0.6	0.4	1.4	0.4	0.2				100.0
Presses	2.5	34.3	24.3	9.4	4.0	0.5	0.2	6.3	1.4	3.4	0.3	13.5				100.0
Shears & punch. mach.	9.7	9.7	50.9	11.9	1.8		0.4	3.1			5.3	7.1				100.0
Sheet metal work. mach.	3.0	5.1	63.3	5.3	0.6			4.5				14.3	0.6	2.1	1.3	100.0
Wire process. mach.			2.6					11.3				86.1				100.0
Other forming machines		81.5	14.8									3.7				100.0
Total	3.4	6.9	26.0	9.3	9.5	1.2	0.3	2.7	4.0	7.0	0.7	18.5	0.7	9.1	0.7	100.0

Source: VDMA Machine Tool Statistics (1995, p. 10) (based on special survey).

Table A.3: Comparison of Real Output (in Units) of Six-Digit Commodity Groups of Machine Tools in West Germany: Average Annual Growth Rate from 1960 to 1989

Product Code (1989)	Product	Reclassification (last two digits of 1960 Code)	Average annual growth of real output (percent)
321191	Multi spindle boring units	=	8.69
321225	Toggle lever and crank drawing presses	= 24	6.58
321219	Other metal forming machines	=	5.99
321259	Other wire working machines	= 55+59	5.98
321198	Other special purpose machines for metal cutting purposes	= 94+95	5.89
321153	Vertical and circular table milling machines	=	5.77
321126	Threading machines	=	4.48
321228	Other mechanical presses	= 28+29	4.35
321232	Hydraulic H-frame and straight-sided hydraulic presses	=	4.03
321258	Stranding and cable making machines	= 57+58	4.01
321155	Tool milling machines	=	3.87
321221	Hand lever and foot pedal presses	=	3.78
321246	Spinning and planishing lathes, thread bulging machines	=	3.55
321161	Circular sawing machines	=	2.83
321136	Single spindle bar and long turning automatics	= 33 (arbitrarily)	2.51
321234	Hydraulic folding presses, press brakes	=	2.30
321238	Other hydraulic presses	= 39	2.26
321173	Cylindrical grinding machines for special purposes	=	1.99
321188	Gear grinding, lapping, polishing, and shaving machines	=	1.96
321242	Shears and metal punching machines	=	1.70
321129	Other turning machines (lathes)	= 28+29	1.36
321148	Other drilling machines	= 45+46	1.33
321154	Surface milling and plano-milling machines	=	1.27
321243	Sheet metal straightening, bending, and folding machines	=	0.91
321134	Multi spindle bar and chucking automatics	= 35	0.72
321157	Copy milling and engraving machines	= 56	0.52
321245	Plate rolling machines	=	0.48
321251	Wire-drawing machines	=	0.47
321141	Bench type, pillar, and column type drilling machines	=	0.39
321165	Reciprocating and band sawing machines	=	-0.06
321244	Flanging, crimping, seaming, and beading machines	=	-0.26
321119	Broaching machines	=	-0.67
321215	Concrete bar bending machines and shears	=	-0.93

Table A.3: continuation

321175	Surface grinding machines	=	-1.02
321195	Rotary indexing table and indexing drum milling machines	= 93	-1.03
321167	Other sawing, filing, and cutting-off machines	= 64+66+67	-1.22
321176	Honing and lapping machines	=	-1.32
321138	Single spindle chucking automatics	= 37 (arbitrarily)	-1.55
321241	Shears with hand or foot drive	=	-1.91
321159	Other milling machines	= 57+59	-2.00
321179	Other grinding, lapping, and polishing machines	= 78+79	-2.01
321231	Open gap hydraulic presses	=	-2.25
321189	Other gear cutting machines	= 81+87+89	-2.29
321133	Turret lathes	= 31+32	-2.38
321214	Riveting machines	=	-2.41
321233	Hydraulic drawing presses	=	-2.45
321177	Tool grinding machines	=	-2.80
321149	Tapping machines	=	-2.98
321121	Universal lathes up to 800 mm diameter	=	-3.05
321172	Internal cylindrical grinding machines	=	-3.21
321183	Hobbing machines for cylindrical gears	=	-3.27
321127	Turning, boring, and cutting-off machines	=	-3.50
321171	External cylindrical grinding machines	=	-3.58
321152	Universal, horizontal, and vertical milling machines	= 51+52	-3.91
321249	Other plate forming machines	=	-4.04
321279	Thread rolling mills	= 68	-4.04
321122	Universal lathes > 800 mm diameter	=	-4.48
321158	Horizontal boring and milling machines	=	-4.61
321142	Radial drilling machines	=	-4.74
321252	Wire bending/forming machines, coiling machines for spirals	=	-5.21
321118	Planing and shaping machines for special purposes	=	-5.45
321275	Threading machines	= 64+66	-5.63
321212	Hammers for peening, planishing and polishing, etc.	=	-6.42
321211	Hammers for drawing-out, die-forging hammers	=	-6.47
321253	Chain making machines	=	-8.63
321146	Multi spindle boring and drilling machines	= 43+44	-9.80
321125	Small lathes (watchmaker's and bench lathes)	=	-10.53

Note: The growth rates are based on the production statistics for six-digit commodity groups. The 1960 data was reclassified into the 1989 classification scheme.

Sources: VDMA Machine Tool Statistics (1960/61; 1989).

Table A.4: The Rothenberger Family – Participations in the Machine Tool Industry, 1991 (according to the Holding Companies Pittler Maschinenfabrik AG and Autania AG)

Firm and product group	Shareholders equity million DM	Shares of Pittler Holding (percent)	Autania Holding (percent)	Sales 1991 million DM
Pittler AG	49.4			
Autania AG	70.0			
Turning machines:				
1. HEID Maschinenfabrik AG, A-Stockerau				
2. TORNOS K'MX, F-Mulhouse				
3. MOTCH Corporation, U.S.A.-Cleveland	2.7	95.0		22.3
4. NEUE MAGDEBURGER Werkzeugmaschinenfabrik GmbH, D-Sinsheim	-2.7	80.0		21.5
5. PITTLER GmbH, D-Langen	21.4	80.0		95.3
6. PITTLER Máquinas Ltda., Brasilien-Limeira	10.5	96.0		14.1
7. PITTLER-TORNOS Werkzeugmaschinen GmbH, D-Leipzig	63.8	24.0	25.0	
8. TORNOS-BECHLER S.A., CH-Moutier	133.4	40.0		
9. WIRTH et GRUFFAT Machines Outils, F-Pringy				
Grinding machines:				
1. BUDERUS Schleiftechnik GmbH, D-Ehringshausen	25.8	70.5		37.5
2. DISKUS WERKE Schleiftechnik GmbH, D-Frankfurt am Main	3.3	20.3		
3. ELB-SCHLIFF Werkzeugmaschinen GmbH, D-Barbenhausen	30.0		15.4	
4. MSO Schleiftechnik GmbH, D-Ehrighausen	0.8	70.5		
5. NAXOS-UNION Schleifmittel- u. Schleifmaschinen AG, D-Frankfurt am Main	15.4	25.0		
Boring, drilling and milling machines:				
1. PRÄWEMA Werkzeugmaschinenfabrik GmbH, D-Eschwege	-1.2	78.4		31.1
2. HERMANN KOLB Maschinenfabrik AG, D-Köln	5.7	63.8		35.6
3. FRITZ WERNER Werkzeugmaschinen AG, D-Berlin	112.2	67.5		130.6
Rolling mills:				
1. BAD DÜBEN Profilwalzmaschinen GmbH, D-Bad Düben	22.9	51.0		8.5
Drives and other units:				
1. System-Antriebstechnik Dresden GmbH	1.0		97.0	
2. Eltek Elektroanlagen GmbH	1.0		97.0	

Table A.4: continuation

Research firms:			
1. Gerfema GmbH	2.0	10.0	
2. FZM Forschungszentrum	1.0	10.0	
Machine tool trade:			
1. FRITZ WERNER Werkzeugmaschinen International GmbH, D-Wiesbaden			36.6
2. PITTLER (U.K.) Ltd., U.K.-Milton Keynes			7.7
3. Colmant-Wagner S.A.	4.5	20.0	
4. Wemex Italia S.p.A.	2.8	20.0	
Other sales:			2.7
Overall sales in 1991 according to the definition of the group (in million DM):			
Consolidated sales of Pittler			443.6
Sales of the whole MT Group including Pittler, Tornos-Bechler, and Diskus-Naxos (Annual Report 1991)			773.7
Sales of the whole MT Group including Pittler, Tornos-Bechler, and Diskus-Naxos (Produktion 1992, No. 40)			874.0

Sources: Pittler Maschinenfabrik AG (1991); Produktion, No. 40, 1992. Regarding participations of Autania AG the following source was used: Wirtschaftswoche, No. 15, 1992.

Table A.5: Events in the Development of NC Machine Tools in the United States of America, Europe/West Germany, and Japan

Time	United States	Europe/West Germany	Japan
1946		An AEG research institute of about 70 employees headed by W. Schmid develops a relief control system for machine tools. The system is based on a tape recorder recording the control information during the production of the first piece and using that for the automatic production of the following pieces. The information is recorded as a succession of tones. According to Schmid his control was fully functioning in 1948.	
1947	J. T. Parsons develops the basic idea of numerical control while using one of the first computers to calculate stencils needed to manufacture rotor blades for helicopters (jig boring machine with punch card control).		
1949	Parsons and the MIT receive an U.S. Air Force contract to develop a 3-axis contouring controlled milling machine.		
1951		Schmid presents a lathe from Alfred Herlicq et Fils using his control principle at the 1st European Machine Tool Exhibition in Paris. Technical problems and the "presentation effect" are reported. The machine does not show up at the 2nd Exhibition in Hannover 1952.	

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1952	At the MIT Servomechnism Laboratory the first functioning NC machine tool is presented, a Cincinnati Hydrol vertical milling machine. 3-axis simultaneous moves were feasible due to an electronic tube control using as data input punched paper tape (development costs: 12 "man years" and a budget of U.S.$ 300,000). The Scientific American reports in its September issue on the development of that U.S.-milling machine demonstrating a workpiece and a punched tape, but without reporting on the structure of the machine.		The U.S. numerical control concept was introduced in Japan by Prof. Takahashi at the Automatic Control Research Conference. His report and an article in the September issue of the Scientific American triggered intense research efforts at firms, universities, and other public institutions. The aim was to develop a simple Japanese NC system at the Tokyo Institute of Technology (TIT), the Department of Precision Machinery Engineering, and the Electronic Sciences Laboratory of the University of Tokyo.
1953	The first commercial numerical control is available due to a cooperation of MIT, Glenn Martin Co., Bendix Co., and Kearney Trecker, all supported by U.S. Air Force.		Dr. Inaba, at that time employee of Fujitsu and a key inventor and developer in Japan, received a microfiche of the final report of the MIT project due to his personal contacts to Takahashi in 1953. (Inaba: "That was our bible.") The " Fujitsu et al." project—based on the above mentioned network—focused on the development of a "point-to-point control system" using a copy turning machine. The copying device was substituted by the NC unit. Further more, a pulse motor to translate the digital control information into circular movement was projected.
1954	Bendix buys Parsons' patent rights and begins with the industrial production of NC using electronic tubes.		

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1955	Chicago Machine Tool Exhibition: 35 out of 152 exhibitors present NC machine tools. Most interesting are eleven NC machining centers for milling and boring. Already implemented are automatic change of tools and partly of work pieces. Kearney & Trecker demonstrates a clear lead in technology (know-how).	Presentation of the first British NC machine tool in Norwich by Laurence, Scott & Electromotors with a controller of EMI Electronics based on punched paper tape input media. Similar to the U.S.A. design, Britain takes the European lead due to a demanding aircraft industry. A British-American Joint Venture between Cincinnati Milling and EMI was supported by the U.S. Air Force National Commands to develop a NC milling machine. The machine was ready in 1959.	
1956	U.S. Air Force orders 170 NC machine tools at an average price of more than U.S.$ 880,000 ("Bulk-buy Machine Tool Program"). Contracting firms achieve leading market position.	West Germany: First public dissemination of information on numerical control systems by MIT-Professor M. Shaw at the 8th Machine Tool Workshop chaired by Prof. Opitz in Aachen. Shaw reported on punch card and tape controls and on the development of the MIT NC milling machine. At the same workshop a German NC lathe with magnetic tape control was presented.	Fujitsu with its technological core in telecommunications decided to move into the field of process control. Dr. Inaba received the official order to develop a controller. The first Japanese NC machine tool, a NC turret punch press is available.
1957		Schiess has developed the first German NC boring and milling unit using a Brown, Bowerie and Cie. controller.	The first NC jig boring machine is presented at the Japanese Machine Tool Exhibition. The Tokyo Institute of Technology announces the development of a NC lathe.
1958	Presentation of the first symbolic NC programming language "Automatic Programmed Tools" (ATP) developed at MIT.	A large NC milling machine, 3-axis controlled was manufactured by Ferranti and the development department of the Ministry of Supply. In the same year four further NC machine tools are presented by Ferranti, EMI, EMCO Electronics, and British Thompson.	Makino Milling exhibits the first Japanese NC milling machine with FANUC control. The initiative comes from Makino.

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1959		13 European producers exhibit NC machine tools at the 6th European Machine Tool Exhibition in Paris (eight British, three German, France and Switzerland one each). Heller presents the first German horizontal NC milling and boring machine.	Dr. Inaba receives a pathbreaking patent for coupling a pulse-motor with a hydraulic-servo-motor. The patent lasts for 13 years and provides the basis for the future economic success of FANUC and the Japanese machine tool industry. Beginning of NC development at the MITI research institute. Ikegai exhibits the first NC lathe at the Japanese machine tool fair. FANUC sells the first commercial NC controller for a milling machine to Hitachi Seiko. First appearance of the trade-mark FANUC.
1960	Technological breakthroughs are presented at the Chicago Exhibition, among other things eleven NC machining centers out of more than 100 NC machine tools.	Hannover Exhibition: 14 German firms present new NC machine tools. Among them Collet & Engelhard, Scharmann, Berliner Maschinenbau AG, Heller, H. Kolb, Hüller, F. Werner, Droop & Rein, Waldrich, and Pittler, are exhibitors of NC lathes.	
1961		7th European Exhibition in Brussels: Roughly 40 NC machine tools with linear-path and with continuous path controls are presented; Germany 19, Britain 9, Switzerland 6, Belgium, Italy and France 2 each and the Netherlands 1. Only 8 machines are NC lathes. Except in one U.S.-case all control systems are European developments which indicates the attempts of autonomous developments in Europe.	
1962	Roughly 2,500 installed NC machine tools.		

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1963		Publication of the first basic study in West Germany on "The Numerical Control of Machine Tools" by Dr. Simon (Technical University Darmstadt).	Installation of the first "Direct Numerical Control" (DNC) process control computer at Isuzu Motors.
		8th European Exhibition in Milan: 70 NC machine tools are exhibited. Fast diffusion and application on NC machine tools in Europe.	
		Introduction of the second controller generation based on semiconductors.	
1965		The 9th European Exhibition is dominated by NC machine tools.	FANUC 250, the first "Computer Numerical Control" (CNC) controller is available. Installation with Mazda to manufacture "Wankel engine."
			Commercial breakthrough and sales boom with FANUC 260, a positioning and straight cutting control with three electric-servo-motors at a price of 1.5 million Yen (approx. DM 20,000).
1966		Presentation of controllers based on integrated circuits (ICs) at the NC-Machine-Tool-Exhibition in London.	
1968	Development of the first system of DNC, the "Omni-control" by Sandstrand.		First DNC controller, the FANUC 240, delivered to Japan Nation Railways.
	Advantage: Sharing of computing costs among a number of NC machine tools. Slow process of diffusion due to insufficient software and high computer costs.		
1969			FANUC 240A is ready. A modular NC lathe controller with easy adjustment to customer needs.

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1970			Joint national MITI program of five machine tool producers, Fujitsu, and the Mechanical Technology Institute of MITI, in order to develop DNC systems.
1971	Introduction of the first microprocessor by Intel, the Intel 4004.	Introduction of numerical control systems based on standard mini-computers. These systems are soon replaced by microprocessor CNCs. One of the first German CNC lathes is presented by Gerad Duelen at the European Exhibition in Milan. The system uses a DEC minicomputer PDP 8.	
1972			Foundation of FANUC Ltd. as a private company.
1975			First CNC lathe controller (FANUC 2000 C) using micro-processors, ROM and RAM.
1979			The FANUC System 6T/6M is available with very modern technology. It became the world's most successful CNC controller with about 100,000 units being sold.
1980	Attempts to develop "Manufacturing Automated Protocol" (MAP) by General Motors in order to increase manufacturing communication and efficiency. Parallel working group at Boeing working on same issue ("Technical and Office Protocols," TOP).	Integrated programming utilities with CNC systems lead to a "religious war" on the use of "Manual Data Input Control." ESPRIT project on Communica-tions Network for Manufacturing Applications (CNMA). The CNMA concept is similar to that of MAP and TOP. Foundation of an experimental center for CIM technologies in Genova/Italy. The European Center for Research and Integration in CIM ("CIRCE") aims at know-how in CIM design and application.	

Table A.5: continuation

Time	United States	Europe/West Germany	Japan
1984		Graphic units within CNC systems facilitate "programming at the shopfloor."	
1987		7th EMO exhibition in Milan: The way to the automated factory seems feasible due to standardized interfaces allowing information exchange within CIM.	
1990		Digital interfaces between numerical control and drives allowing higher precision of axis control. The system developed in Germany is independent of specific producers ("High level Data Link Control," HDLC protocols).	

Sources: Holland (1989); Kief (1991a); Reintjes (1991); Spur (1991); Spur, Specht, and Schröder (1994); Schröder (1995); Ehrnberg and Jacobsson (1997).

Table A.6: Imports in West Germany for Machine Tools by Countries, 1952-1990 (absolute values and change in percent)

Import from	1952	1960	1970	1980	1990	Change in percent 1980-1990
	Import value in DM 1,000					
Switzerland	19.8	74.6	170.3	480.9	1,141.0	137.3
Japan			8.3	217.7	658.0	202.3
Italy	0.4	11.9	88.6	218.3	636.0	191.3
Great Britain	3.0	17.2	82.3	132.6	285.0	114.9
Austria	1.0	12.3	24.6	70.3	263.0	274.1
France	2.9	16.0	91.0	159.4	259.0	62.5
U.S.A.	8.6	120.4	95.9	114.5	204.0	78.2
Spain		0.9	20.3	67.4	165.0	144.8
Netherlands	0.6	8.9	40.4	50.8	149.0	193.3
Sweden	1.2	11.5	26.8	63.9	112.0	75.3
Belgium/Luxemburg		1.8	13.3	35.2	60.0	94.0
Taiwan					70.0	
Denmark	0.2	1.1	4.8	23.6	50.0	111.9
Czechoslovakia			13.5	30.6	30.6	37.0
Yugoslavia		0.3	13.2	11.0	37.0	236.4
Soviet Union		2.2	11.6	9.2		
Poland		0.9	7.5	12.3		
Hungary		2.2	5.5	27.3		
Rumania			6.5	8.8		
Other countries	0.7	1.0	13.9	48.4	237.0	
Totals	40.2	308.2	777.3	1,807.0	4,397.0	143.3
G.D.R. (Intra-German Trade)	0.4	28.9	64.7		99.6	

Source: VDMA Machine Tool Statistics (various years).

Table A.7: Price Competitiveness of West German Versus Japanese Mechanical Engineering Products (MEP) in Terms of the Real Exchange Rate

Year	Price index for MEP in West Germany	Price index for MEP in Japan	Nominal exchange rate index (Yen/DM 1)	Real exchange rate index for MEP
1985	100.0	100.0	100.0	100.0
1986	102.8	99.0	101.1	105.0
1987	105.0	97.0	94.2	102.0
1988	106.9	97.0	86.5	95.3
1989	109.9	100.0	103.9	114.2
1990	113.7	103.0	111.3	122.9

Note: The real exchange rate index was computed in order to show the price competitiveness of West German mechanical engineering products versus those of Japan. It accounts for differences in inflation rates and in the value of the DM versus the Yen. If the real exchange rate index equals 100, the real value of the DM has not changed since the base year. If the real exchange rate index is greater than 100, the DM is overvalued compared to the base year, and West German mechanical engineering products have become less competitive than the Japanese Products.

$$\textit{Real exchange rate index} = \frac{\textit{Nominal exchange rate index} \times \textit{German price index}}{\textit{Japanese price index}}$$

Sources: VDMA Handbook (1991, p. 258); Statistisches Jahrbuch (1992).

Table A.8: Return on Total Capital after Tax (ROC) and Z Values

Firm	Firm No.	1986	1987	1988	1989	1990	1991	1992	1993	1994	Averages of ROC (percent) 1988-94	Averages of ROC (percent) 1991-94	Z values according to Altman/ Hänchen 1991-1994	Rank by Z values 1991-1994
Autania AG	1002		13.51	1.76	4.35	8.24	1.62	-0.94	-12.62	2.98	0.77	-2.24	-2.1724	22
Autania Group	1001							1.33	3.12	-0.98			1.1026	13
Deckel AG	117	6.77	5.48	4.38	-5.69	4.25	7.62						-3.2607***	24
Deckel Group	1012			6.06	-5.72	5.36	-10.50						-4.0303***	26
Maho AG	665		4.79	5.58	4.59	1.66	-30.18						-14.9240***	30
Maho Group	1018			5.84	5.21	0.52	-19.24						-10.3050***	29
Deckel Maho AG	720							-21.72					-1.7330***	18
Dörries Scharmann/Schiess AG	85	0.67	-3.95	3.17	4.45	2.85	4.56	5.01	-6.40	3.86	2.50	1.76	0.8819	15
Dörries Scharmann Group	387							5.40	-9.84	3.75			0.9266	14
Eumuco AG	1003		5.86	5.46	4.22	2.51	2.60	4.63	5.56	2.89	3.98	3.92	2.8251	11
Ex-Cell-O Group	1000					5.78	6.22	8.94	4.95	-5.88		3.56	3.2214	10
Gildemeister AG	162	10.04	13.45	8.45	7.87	6.69	-1.20	-26.18	-14.19	-11.85	-4.34	-13.35	-6.9141	27
Gildemeister Group	445	6.98	9.21	3.46	5.86	4.78	-1.79	-12.27	-11.53	-4.46	-2.28	-7.51	-2.1570	21
IWKA AG	337	8.07	7.79	7.16	6.45	5.37	6.37	6.91	6.73	6.20	6.46	6.55	15.7873*	1
IWKA Group	1014		4.00	4.07	3.75	3.90	4.39	4.76	3.83	3.10	3.97	4.02	10.3736	5
Müller-Weingarten AG	179	1.50	1.57	1.45	2.98	2.25	2.34	2.54	2.52	1.70	2.25	2.27	11.9981	3
Pittler AG	144	20.69	31.72	9.48	5.42	4.42	-1.05	-34.94	-12.19	3.27	-3.65	-11.23	-6.9813	28
Pittler Combine	429		21.82	7.86	5.88	6.17	-0.49	-8.89	-13.12	2.05	-0.08	-5.11	-1.8463	20
Rothenberger Group	1007			3.08	5.01	5.27	5.41	-9.65	1.72	0.38		-0.53	-1.8446*	19
Schütte GmbH	1010		23.19	20.88	18.49	26.54	23.33	8.09	-19.89	-9.03	9.77	0.62	5.9681**	8
Schuler GmbH	1009						8.61	5.58	3.80	3.86		5.46	10.4858	4
Schuler Group	1017						5.11	4.95	4.04	3.81		4.48	8.3884	7
Schumag AG	235	9.50	10.17	10.87	16.12	9.18	9.34	8.18	11.55	9.29	10.65	9.59	14.5935	2

Table A.8: continuation

Thyssen Industrie AG	237	4.98	5.40	5.24	3.44	4.57	5.53	10.81	3.61	2.23	5.06	5.55	3.5119	9
Thyssen Industrie Group	498	4.10	3.96	4.38	2.07	3.47	1.11	5.69	4.43	2.59	3.39	3.46	8.7588	6
Traub AG	612		6.19	5.96	5.27	4.71	-1.88	-7.95	-5.57	0.76	0.19	-3.66	-3.0299	23
Traub Group	1013		5.81	6.81	5.42	4.13	-2.12	-7.95	-11.43	-0.42	-0.79	-5.48	-3.6476	25
Trumpf GmbH	1008			12.78	13.43	4.61							-	-
Trumpf Group	1011			10.64	11.51	8.92	5.18	-1.76	1.72	13.11	7.04	4.56	2.5930	12
Walter AG (and GmbH)	1005			5.50	8.18	5.39	3.97	-8.46	-2.31	5.58	2.55	-0.30	-0.0036	16
Walter Group	1016				5.47	2.59	0.55	-8.68	-2.76	4.75		-1.54	-1.2383	17

Note regarding the Z values:
The computation of the Z values is based on the averages of the criterias for the years 1991-1994. The discriminant function is based on coefficients estimated by Hänchen for a sample of German firms. In some cases only four criteria were available (*). If four criteria were only partly available this is indicated by **. In those cases where observations were available for only one year this is indicated by *** .

Table A.9: Return on Total Capital after Tax (ROC, percent)

										Averages		Rank no.
Firm	1986	1987	1988	1989	1990	1991	1992	1993	1994	1988-1994	1991-1994	1991-1994
Schumag AG	9.50	10.17	10.87	16.12	9.18	9.34	8.18	11.55	9.29	10.65	9.59	1
Trumpf Group			10.64	11.51	8.92	5.18	-1.76	1.72	13.11	7.04	4.56	2
Schuler Group						5.11	4.95	4.04	3.81		4.48	3
IWKA Group		4.00	4.07	3.75	3.90	4.39	4.76	3.83	3.10	3.97	4.02	4
Eumuco AG		5.86	5.46	4.22	2.51	2.60	4.63	5.56	2.89	3.98	3.92	5
Ex-Cell-O Group					5.78	6.22	8.94	4.95	-5.88		3.56	6
Thyssen Industrie Group	4.10	3.96	4.38	2.07	3.47	1.11	5.69	4.43	2.59	3.39	3.46	7
Müller-Weingarten AG	1.50	1.57	1.45	2.98	2.25	2.34	2.54	2.52	1.70	2.25	2.27	8
Dörries Scharmann/Schiess AG	0.67	-3.95	3.17	4.45	2.85	4.56	5.01	-6.40	3.86	2.50	1.76	9
Schütte GmbH		23.19	20.88	18.49	26.54	23.33	8.09	-19.89	-9.03	9.77	0.62	10
Rothenberger Group			3.08	5.01	5.27	5.41	-9.65	1.72	0.38		-0.53	11
Walter Group				5.47	2.59	0.55	-8.68	-2.76	4.75		-1.54	12
Pittler Combine		21.82	7.86	5.88	6.17	-0.49	-8.89	-13.12	2.05	-0.08	-5.11	13
Traub Group		5.81	6.81	5.42	4.13	-2.12	-7.95	-11.43	-0.42	-0.79	-5.48	14
Gildemeister Group	6.98	9.21	3.46	5.86	4.78	-1.79	-12.27	-11.53	-4.46	-2.28	-7.51	15

Table A.10: Return on Equity Capital after Tax (ROE, percent)

Firm	1986	1987	1988	1989	1990	1991	1992	1993	1994	Averages 1988-1994	Averages 1991-1994	Rank no. 1991-1994
Schuler Group						20.57	23.09	18.80	14.19		19.16	1
Schumag AG	19.85	18.95	21.28	32.20	18.76	19.58	15.67	18.95	13.08	19.93	16.82	2
Thyssen Industrie Group	6.51	6.72	11.75	0.03	10.09	12.21	21.17	9.21	6.71	10.17	12.32	3
IWKA Group		11.44	11.21	10.83	7.74	8.94	9.48	8.20	6.59	9.00	8.30	4
Müller-Weingarten AG	1.99	1.58	3.16	8.11	4.45	9.24	9.51	6.90	2.53	6.27	7.04	5
Eumuco AG		11.01	11.06	5.10	-3.34	-0.12	-11.21	1.90	2.35	0.82	-1.77	6
Ex-Cell-O Group					15.45	10.85	14.75	6.52	-58.74		-6.66	7
Trumpf Group			22.68	22.13	12.60	0.70	-41.37	-16.28	26.87	3.90	-7.52	8
Schütte GmbH		45.96	42.44	42.70	47.81	44.54	0.02	-64.44	-30.69	11.77	-12.64	9
Dörries Scharmann/Schiess AG	-28.89	-48.32	11.60	9.92	3.52	0.00	-9.00	-73.06	0.87	-8.02	-20.30	10
Rothenberger Group			-2.77	0.57	0.66	0.17	-57.50	-13.88	-24.56		-23.94	11
Walter Group				19.31	5.59	-10.97	-53.64	-35.11	-0.13		-24.96	12
Pittler Combine		35.04	8.96	7.05	9.15	-11.31	-46.50	-125.03	-4.51	-23.17	-46.84	13
Traub Group		13.03	11.24	7.57	2.58	-31.83	-234.95	-63.51	-15.69	-46.37	-86.50	14
Gildemeister Group	26.54	27.00	8.23	12.75	8.80	-19.46	-131.24	-401.35	-54.98	-82.46	-151.76	15

Note: The high negative return on the equity capital rates of Gildemeister, Pittler, and Traub are due to low equity capital and high losses. The computation of the ROE measure is illustrated by using an example from the Gildemeister Group. The Group had a ROE of -401.35 percent in 1993. This was computed as follows: The subscribed capital of DM 49.48 million is reduced by deposits owed on the subscribed capital (VAR_1101), that is by DM 35.36 million which leads to DM 14.12 million equity capital. The "special reserves on equity portion (VAR_1245)" of DM 4.96 million are added to the "net loss/net profit (VAR_1482)" of DM -59.15 million, which adds up to DM -56.57 million. This amounts to a percentage of the equity capital of DM 14.12 million and leads to a ROE figure of 400.6 percent or more precisely (using the nonrounded figures) of -401.35 percent.

Table A.11: Ratio of Shareholder Equity (percent)

Firm	1986	1987	1988	1989	1990	1991	1992	1993	1994	Averages 1988-1994	Averages 1991-1994	Rank no. 1991-1994
Schumag AG	35.4	40.9	41.9	45.8	42.0	41.7	43.3	51.3	65.1	47.3	50.3	1
Schütte GmbH	41.0	32.9	32.4	28.8	32.8	34.3	36.1	41.1	41.4	35.3	38.2	2
IWKA Group	25.5	27.1	25.8	25.1	28.6	28.5	31.7	30.5	28.0	28.3	29.7	3
Rothenberger Group		47.0	35.6	28.3	32.1	38.7	30.7	27.2	20.2		29.2	4
Walter Group			27.0	25.7	38.5	34.5	27.0	23.4	25.6		27.6	5
Trumpf Group		27.9	29.2	31.1	29.3	26.1	22.7	24.4	29.4	27.5	25.6	6
Ex-Cell-O Group				19.6	15.8	29.6	28.4	28.5	14.8		25.3	7
Pittler Combine	47.3	57.8	58.1	50.1	43.4	37.9	28.8	13.2	19.8	35.9	24.9	8
Eumuco AG	28.3	28.3	29.4	24.8	22.6	15.2	19.4	25.6	24.9	23.1	21.3	9
Dörries Scharmann/Schiess AG	7.1	14.7	13.6	20.2	21.9	15.3	15.9	17.6	23.8	18.3	18.2	10
Traub Group		33.5	39.4	35.8	29.2	22.5	6.3	21.7	17.1	24.6	16.9	11
Thyssen Industrie Group	21.7	22.0	15.9	14.4	12.7	13.6	14.4	17.2	15.2	14.8	15.1	12
Gildemeister Group	16.8	28.7	28.3	32.9	31.5	25.8	13.8	4.5	14.3	21.6	14.6	13
Müller-Weingarten AG	15.4	15.6	15.8	15.1	16.6	12.5	13.6	14.2	16.6	14.9	14.2	14
Schuler Group					11.8	9.3	8.1	9.6	11.1		9.5	15

Table A.12: Return on Sales after Tax (ROS, percent)

									Averages		Rank no.
Firm	1986	1987	1988	1989	1990	1991	1992	1993	1994	1988-1994	1991-1994	1991-1994
Schumag AG	6.34	6.56	7.67	14.58	6.84	5.85	5.63	8.16	10.91	8.52	7.64	1
Eumuco AG		6.32	5.61	5.84	2.89	3.61	4.25	6.59	2.71	4.50	4.29	2
Schuler Group						5.14	4.41	3.76	3.73		4.26	3
Trumpf Group			8.16	8.56	7.19	4.67	-1.58	1.58	9.99	5.51	3.66	4
IWKA Group		2.99	3.01	3.02	3.06	3.26	3.68	3.28	2.79	3.16	3.25	5
Thyssen Industrie Group	2.82	2.88	4.01	2.06	3.24	1.01	4.51	3.91	2.73	3.07	3.04	6
Ex-Cell-O Group					6.20	5.72	7.16	5.01	-7.15		2.69	7
Dörries Scharmann/Schiess AG	0.61	-5.05	4.00	4.27	4.45	8.29	15.09	-20.96	6.12	3.04	2.13	8
Müller-Weingarten AG	0.92	1.19	1.04	1.97	1.25	1.78	1.75	1.88	1.21	1.55	1.65	9
Rothenberger Group			2.68	5.21	5.62	5.15	-8.23	1.71	0.32		-0.26	10
Walter Group				5.36	2.90	0.67	-10.13	-3.25	4.56		-2.04	11
Schütte GmbH		15.72	14.91	15.64	18.82	15.54	7.40	-31.83	-11.19	4.18	-5.02	12
Pittler Combine		28.23	11.44	8.55	8.49	-0.70	-11.36	-18.45	2.82	0.11	-6.92	13
Gildemeister Group	4.52	6.39	2.81	5.23	3.96	-1.63	-11.04	-14.05	-6.11	-2.97	-8.20	14
Traub Group		4.91	5.82	4.52	3.90	-2.30	-9.48	-22.01	-0.55	-2.87	-8.59	15

Table A.13: Value Added per Employee (in thousand DM)

										Averages (in thousand DM)		Rank no.
Firm	1986	1987	1988	1989	1990	1991	1992	1993	1994	1988-1994	1991-1994	1991-1994
Schuler Group					89,479	97,706	107,098	110,947	105,173		105,231	1
Trumpf Group		97,126	103,247	104,991	101,225	91,648	77,046	83,465	121,994	97,660	93,538	2
IWKA Group	75,875	79,617	75,709	83,192	82,660	89,924	93,621	93,125	96,086	87,760	93,189	3
Müller-Weingarten AG	63,664	62,729	68,010	75,586	71,682	82,202	98,971	95,638	88,559	82,950	91,343	4
Ex-Cell-O Group				97,807	92,545	97,780	98,335	96,986	60,975		88,519	5
Eumuco AG		87,377	85,625	83,355	76,820	81,628	89,978	63,862	86,803	81,153	80,567	6
Schumag AG	62,505	71,185	69,079	58,224	64,561	77,935	75,657	81,765	82,286	72,787	79,411	7
Walter Group				87,246	-87,415	73,279	59,732	77,275	99,615		77,475	8
Thyssen Industrie Group			64,261	66,058	67,979	65,209	69,595	65,121	78,192	68,059	69,529	9
Schütte GmbH	75,490	80,468	87,164	89,504	103,293	102,743	79,460	34,525	55,487	78,882	68,054	10
Rothenberger Group		15,993	26,693	37,441	51,780	71,931	45,111	66,575	67,301		62,730	11
Gildemeister Group	80,360	83,763	80,738	86,076	82,285	78,562	65,723	41,889	55,698	70,139	60,468	12
Traub Group		61,480	70,453	78,436	77,178	68,291	56,951	36,502	65,054	64,695	56,700	13
Pittler Combine	83,340	90,175	63,511	56,615	75,281	60,752	48,710	-0,875	58,345	51,763	41,733	14
Dörries Scharmann/Schiess AG	58,767	59,727	76,068	77,577	58,055	53,112	60,804	-28,702	-99,207	28,244	-3,498	15

Table A.14: NC Machine Tool Imports of West Germany by Machine Tool Type: Average Annual Growth Rates of Units and Unit Value from 1985 to 1990

		1990				1985			1990-1985 Average annual growth rates (percent)	
Product Code	Type of machine tool	Units	Value (DM 1,000)	Pct-Share of total NC imports	Unit value DM	Units	Value (DM 1,000)	Unit value DM	Units	Unit value
32111	Planing, shaping, slotting and broaching machines	3	2,626	0.1	875,333					
32112	Lathes, cutting-off machines, threading machines	1,793	244,494	12.8	136,360	710	119,873	168,835	20.4	-4.2
32113	Turret lathes, automatics	1,687	253,603	13.3	150,328	513	90,443	176,302	26.9	-3.1
32114	Drilling, boring and tapping machines	360	32,693	1.7	90,814	742	154,645	208,416	-13.5	-15.3
32115	Milling machines, horizontal boring and milling machines	1,971	291,554	15.3	147,922	1,068	217,203	203,374	13.0	-6.2
32116	Sawing and filing machines	235	11,777	0.6	50,115	16	6,898	431,125	71.2	-35.0
32117	Grinding, lapping and polishing machines	714	216,051	11.3	302,592	249	68,521	275,185	23.5	1.9
32118	Gear cutting machines	57	41,988	2.2	736,632	5	2,526	505,200	62.7	7.8
not coded	EDM, laser and physicochemical process machine tools	1,277	241,234	12.7	188,907	626	124,469	198,832	15.3	-1.0
not coded	Machining centres	1,607	322,475	16.9	200,669					
3211	Machine tools, cutting type	9,704	1,658,495	87.1	170,908	3,929	784,578	199,689	19.8	-3.1
32121	Hammers, forging, riveting, bending and straightenig machines etc.	6	10,981	0.6	1,830,167	2	72	36,000	24.6	119.4
32122	Mechanical presses	18	15,576	0.8	865,333	17	8,227	483,941	1.2	12.3
32123	Hydraulic presses	46	12,198	0.6	265,174	57	11,874	208,316	-4.2	4.9
32124	Shears and sheet metal working machines	1,509	207,751	10.9	137,675	287	59,818	208,425	39.4	-8.0
3212	Machine tools, forming type	1,579	246,506	12.9	156,115	363	79,991	220,361	34.2	-6.7
	Machine tools, totals	11,283	1,905,001	100.0		4,292	864,569			

Sources: VDMA Machine Tool Statistics (1985; 1990).

8. References

Abbott, Lawrence (1955), *Quality and Competition*, New York: Columbia University Press.

Albach, Horst (1973), "Das Gutenberg-Oligopol," in: Helmut Koch (ed.), *Zur Theorie des Absatzes. Erich Gutenberg zum 75. Geburtstag*, Wiesbaden: Gabler, pp. 9-33.

Albach, Horst (1980), "Average and Best-Practice Production Functions in German Industry," *The Journal of Industrial Economics*, Vol. 29 (September), pp. 55-70.

Albach, Horst (1984), "The Rate of Return in German Manufacturing Industry: Measurement and Policy Implications," in: Daniel M. Holland (ed.), *Measuring Profitability and Capital Costs: An International Study*, Lexington, MA: Lexington Books, pp. 273-311.

Albach, Horst (1987), "Investitionspolitik erfolgreicher Unternehmen," *Zeitschrift für Betriebswirtschaft*, Vol. 57, No. 7, pp. 636-661.

Albach, Horst (1988), "Maßstäbe für den Unternehmenserfolg," in: Herbert H. Henzler (ed.), *Handbuch Strategische Unternehmensführung*, Wiesbaden: Gabler, pp. 69-83.

Albach, Horst (1990), "Das Management der Differenzierung – Ein Prozeß aus Kreativität und Perfektion," *Zeitschrift für Betriebswirtschaft*, Vol. 60, No. 8, pp. 773-788.

Albach, Horst (1994), *Culture and Technical Innovation: A Cross-Cultural Analysis and Policy Recommendations*, Research Report 9, The Academy of Science and Technology in Berlin, Berlin/New York: Walter de Gruyter.

Albach, Horst (1996a), *The Growth of the Firm*, mimeo, Berlin.

Albach, Horst (1996b), "Global Competition Among the Few," Discussion Paper FS IV 96-6, Wissenschaftszentrum Berlin für Sozialforschung.

Albach, Horst (1996c), *Global Competition Among the Few*, The 1996 Göran and Luise Ehrnrooth-Lectures held at the Swedish School of Economics and Business Administration on May 14, 1996, forthcoming.

Albach, Horst, Kurt Bock, and Thomas Warnke (1984), "Wachstumskrisen von Unternehmen," *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung*, Vol. 36, No. 10, pp. 779-793.

Albach, Horst, Thomas Brandt, Achim Konitz, Andreas Schmidt, and Eric Willud (1994), "Dokumentation der Bonner Stichprobe – Zur Datenbank der Jahresabschlüsse deutscher Aktiengesellschaften," Discussion Paper FS IV 94-4, Wissenschaftszentrum Berlin für Sozialforschung.

Albach, Horst, Manfred Fleischer, and Jim Y. Jin (1994), "The Dynamics of Markets and Firms," in: Wolfgang Zapf and Meinolf Dierkes (eds.), *Institutionenvergleich und Institutionendynamik. WZB-Jahrbuch 1994*, Berlin: edition sigma, pp. 290-309.

Albach, Horst, and Thomas Held (1983), "Rentabilität und Finanzkraft deutscher Industrieaktiengesellschaften der metallverarbeitenden Industrie – Ein Vergleich mit den Ergebnissen von Eero Artto," *Zeitschrift für Betriebswirtschaft*, Vol. 83, pp. 203-212.

Albach, Horst, and Andreas Moerke (1996), "Die Überlegenheit der japanischen Unternehmen im globalen Wettbewerb," Discussion Paper FS IV 96-4, Wissenschaftszentrum Berlin für Sozialforschung.

Altman, Edward I. (1968), "Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankcruptcy," *The Journal of Finance*, Vol. 23, pp. 589-609.

Altman, Edward I. (1971), *Corporate Bankruptcy in America*, Lexington, MA: Heath Lexington Books.

American Machinist (1983), *13th American Machinist Inventory Market Potentials Report*, New York: McGraw-Hill.

American Machinist Blue Bulletin (various years), "Machine-Tool Scorecard," edited by Anderson Ashburn. The 1994 and 1995 Scorecards were published as AMT Financial Bulletin "The Blue Bulletin," McLean, VA.

Ames, B. Charles (1968), "Marketing Planning for Industrial Products," *Harvard Business Review*, Vol. 46 (September-October), pp. 100-111.

Anderson, Simon P., André de Palma, and Jacques-Francois Thisse (1992), *Discrete Choice Theory of Product Differentiation*, Cambridge, MA: The MIT Press.

Arbeitskreis "Marketing in der Investitionsgüter-Industrie" der Schmalenbach-Gesellschaft (1977), "Standardisierung und Individualisierung – ein produktpolitisches Entscheidungsproblem," in: Werner H. Engelhardt and Gert Laßmann (eds.), *Anlagen-Marketing, Zeitschrift für betriebswirtschaftliche Forschung*, Sonderheft 7/77, Opladen.

Argenti, John (1976), *Corporate Collapse: The Causes and Symptoms*, New York: Wiley.

Artto, Eero (1982), "Comparison of the Competitive Capacity of Finnish, Swedish and West German Metal Industry Enterprises 1971-1978," *Zeitschrift für Betriebswirtschaft*, Vol. 52, pp. 754-765.

Artto, Eero (1996), "Performance and International Competitiveness of Listed Metal Industry Groups 1987-1995: Finland vs Sweden and Germany," Working Papers W-167, Helsinki School of Economics and Business Administration.

d'Aspremont, Claude, Jean J. Gabszewicz, and Jacques-Francois Thisse (1979), "On Hotelling's 'Stability in Competition'," *Econometrica*, Vol. 47, pp. 1045-1050.

Audretsch, David B. (1995), *Innovation and Industry Evolution,* Cambridge, MA/London: The MIT Press.

Autania AG, *Geschäftsbericht/Annual Report*, various years.

Backhaus, Klaus (1992), *Investitionsgütermarketing*, 3rd edition, München: Vahlen.

Baily, Martin Neil, and Alok K. Chakrabarti (1988), *Innovation and the Productivity Crisis,* Washington, DC: The Brookings Institution.

Bain, Joe S. (1956), *Barriers to New Competition*, Cambridge, MA: Harvard University Press.

BCG (Boston Consulting Group) (1985), *Strategic Study of the Machine Tool Industry. Final Report prepared for the Commission of the European Communities*, February 1985, Düsseldorf/ London/München/Paris.

Beath, John, and Yannis Katsoulacos (1991), *The Economic Theory of Product Differentiation*, Cambridge/New York/Melbourne: Cambridge University Press.

Benston, Georg J. (1985), "The Validity of Profits-Structure with Particular Reference to the FTC's Line of Business Data," *American Economic Review*, Vol. 75 (March), pp. 37-67.

Berliner Bank AG (ed.) (1990), *Werkzeugmaschinenbau in der DDR, Unternehmer-Report,* No. 1, in collaboration with Werner Hübner and Wolfgang Marschall, Berlin.

Berry, Steven (1994), "Estimating Discrete Choice Models of Oligopoly Product Differentiation," *Rand Journal of Economics*, Vol. 25, pp. 242-262.

Berry, Steven, James Levinsohn, and Ariel Pakes (1995), "Automobile Prices in Market Equilibrium," *Econometrica*, Vol. 63, pp. 841-890.

Bester, Helmut, and Emmanuel Petrakis (1993), "The Incentives for Cost Reduction in a Differentiated Industry," *International Journal of Industrial Organization*, Vol. 11, pp. 519-534.

Brander, James A., and Barbara J. Spencer (1983), "Strategic Commitment with R&D: The Symmetric Case," *The Bell Journal of Economics*, Vol. 14, No. 1, pp. 225-235.

Bresnahan, Timothy F. (1989), "Empirical Studies of Industries with Market Power," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. II, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 1011-1057.

Brockhoff, Klaus (1968), "On a Duopoly with a Doubly Kinked Demand Function," *Zeitschrift für die gesamte Staatswissenschaft*, Vol. 124, pp. 451-466.

Brockhoff, Klaus (1988), "Die Bewährung von Gutenbergs Preis-Absatz-Funktion im Zigarettenmarkt," *Zeitschrift für Betriebswirtschaft*, Vol. 58, pp. 828-838.

Brödner, Ernst (1960), "Sind Massenfertigungsmethoden und Fließfertigung im Werkzeugmaschinenbau möglich?" *Industrie-Anzeiger*, Vol. 82, No. 83, pp. 1387-1393.

Brödner, Peter (1990), *The Shape of Future Technology*, London et al.: Springer.

Buxbaum, Bertold (1919), "Der deutsche Werkzeugmaschinen- und Werkzeugbau im 19. Jahrhundert," *Beiträge zur Geschichte der Technik und Industrie*, Vol. 9, pp. 97-129.

Canesi, Marco (1990), "Attualità delle economie di scala: una verifica empirica su un comparto della meccanica strumentale," *Economia e politica industriale*, Vol. 68, pp. 103-133.

Capon, Noel, John U. Farley, and Scott Hoenig (1990), "Determinants of Financial Performance: A Meta-Analysis," *Management Science*, Vol. 36, No. 10 (October), pp. 1143-1159.

Carlsson, Bo (1990), "Small-Scale Industry at a Crossroads: U.S. Machine Tools in Global Perspective," in: Zoltan J. Acs and David B. Audretsch (eds.), *The Economics of Small Firms: A European Challenge*, Dordrecht/Boston/London: Kluwer, pp. 171-193.

Caves, Richard E., and Michael E. Porter (1977), "From Entry Barriers to Mobility Barriers: Conjectural Decisions and Contrived Deterrence to New Competition," *Quarterly Journal of Economics*, Vol. 91 (May), pp. 421-441.

Caves, Richard E., and Michael E. Porter (1978), "Barriers to Exit," in: Robert T. Masson and P. David Qualls (eds.), *Essays on Industrial Organization in Honor of Joe S. Bain*, Cambridge, MA: Ballinger, pp. 39-69.

Caves, Richard E., and Peter Williamson (1985), "What is Product Differentiation Really?" *Journal of Industrial Economics*, Vol. 36, pp. 112-131.

CEC Report (Commission of the European Communities) (1990), *Strategic Study on EC Machine Tools Sector. Final Report*, WS Atkins Management Consultants in association with Ifo-Institut and others, Brussels (May).

CEC (Commission of the European Communities) (eds.) (1995), *Panorama of the EC Industry 1995*, Luxembourg: Office for Official Publications of the European Communities.

Chamberlin, Edward H. (1962, 1933), *The Theory of Monopolistic Competition*, 8th ed., Cambridge, MA: Harvard University Press (1st ed. published in 1933).

Charnes, Abraham, and William W. Cooper (1985), "Preface to Topics in Data Envelopment Analysis," *Annals of Operations Research*, Vol. 2, pp. 59-94.

Coenenberg, Adolf G., and Martin Prillmann (1995), "Erfolgswirkungen der Variantenvielfalt und Variantenmanagement – Empirische Erkenntnisse aus der Elektronikindustrie," *Zeitschrift für Betriebswirtschaft*, Vol. 65, No. 11, pp. 1231-1253.

Comanor, William S., and Thomas A. Wilson (1967), "Advertising, Market Structure, and Performance," *Review of Economics and Statistics*, Vol. 49, pp. 423-440.

Cooper, Lee G., and Akihiro Inoue (1996), "Building Market Structures From Consumer Preferences," *Journal of Marketing Research*, Vol. 33 (August), pp. 293-306.

Corey, E. Raymond (1976), *Industrial Marketing: Cases and Concepts*, 2nd ed., Englewood Cliffs, NJ: Prentice-Hall.

Dansby, Robert E., and Robert D. Willig (1979), "Industry Performance Gradient Indexes," *American Economic Review*, Vol. 69 (August), pp. 249-260.

Davidson, Carl, and Raymond Deneckere (1986), "Long-Run Competition in Capacity, Short-Run Competition in Price, and the Cournot Model," *Rand Journal of Economics*, Vol. 17, No. 3, pp. 404-415.

Davis, Evan, and John Kay (1990), "Assessing Corporate Performance," *Business Strategy Review*, Vol. 1 (Summer), pp. 1-16.

Deckel AG, *Geschäftsbericht/Annual Report*, various years.

Dellmann, Kurt (1991), "Einflußgrößen der Erfolgsdynamik," in: Klaus-Peter Kistner and Reinhart Schmidt (eds.), *Unternehmensdynamik. Horst Albach zum 60. Geburtstag*, Wiesbaden: Gabler, pp. 419-441.

Dertouzos, Michael L., Richard K. Lester, Robert M. Solow, and The MIT Commission on Industrial Productivity (1989), *Made in America: Regaining the Productive Edge*, Cambridge, MA/London: The MIT Press.

Dixit, Avinash K. (1979), "A Model of Duopoly Suggesting a Theory of Entry Barriers," *Bell Journal of Economics*, Vol. 10, pp. 20-32.

Dörries Scharmann AG, *Geschäftsbericht/Annual Report*, various years.

Downie, Jack (1958), *The Competitive Process*, London: Duckworth.

Duke, John, and Horst Brand (1981), "Cyclical Behavoir of Productivity in the Machine Tool Industry," *Monthly Labor Review*, Vol. 104, No. 11 (November), pp. 27-34.

Dupuit, J. (1844), "De la Mesure de l'Utilité des Travaux Publics," Translation in AEA Readings in Welfare Economics, edited by Kenneth Arrow and T. Scitovsky.

Eaton, Curtis B., and Richard G. Lipsey (1989), "Product Differentiation," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. I, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 723-768.

Ehrnberg, Ellinor, and Staffan Jacobsson (1993), "Technological Discontinuity and Competitive Strategy – Revival Through FMS for the European Machine Tool Industry?" *Technological Forecasting and Social Change*, Vol. 44, pp. 27-48.

Ehrnberg, Ellinor, and Staffan Jacobsson (1997), "Indicators of Discontinuous Technological Change: An Exploratory Study of two Discontinuities in the Machine Tool Industry," *R&D Management*, Vol. 27, pp. 107-126.

The Engineer (1984), "Switching the Focus to the Buyer," May 17, pp. 24-26.

Ernst, Holger (1996), *Patentinformationen für die strategische Planung von Forschung und Entwicklung*, Wiesbaden: Deutscher Universitäts-Verlag.

Ernst, Holger (1997), "The Use of Patent Data for Technological Forecasting: The Diffusion of CNC-Technology in the Machine Tool Industry," *Small Business Economics* (forthcoming).

Eumuco AG, *Geschäftsbericht/Annual Report*, various years.

Ewers, Hans-Jürgen, Carsten Becker, and Michael Fritsch (1990), *Wirkungen des Einsatzes computergestützter Techniken in Industriebetrieben*, Berlin/New York: de Gruyter.

Ex-Cell-O AG, *Geschäftsbericht/Annual Report*, various years.

Fandel, Günter (1994), *Produktion I. Produktions- und Kostentheorie*, 4th ed., Berlin/Heidelberg/New York: Springer.

Fandel, Günter, Harald Dyckhoff, and Joachim Reese (1990), *Industrielle Produktionsentwicklung. Eine empirisch-deskriptive Analyse ausgewählter Branchen*, Berlin/Heidelberg/New York: Springer.

Fisher, Franklin M., and John J. McGowan (1983), "On the Misuse of Accounting Rates of Return to Infer Monopoly Profits," *American Economic Review*, Vol. 73 (March), pp. 82-97.

Flimm, Carl, and Reiner G. Saurwein (1992), "Aufbau und Struktur des NIFA-Panels," in: Josef Schmid and Ulrich Widmaier (eds.), *Flexible Arbeitssysteme im Maschinenbau*, Opladen: Leske + Budrich, pp. 15-33.

Frantz, Roger S. (1988), *X-Efficiency: Theory, Evidence and Applications*, Boston/Dordrecht/Lancaster: Kluwer Academic Publishers.

Frick, Klaus Dieter (1991), "Entwicklung des deutschen Drehmaschinenbaus," *Werkstatt und Betrieb*, Vol. 124 (May), pp. 343-347.

Friedman, James W. (1983), *Oligopoly Theory*, Cambridge: Cambridge University Press.

Fritsch, Michael (1990), *Arbeitsplatzentwicklung in Industriebetrieben: Entwurf einer Theorie*, Berlin: de Gruyter.

Fuss, Melvyn A., and Leonard Waverman (1992), *Costs and Productivity in Automobile Production: The Challenge of Japanese Efficiency*, Cambridge: Cambridge University Press.

Gale, Bradley T., and Ben S. Branch (1982), "Concentration versus Market Share: Which Determines Performance and Why does it Matter?" *Antitrust Bulletin*, Vol. 27 (Spring), pp. 83-105.

Gellman Research Associates (1976), *Indicators of International Trends in Technological Innovation*, prepared by S. Feinman and W. Fuentevilla, for the National Science Foundation (PB-263 738), Washington, DC.

Geroski, Paul (1983), "Some Reflections on the Theory and Application of Concentration Indices," *International Journal of Industrial Organization*, Vol. 1, pp. 79-94.

Gilbert, Richard J. (1989), "Mobility Barriers and the Value of Incumbency," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. I, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 475-535.

Gildemeister AG, *Geschäftsbericht/Annual Report*, various years.

Glunk, Fritz R. (1991), *Ein Jahrhundert VDW*, München: Britting Verlag.

Goldberg, Pinelopi Koujianou (1995), "Product Differentiation and Ologopoly in International Markets: The Case of the U.S. Automobile Industry," *Econometrica*, Vol. 63, No. 4 (July), pp. 891-951.

Gordon, Robert J. (1989), "The Postwar Evolution of Computer Prices," in: Dale W. Jorgenson and Ralph Landau (eds.), *Technology and Capital Formation*, Cambridge, MA: The MIT Press, pp. 77-125.

Gravelle, Hugh, and Kay Rees (1992), *Microeconomics*, 2nd ed., London/New York: Longman.

Greene, William H. (1993), *Econometric Analysis*, 2nd ed., New York: Macmillan.

Greene, William H. (1996), *Frontier Production Functions*, mimeo, New York University, New York.

Gutenberg, Erich (1965), "Zur Diskussion der polypolistischen Absatzkurve," *Jahrbücher für Nationalökonomie und Statistik*, Vol. 177, pp. 289-303.

Gutenberg, Erich (1983), *Grundlagen der Betriebswirtschaftslehre, Band 1: Die Produktion*, 24th ed., Berlin/Heidelberg/New York: Springer.

Gutenberg, Erich (1984, 1955), *Grundlagen der Betriebswirtschaftslehre, Band 2: Der Absatz*, 17th ed., Berlin/Heidelberg/New York: Springer (1st ed. published in 1955).

Hänchen, Axel (1983), *Überprüfung der Z-Funktion von Altmann für die Bundesrepublik Deutschland*, Master Thesis, University of Bonn.

Hall, Robert L., and Charles J. Hitch (1939), "Price Theory and Business Behavior," *Oxford Economic Papers*, Vol. 2 (May), pp. 12-45.

Hambrick, Donald C. (1983), "High Profit Strategies in Mature Capital Goods Industries: A Contingency Approach," *Academy of Management Journal*, Vol. 26, No. 4, pp. 687-707.

Hauptmanns, Peter, and Beate Seitz (1992), "Betriebspanel: Ein alternativer Weg industriesoziologischer Forschung? Zur methodischen Konzeption der ersten Welle des NIFA-Panels," in: Josef Schmid and Ulrich Widmaier (eds.), *Flexible Arbeitssysteme im Maschinenbau*, Opladen: Leske + Budrich, pp. 35-53.

Hauptmanns, Peter, Rainer G. Saurwein, and Louise Dye (1992), "Die Diffusion rechnergestützter Technik im deutschen Maschinenbau," in: Josef Schmid and Ulrich Widmaier (eds.), *Flexible Arbeitssysteme im Maschinenbau*, Opladen: Leske + Budrich, pp. 57-73.

Hay, Donald A., and Derek J. Morris (1991), *Industrial Economics and Organization: Theory and Evidence*, 2nd rev. ed., Oxford et al.: Oxford University Press.

Henderson, Bruce D. (1968), *Perspectives on Experience*, Boston: Boston Consulting Group.

Hinder, Walter, and Sabine Bartosch (1987), *Strategisches Wettbewerbsverhalten in stagnierenden Märkten. Eine empirische Untersuchung der Damenoberbekleidungsindustrie der Bundesrepublik Deutschland*, Frankfurt am Main et al.: Verlag Peter Lang.

Hirsch, Werner Z. (1952), "Manufacturing Progress Functions," *Review of Economics and Statistics*, pp. 143-155.

Hoffmann, Walter G. (1965), *Das Wachstum der Deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts*, Berlin: Springer.

Holland, Max (1989), *When the Machine Stopped – A Cautionary Tale from Industrial America*, Boston: Harvard Business School Press.

Homburg, Christian (1995a), *Kundennähe von Industriegüterunternehmen: Konzeption – Erfolgswirkungen – Determinanten*, Wiesbaden: Gabler.

Homburg, Christian (1995b), "Closeness to the Customer in Industrial Markets," *Zeitschrift für Betriebswirtschaft*, Vol. 65, pp. 309-331.

Horn, Ernst-Jürgen, Henning Klodt, and Christopher Saunders (1985), "Advanced Machine Tools: Production, Diffusion and Trade," in: Margaret Sharp (ed.), *Europe and the New Technologies: Six Case Studies in Innovation and Adjustment*, London: Francis Pinter, pp. 46-86.

Hotelling, Harold (1929), "Stability in Competition," *Economic Journal*, Vol. 39, pp. 41-57.

Ijiri, Yuji, and Herbert A. Simon (1964), "Business Firm Growth and Size," *American Economic Review*, Vol. 54, pp. 77-89.

Ireland, Norman J. (1987), *Product Differentiation and Non Price Competition*, Oxford: Blackwell.

Irsch, Norbert (1988), "Zum Zusammenhang von Unternehmensgröße und Rentabilität in der Bundesrepublik Deutschland in der Mitte der 80er Jahre," *Jahrbuch für Nationalökonomie und Statistik*, Vol. 205/6, pp. 519-537.

IWKA AG, *Geschäftsbericht/Annual Report*, various years.

Jacobs, Siegfried (1992), *Strategische Erfolgsfaktoren der Diversifikation*, Wiesbaden: Gabler.

Jacobsson, Staffan (1986), *Electronics and Industrial Policy. The Case of Computer Controlled Lathes*, London: Allen & Unwin.

Jahresgutachten 1995/1996 des Sachverständigenrates zur Begutachtung der gesamtwirtschaftlichen Entwicklung, Bundestagsdrucksache 13/3016, Bonn.

Jaumandreu, Jordi, and Joaquin Lorences (1996), *Modelling Price Competition under Product Differentiation with Panel Data (An Application to the Spanish Loans Market)*, paper presented at the 23rd Annual E.A.R.I.E. Conference, Vienna, September 7-10, 1996.

Kekre, Sunder, and Kannan Srinivasan (1990), "Broader Product Line: A Necessity to Achieve Success?" *Management Science*, Vol. 36, No. 10, pp. 1216-1231.

Kief, Hans B. (1991a), *NC/CNC Handbuch '91*, München/Wien: Hanser.

Kief, Hans B. (1991b), "Von der NC zur CNC – die Entwicklung der numerischen Steuerungen: ein Rückblick aus der Sicht eines Numerikers," *Werkstatt und Betrieb*, Vol. 124 (May), pp. 385-390.

Kilger, Wolfgang (1962), "Die quantitative Ableitung polypolistischer Preisabsatzfunktionen aus den Heterogenitätsbedingungen atomistischer Märkte," in: Helmut Koch (ed.), *Zur Theorie der Unternehmung. Festschrift zum 65. Geburtstag von Erich Gutenberg*, Wiesbaden: Gabler, pp. 269-309.

Kleinknecht, Alfred (1984), *Innovation Patterns in Crisis and Prosperity: Schumpeter's Long Cycle Reconsidered*, Ph.D. Thesis, Free University Amsterdam.

Klingelnberg, Diether (1992), "Schlußfolgerungen aus der Sicht des VDW," in: Hans-Böckler-Stiftung and Industriegewerkschaft Metall (eds.), *Lean Production: Kern einer neuen Unternehmenskultur und einer innovativen und sozialen Arbeitsorganisation?*, Baden-Baden: Nomos Verlagsgesellschaft, pp. 132-138.

Kotler, Philip (1997), *Marketing Management: Analysis, Planning, Implementation, and Control*, 9th ed., Upper Saddle River, NJ: Prentice-Hall International.

Kravis, Irving B., and Robert E. Lipsey (1971), *Price Competitiveness in World Trade*, New York/London: N.B.E.R. and Columbia University Press.

Kreps, David M. (1990), *A Course in Microeconomic Theory*, Hemel Hempstead: Harvester Wheatsheaf.

Kreps, David M., and José A. Scheinkman (1983), "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes," *Bell Journal of Economics*, Vol. 14, pp. 326-337.

Kriegbaum, Herbert, and Sabine Sobczak (1989), *EG-Maschinenbau: Strukturen und Trends*, Frankfurt am Main: Maschinenbau-Verlag.

Kümmerle, Walter (1992), "The Global Strategy of Leading Japanese Pharmaceutical Enterprises," *Zeitschrift für Betriebswirtschaft*, Ergänzungsheft 2/92, pp. 99-119.

Lancaster, Kelvin (1979), *Variety, Equity, and Efficiency – Product Variety in an Industrial Society*, New York: Columbia University Press.

Leibenstein, Harvey (1966), "Allocative Efficiency vs. X-Efficiency," *American Economic Review*, Vol. 56, pp. 392-415.

Leibenstein, Harvey (1987), *Inside the Firms: The Inefficiencies of Hierarchy*, Cambridge: Harvard University Press.

Leibinger, Berthold (1996), "Zurück zum Volumengeschäft? – Zukunftschancen für den deutschen Werkzeugmaschinenbau," *Werkstatt und Betrieb*, Vol. 129, pp. 836-837.

Levitt, Theodore (1983), "The Globalization of Markets," *Harvard Business Review*, Vol. 61 (May-June), pp. 92-102.

Lyons, Bruce (1980), "A New Measure of Minimum Efficient Plant Size in UK Manufacturing Industry," *Economica*, Vol. 47, pp. 19-34.

Maho AG, *Geschäftsbericht/Annual Report*, various years.

Maltzan, Bernd Freiherr von (1978), " 'Average'-Produktionsfunktionen und Effizienzmessung über 'frontier production functions' – dargestellt an Bilanzdaten von Aktiengesellschaften der Chemieindustrie aus der Bonner Stichprobe," *Bonner Betriebswirtschaftliche Schriften*, Vol. 3, Bonn.

Mansfield, Edwin (1962), "Entry, Gibrat's Law, Innovation, and the Growth of Firms," *American Economic Review*, Vol. 52 (December), pp. 1023-1051.

Maschke, Helmut (1987), "Umsetzung strategischer Ziele in die Vertriebspraxis," in: VDMA (ed.), *Erfolgreiche Marketingstrategien. Maschinenbauer berichten über ihre Erfahrungen*, Frankfurt am Main: Maschinenbau-Verlag, pp. 67-100.

Mas-Colell, Andreu, Michael D. Whinston, and Jerry R. Green (1995), *Microeconomic Theory*, New York/Oxford: Oxford University Press.

McGee, John, and Howard Thomas (1986), "Strategic Groups: Theory, Research and Taxonomy," *Strategic Management Journal*, Vol. 7, pp. 141-160.

Mengel, Heinrich Wilhelm (1933), *Strukturwandlungen und Konjunkturbewegungen in der Werkzeugmaschinenindustrie*, Ph.D. Thesis, Technische Hochschule Berlin.

Mensch, Gerhard (1975), *Das technologische Patt. Innovationen überwinden die Depression*, Frankfurt am Main: Umschau Verlag; English Edition: Gerhard Mensch (1979), *Stalemate in Technology. Innovations Overcome Depression*, Cambridge, MA: Ballinger.

Monopolkommission (1990), *8. Hauptgutachten 1989/89: Wettbewerbspolitik vor neuen Herausforderungen, Anlagenband*, Baden-Baden: Nomos Verlagsgesellschaft.

Monopolkommission (1996), *11. Hauptgutachten 1994/95: Wettbewerbspolitik in Zeiten des Umbruchs, Anlagenband*, Baden-Baden: Nomos Verlagsgesellschaft.

Moroff, Gerhard (1993), *Werkzeugmaschinen in der industriellen Produktion*, Berlin: Duncker & Humblot.

Mueller, Dennis C. (1990), "Profits and the Process of Competition," in: Dennis C. Mueller (ed.), *The Dynamics of Company Profits: An International Comparison*, Cambridge et al.: Cambridge University Press, pp. 1-14.

Müller, Jan (1977), "Verschärfte Strukturprobleme in der Werkzeugmaschinenindustrie," *Ifo-Schnelldienst*, Vol. 30, No. 28 (October), pp. 7-12.

Müller-Weingarten AG, *Geschäftsbericht/Annual Report*, various years.

Nagel, Bernhard, and Hildegard Kaluza (1988), *Eigentum und Markt im Maschinenbau*, Baden-Baden: Nomos.

Neumann, Manfred, Ingo Böbel, and Alfred Haid (1983), "Business Cycle and Industrial Market Power: An Empirical Investigation for West German Industries 1965-1977," *Journal of Industrial Economics*, Vol. 32, pp. 187-196.

Newman, Howard H. (1978), "Strategic Groups and the Structure-Performance Relationship," *Review of Economics and Statistics*, Vol. 64, pp. 417-427.

Norsworthy, John R., and Show Ling Jang (1992), *Empirical Measurement and Analysis of Productivity and Technological Change*, Amsterdam/London/New York/Tokyo: North-Holland.

O'Brien, Peter (1987), "Machine Tools: Growing Internationalization in Small Firm Industry," *Multinational Business*, No. 4 (Winter), pp. 23-34.

Odagiri, Hiroyuki, and Hideki Yamawaki (1990), "The Persistence of Profists: International Comparison," in: Dennis C. Mueller (ed.), *The Dynamics of Company Profits: An International Comparison*, Cambridge et al.: Cambridge University Press, pp. 169-185.

Oppenländer, Karl Heinrich (1990), "Ertragskraft als Voraussetzung für Innovationen – Sind unternehmensgrößenspezifische Unterschiede zu erkennen?" in: Bernhard Gahlen (ed.), *Marktstruktur und gesamtwirtschaftliche Entwicklung*, Berlin et al.: Springer, pp. 253-271.

von der Osten, Dinnes-Johannes (1990), *Die Wettbewerbssituation im deutsch-amerikanischen Investitionsgüterhandel der 80er Jahre: Eine Untersuchung ihrer makro- und* *mikroökonomischen Bestimmungsfaktoren am Beispiel der Werkzeugmaschinenindustrie*, Ph.D. Thesis, Freie Universität Berlin, Rheinfelden: Schäuble.

Ottwaska, Dieter (1964), *Das Leistungspotential der Werkzeugmaschinenindustrie der Bundesrepublik Deutschland. Eine Untersuchung über Struktur, Produktion und Weltmarktabsatz im internationalen Vergleich (1950-1960)*, Ph.D. Thesis, Wirtschaftshochschule Mannheim.

Panzar, John (1989), "Technological Determinants of Firm and Industry Structure," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. I, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 3-59.

Pavitt, Keith (1984), "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory," *Research Policy*, Vol. 13, pp. 343-373.

de Pay, Diana (1987), *Die Organisation von Innovationen*, Wiesbaden: Gabler.

Perlitz, Manfred (1979), "Empirische Bilanzanalyse," *Zeitschrift für Betriebswirtschaft*, Vol. 49, pp. 835-849.

Peters, Thomas J., and Robert H. Waterman (1982), *In Search of Excellence*, New York: Harper & Row.

Phlips, Louis, and Jacques-Francois Thisse (1982), "Spatial Competition and the Theory of Differentiated Markets: An Introduction," *The Journal of Industrial Economics*, Vol. 31, No.1/2, pp. 1-9.

Pine, B. Joseph (1993), *Mass Customization*, Boston: Harvard Business School Press.

Pittler Maschinenfabrik AG, *Geschäftsbericht/Annual Report*, various years.

Plinke, Wulff (1992), "Fallgruben der Kundenorientierung überspringen," *Absatzwirtschaft* (asw), Vol. 3, KS, pp. 97-101.

Porter, Michael E. (1980), *Competitive Strategy*, New York: The Free Press.

Porter, Michael E. (1985), *Competitive Advantage*, New York: The Free Press.

Pratten, Cliff F. (1971), *Economies of Scale in Manufacturing Industries*, Cambridge: Cambridge University Press.

Produktion (1991), No. 39, September 26, 1991, p. 3.

Produktion (1992a), "Die Stärken dort ausspielen, wo der Mittelstand Schwächen hat. Vulkan Industrie übernimmt Dörries Scharmann," *Produktion*, No. 20, May 14, 1992, p. 1.

Produktion (1992b), "Die besten Fabriken des Jahres 1992. Maho Seebach GmbH: Kaizen in Thüringen," *Produktion* (September), pp. 40-48.

Produktion (1992c), "Der große Unterschied – Vergleichende Betrachtung des deutschen und japanischen Werkzeugmaschinenbaus," *Produktion*, No. 35, August 27, 1992, pp. 16-17.

Produktion (1992d), "Mut zu radikalen Änderungen. Zur Situation des europäischen Werkzeugmaschinenbaus," *Produktion*, No. 18, April 30, 1992, p. 3.

Produktion (1992e), "Unser Problem heißt Produktivität. Vergleichende Studie über deutsche und japanische WZM-Bauer," *Produktion*, No. 27, July 2, 1992, p. 1.

Produktion (1995), No. 43, October 26, 1995, p. 3.

Ramanujam, Vasudevan, and P. Rajan Varadarajan (1989), "Research on Corporate Diversification: A Synthesis," *Strategic Management Journal*, Vol. 10, pp. 523-551.

Ravenscraft, David J. (1983), "Structure-Profit Relationships at the Line of Business and Industry Level," *Review of Economics and Statistics*, Vol. 65 (February), pp. 22-31.

Reintjes, J. Francis (1991), *Numerical Control – Making a New Technology*, New York: Oxford University Press.

Reitsperger, Wolf D., Shirley J. Daniel, Stephen B. Tallman, and William G. Cismar (1993), "Product Quality and Cost Leadership: Compatible Strategies?" *Management International Review*, Vol. 33, Special Issue, No. 1, pp. 7-21.

Rendeiro, Joao O. (1988), "Technical Change and Vertical Disintegration in Global Competition: Lessons from Machine Tools," in: Neil Hood and Jan-Erik Vahlne (eds.), *Strategies in Global Competition*, London/New York/Sydney: Croom Helm, pp. 209-224.

Robinson, Richard B., and John A. Pearce (1988), "Planned Patterns of Strategic Behavior and their Relationship to Business Unit Performance," *Strategic Management Journal*, 9 (1), pp. 43-60.

Rolt, Lionel Thomas Caswell (1965), *Tools for the Job – A Short History of Machine Tools*, London: B. T. Batsford.

Rosenkranz, Stephanie (1995), "Simultaneous Choice of Process and Product Innovation," Discussion Paper FS IV 95-24, Wissenschaftszentrum Berlin für Sozialforschung.

Rosenkranz, Stephanie (1996), *Cooperation for Innovation*, Berlin: edition sigma.

Rothenberger AG, *Geschäftsbericht/Annual Report*, various years.

Rühlmann, Marcus (1992), *Wettbewerbsstrategien im Werkzeugmaschinenbau. Ein deutsch-japanischer Vergleich*, Master Thesis, Department of Economics, Free University of Berlin.

Rumelt, Richard P. (1974), *Strategy, Structure, and Economic Performance*, Division of Research, Harvard Business School, Boston.

Sahal, Devendra (1981), *Patterns of Technological Innovation*, Reading, MA: Addison-Wesley.

Salop, Steven C. (1979), "Monopolistic Competition with Outside Goods," *Bell Journal of Economics*, Vol. 10, pp. 141-156.

Salter, Wilfred E. G. (1966), *Productivity and Technical Change*, 2nd ed., Cambridge: Cambridge University Press.

Scherer, Frederic M., and David Ross (1990), *Industrial Market Structure and Economic Performance*, 3rd edition, Boston: Houghton Mifflin Co.

Schlesinger, Georg (1928), "30 Jahre deutscher Werkzeugmaschinenbau," *Werkstattstechnik*, Vol. 22, No. 20 (October), pp. 549-554.

Schmalensee, Richard (1987), "Collusion versus Differential Efficiency: Testing Alternative Hypotheses," *The Journal of Industrial Economics*, Vol. 35, No. 4, pp. 399-425.

Schmalensee, Richard (1989a), "Inter-Industry Studies of Structure and Performance," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. II, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 951-1009.

Schmalensee, Richard (1989b), "Intra-Industry Profitability Differences in US Manufacturing 1953-1983," *The Journal of Industrial Economics*, Vol. 37, No. 4 (June), pp. 337-357.

Schmid, Josef, and Ulrich Widmaier (1992), *Flexible Arbeitssysteme im Maschinenbau*, Opladen: Leske + Budrich.

Schönbrodt, Bernd (1981), *Erfolgsprognosen mit Bilanzkennzahlen*, Frankfurt am Main/Bern: Lang.

von Schöning, Karl-Viktor (1980), *Innovationspotential in der Fertigungstechnik*, München/ Wien: Hanser.

Schohl, Frank (1990), "Persistence of Profits in the Long Run," *International Journal of Industrial Organization*, Vol. 8, pp. 385-404.

Schohl, Frank (1992), *Renditeunterschiede und Schumpetersche Entwicklung: Eine empirische Untersuchung*, Berlin: Duncker & Humblot.

Schröder, Sascha (1995), *Innovation in der Produktion – Eine Fallstudienuntersuchung zur Entwicklung der numerischen Steuerung*, München/Wien: Hanser.

Schütte GmbH, *Geschäftsbericht/Annual Report*, various years.

Schuler GmbH, *Geschäftsbericht/Annual Report*, various years.

Schumag AG, *Geschäftsbericht/Annual Report*, various years.

Schwab, Gerhard (1996), *Die Entwicklung der deutschen Werkzeugmaschinenindustrie von 1945-1995*, Master Thesis, University of Erlangen-Nürnberg, revised version edited by VDW, Frankfurt am Main.

Schwalbach, Joachim (1987a), "Entry by Diversified Firms into German Industries," *International Journal of Industrial Organization*, Vol. 5 (March), pp. 43-50.

Schwalbach, Joachim (1987b), *Diversifizierung, Risiko und Erfolg industrieller Unternehmen*, Postdoctoral Thesis, Wissenschaftliche Hochschule für Unternehmensführung Koblenz.

Schwalbach, Joachim (1988), "Marktanteil und Unternehmensgewinn," *Zeitschrift für Betriebswirtschaft*, Vol. 58, No. 4, pp. 535-549.

Schwalbach, Joachim, and Talat Mahmood (1990), "The Persistence of Corporate Profits in the Federal Republic of Germany," in: Dennis C. Mueller (ed.), *The Dynamics of Company Profits: An International Comparison*, Cambridge et al.: Cambridge University Press, pp. 105-121.

Sciberras, Edmond, and B. D. Payne (1985), *Machine Tool Industry – Technical Change and International Competitiveness*, London: Longman.

Shapiro, Carl (1989a), "Theories of Oligopoly Behavior," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, Vol. I, Amsterdam/New York/Oxford/Tokyo: North-Holland, pp. 329-414.

Shapiro, Carl (1989b), "The Theory of Business Strategy," *Rand Journal of Economics*, Vol. 20, No. 1, pp. 125-137.

Simon, Hermann (1989), *Price Management*, Amsterdam/New York/Oxford/Tokyo: North-Holland.

Simon, Hermann (1990), "Hidden Champions," *Zeitschrift für Betriebswirtschaft*, Vol. 60, No. 9, pp. 875-890.

Simon, Hermann (1996), *Hidden Champions: Lessons from 500 of the World's Best Unknown Companies*, Boston: Harvard Business School Press.

Simon, Herbert A., and Charles P. Bonini (1958), "The Size Distribution of Business Firms," *American Economic Review*, Vol. 48 (September), pp. 607-617.

Spence, Michael (1976), "Product Differentiation and Welfare," *American Economic Review*, Vol. 66 (May), pp. 407-414.

Spur, Günter (1991), *Vom Wandel der industriellen Welt durch Werkzeugmaschinen: Eine kulturgeschichtliche Betrachtung der Fertigungstechnik*. Published by Verein Deutscher Werkzeugmaschinenfabriken e.V. on the occasion of its 100th anniversary, München/ Wien: Hanser.

Spur, Günter, Dieter Specht, and Sascha Schröder (1994), "Die Numerische Steuerung (NC-Machine Tools) – Fallstudien einer erfolgreichen Innovation aus dem Bereich des Maschinenbaus," in: *Culture and Technical Innovation: A Cross-Cultural Analysis and Policy Recommendations*, Research Report 9, The Academy of Science and Technology in Berlin, Berlin/New York: Walter de Gruyter, pp. 621-735.

Sraffa, Piero (1926), "The Laws of Returns under Competitive Conditions," *Economic Journal*, Vol. 36 (December), pp. 535-550.

Statistisches Bundesamt (various years), *Fachserie 4: Produzierendes Gewerbe*, Reihen 4.2.1, 4.2.3, 4.3.2, Wiesbaden.

Statistisches Jahrbuch (1992), Statistisches Bundesamt (ed.), *Statistisches Jahrbuch 1992 für die Bundesrepublik Deutschland*, Stuttgart: Kohlhammer.

Steindl, Josef (1965), *Random Processes and the Groth of Firms*, London: Griffin.

Stigler, George J. (1947), "The Kinky Oligopoly Demand Curve and Rigid Prices," *Journal of Political Economy*, Vol. 65 (October), pp. 432-449.

Stigler, George J. (1958), "The Economies of Scale," *Journal of Law and Economics*, Vol. 1 (October), pp. 54-71.

Sutton, John (1991), *Sunk Costs and Market Structure*, Cambridge, MA/London: The MIT Press.

Sutton, John (1995), "The Size Distribution of Businesses. Part I: A Benchmark Case," London School of Economics, The Economics of Industry Group, Discussion Paper Series, No. EI/9 (December).

Sutton, John (1996), *Technology and Market Structure: Theory and History*, mimeo, London.

Sweezy, Paul M. (1939), "Demand under Conditions of Oligopoly," *Journal of Political Economy*, Vol. 47 (August), pp. 568-573.

Tecnologie Meccaniche (1990, 1991, 1992), "La classifica di costruttori di macchine utensili: Le prime 100 europee."

Thießen, Friedrich (1996), "Erfolgswirkungen der Variantenvielfalt und Variantenmanagement – Anmerkungen zum Beitrag von Adolf G. Coenenberg und Martin Prillmann," *Zeitschrift für Betriebswirtschaft*, Vol. 66, No. 8, pp. 989-992.

Thisse, Jacques-Francois, and George Norman (eds.) (1994), *The Economics of Product Differentiation*, Vol. I and II, Aldershot/Brookfield: Edward Elgar.

Thyssen Industrie AG, *Geschäftsbericht/Annual Report*, various years.

Tirole, Jean (1988), *The Theory of Industrial Organization*, Cambridge, MA: The MIT Press.

Tönshoff, Nils (1996), *Modular Machine Tools – Bundling and Pricing Strategies under Demand Uncertainty*, Wiesbaden: Deutscher Universitäts-Verlag.

Trajtenberg, Manuel (1990), *Economic Analysis of Product Innovation: The Case of CT Scanners*, Cambridge, MA/London: Harvard University Press.

Traub AG, *Geschäftsbericht/Annual Report*, various years.

Trumpf GmbH, *Geschäftsbericht/Annual Report*, various years.

Uhlmann, Luitpold (1989), *Die Gewinne der Industrieunternehmen. Die Höhe der Gewinne 1977 bis 1987 – Daten für Fachzweige und Größenklassen*, in collaboration with Christine Dienst, ifo-Studien zur Industriewirtschaft 38/1, München: Ifo-Institut.

Vasconcellos, J. A., and Donald C. Hambrick (1989), "Key Success Factors: Test of a General Theory in the Mature Industrial-Product Sector," *Strategic Management Journal*, Vol. 10, pp. 367-382.

VDMA (Verband Deutscher Maschinen- und Anlagenbau e.V.) (ed.) (1986), *Maschinen- und Anlagenbau im Zentrum des Investierens*, Frankfurt am Main: Maschinenbau-Verlag.

VDMA Handbook (Verband Deutscher Maschinen- und Anlagenbau e.V.) (ed.) (various years), *Statistisches Handbuch für den Maschinenbau*, Frankfurt am Main: Maschinenbau-Verlag.

VDMA Machine Tools Statistics (Verband Deutscher Maschinen- und Anlagenbau e.V., Fachgemeinschaft Werkzeugmaschinen und Fertigungssysteme) (ed.) (various years), *Statistiken aus dem Deutschen Werkzeugmaschinenbau* (until 1988 the title was: Statistische Zahlen aus dem Werkzeugmaschinenbau – Werkzeugmaschinen-Statistik), Frankfurt am Main.

VDW (Verein Deutscher Werkzeugmaschinenfabriken e.V.) (ed.) (1993), "Strategien der deutschen Werkzeugmaschinenindustrie – Internationale Wettbewerbsposition soll verbessert werden," Press Release incl. 24 Charts, March 23, 1993, Frankfurt am Main.

VDW Machine Tool Inventory (Verein Deutscher Werkzeugmaschinenfabriken e.V.) (ed.) (1976, 1980, 1990), *Altersstruktur des industriellen Werkzeugmaschinenparks in der Bundesrepublik Deutschland*, Frankfurt am Main.

VDW Red Book (Verein Deutscher Werkzeugmaschinenfabriken e.V.) (ed.) (various years), *Werkzeugmaschinen-Bezugsquellenverzeichnis*, Frankfurt am Main.

Vieweg, Hans-Günther (1989), "Entwicklungsperspektiven der Werkzeugmaschinenindustrie," *Ifo-Schnelldienst*, No. 24/89, pp. 28-34.

Vieweg, Hans-Günther (1991), "Der Werkzeugmaschinenbau: Eine Wettbewerbsanalyse für die gesamtdeutsche Branche," *Ifo-Schnelldienst*, No. 21/91, pp. 22-29.

Vieweg, Hans-Günther (1993), "Maschinenbau: Vorübergehende Schwäche oder existentielle Krise?" *Ifo-Schnelldienst*, No. 10/93, pp. 11-21.

Vieweg, Hans-Günther, and Hanns Günter Hilpert (1993), *Japans Herausforderungen an den deutschen Maschinenbau*, Berlin/München: Duncker & Humblot.

Walter AG, *Geschäftsbericht/Annual Report*, various years.

Weck, Manfred (1988), *Werkzeugmaschinen, Band 1: Maschinenarten, Bauformen und Anwendungsbereiche*, 3rd ed., Düsseldorf: VDI Verlag.

Welge, Martin K., and Hans H. Hüttemann (1993), *Erfolgreiche Unternehmensführung in schrumpfenden Branchen*, Stuttgart: Schäffer-Poeschel.

Weiss, Leonard W. (1963), "Factors in Changing Concentration," *Review of Economics and Statistics*, Vol. 45, pp. 70-77.

Widmaier, Ulrich, Hiltrud Niggemann, and Joachim Merz (1994), *What Makes the Difference between Unsuccessful and Successful Firms in the German Mechanical Engineering Industry*, mimeo, Bochum/Lüneburg.

Wieandt, Axel (1994), *Die Entstehung, Entwicklung und Zerstörung von Märkten durch Innovationen*, Stuttgart: Schäffer-Poeschel.

Wied-Nebbeling, Susanne (1975), *Industrielle Preissetzung – Eine Überprüfung der marginal- und vollkostentheoretischen Hypothesen auf empirischer Grundlage*, Tübingen: J. C. B. Mohr (Paul Siebeck).

Williamson, Oliver E. (1981), "The Modern Corporation: Origin, Evolution, Attributes," *Journal of Economic Literature*, Vol. 19, No. 4, pp. 1537-1568.

Wirtschaftswoche (1992), "Extra: Privatisierung," Folge 5, No. 15, April 3, 1992.

Womack, James P., Daniel T. Jones, and Daniel Roos (1990), *The Machine That Changed the World*, New York: Rawson.

Zörgiebel, Wilhelm W. (1983), *Technologie in der Wettbewerbsstrategie. Strategische Auswirkungen technologischer Entscheidungen untersucht am Beispiel der Werkzeugmaschinenindustrie*, Berlin: Erich Schmidt Verlag.

List of Figures

Figure 2.1:	Geographical Distribution of German Machine Tool Firms and User Industries in 1990	32
Figure 2.2:	Unit Values in 1989 and Unit Value Changes from 1960 to 1989 by Type of Machine Tools	35
Figure 2.3:	Orders, Production, Consumption, Exports, and Imports in Real Values for the German Machine Tool Industry from 1954 to 1995	36
Figure 2.4:	Diffusion of CNC Machines in the West German Mechanical Engineering Industry	37
Figure 2.5:	Average Firm Size in Employees for Six Size Classes in the West German Machine Tool Industry, 1960-1990	43
Figure 2.6:	Frequency Distribution of 1,139 Product Innovations Made by Firms of the West German Machine Tool Industry in 1989	57
Figure 2.7:	Return on Capital before Tax for the German Machine Tool Industry (MTI) and the German Mechanical Engineering Industry (MEI), 1970-1993	68
Figure 2.8:	Return on Sales before Tax for the German Machine Tool Industry (MTI) and the German Mechanical Engineering Industry (MEI), 1970-1993	69
Figure 3.1:	Graph of Influences within the Structure-Conduct-Performance Paradigm for Mechanical Engineering Industries	71
Figure 3.2:	Firm Size Distribution in the West German Machine Tool Industry, 1951, 1960, 1970, and 1990 (on probability paper)	77
Figure 3.3:	Demand Functions for Machining Centers Case 1 "Steep Slope" and Case 2 "Flat Slope"	81
Figure 3.4:	Three Typical Demand Structures	86
Figure 3.5:	Gutenberg's Solution of Monopolistic Competition with a Doubly Kinked Demand Curve and Linear Marginal Costs	115
Figure 5.1:	Strategic Map of the International Industry Supplying Machining Centers and FMSs Based on Machining Centers	158
Figure 5.2:	Hexagon Criterion for German Machine Tool Firms, 1991-1994	166
Figure 5.3:	Impact of Product Group Specialization on Return on Capital for a Sample of 12 German Machine Tool Firms, 1991-1994	182

List of Tables

Table 2.1:	Stock of Machine Tools in the West German Manufacturing Sector According to Industries	27
Table 2.2:	Machine Tool Production by Type for West Germany, 1989 and 1960: Average Annual Growth Rates of Units, Value, and Unit Value	30
Table 2.3:	The Products with the Highest and Lowest Annual Growth of Real Output in the West German Machine Tool Industry, 1982-1989	33
Table 2.4:	The 20 Largest German Machine Tool Firms in 1990 and 1994 Ranked According to the Sales of the Group ("Konzern")	39
Table 2.5:	Various Measures of Concentration of the West German Machine Tool Industry, 1987-1993	40
Table 2.6:	Concentration Ratios According to SIC and Commodity Groups West German Machine Tool Industry, 1978-1994	42
Table 2.7:	Distribution by Firm Size for the West German Maschine Tool Industry, 1960 and 1990	43
Table 2.8:	Official German Manufacturing Statistics for SIC/SYPRO-No. 3220 "Manufacturing of Metal Working Machines, Tools for Machines, and Precision Tools" (includes only West Germany)	44
Table 2.9:	Various Estimates of Minimum Efficient Scale (MES) and Minimum Efficient Plant Size (MEP) for the Machine Tool Industry (in employment figures)	46
Table 2.10:	Minimum Efficient Plant Size (MEP) for 14 Product Groups of the West German Machine Tool Industry for 1959 (in employment figures)	48
Table 2.11:	Minimum Efficient Plant Size (MEP) for 14 Product Groups of the West German Machine Tool Industry for 1959 (in units per year sorted according to MEP1/Industry Output)	49
Table 2.12:	Estimated Parameters of Cost Functions for the West German Machine Tool Industry Based on Production Value	51
Table 2.13:	Changes in the Degree of Product Differentation in West German Maschine Tool Firms, 1950-1981	56
Table 2.14:	Innovations Made in Machine Tools and Components in West Germany, 1989 by Firm and Number of Innovative Entries (firms with three and more innovations)	58
Table 2.15:	Distribution of 192 Product Innovations by VDW-Code of Machine Tool Types for 1989	60

Table 2.16: Import Shares in West Germany for Machine Tools by Countries, 1952-1990 (in percent) 62

Table 2.17: Development of the German Machine Tool Industry from 1976 to 1995: Indices on the Number of Firms, Employment, and Production Value 65

Table 2.18: Distribution of Profits and Profit Margins by Firm Size for the West German Machine Tool Industry, 1990-1994 66

Table 3.1: Estimated Pareto Coefficients for the West German Machine Tool Industry, 1951-1990 79

Table 3.2: The Market for Machining Centers (MCs) in 1990: Rough Estimation of Share and Volume for West German Machine Tool Firms 82

Table 3.3: Equilibrium Outputs for Different Market Structures 95

Table 3.4: Cournot Equilibrium for Various Fixed Costs and Levels of n for the Machining Center Market of the German Machine Tool Industry CASE 1: Steep Slope of the Demand Function 100

Table 3.5: Cournot Equilibrium for Various Fixed Costs and Levels of n for the Machining Center Market of the German Machine Tool Industry CASE 2: Flat Slope of the Demand Function 101

Table 3.6: Market Equilibria and Social Optima in Selected Spatial Models of Product Differentiation 106

Table 4.1: The NIFA Panel: Plants Participating in all Four Waves (penultimate column) (the plants were surveyed from 1991-1994 in the respective years) 130

Table 4.2: Correlation Coefficients for the Intercorrelations of Various Efficiency Measures for 359 Plants in the NIFA Panel, 1990-1993 137

Table 4.3: Definition of the Profitability Measure PROFIT1 Using the Evaluation of the Development of Returns in 1991 and 1992 139

Table 4.4: Product Differentiation, Profitability, and Efficiency in Segments of the German Mechanical Engineering Industry, 1990-1992 142

Table 4.5: Variable Definitions for Simultaneous Equation Model 145

Table 4.6: Estimated Regression Coefficients Using the NIFA Panel Data for 1992 for the German Mechanical Engineering and the Machine Tool Industries (2SLS Estimations with t-Statistics in brackets) 149

Table 5.1: Sales, Employment, and the Length of the Product Mix of 85 of the Largest West German Machine Tool Firms in 1990 160

Table 5.2: Indexes of Product Group Specialization (PDIFF4 and PDIFF5) Based on the VDW Classification for a Sample of 12 German Machine Tool Firms 163

Table 5.3: List of the 15 German Machine Tools Firms in the Sample (in alphabetical order) 173

Table 5.4:	Four-Year Averages for Profitability after Tax and Value Added, 1991-1994, and Multiple Rankings for 15 German Machine Tool Firms	176
Table 5.5:	Multiple Rankings According to Profitability, Z Values, and Hexagon Criterion for a Sample of German Machine Tool Firms over the Period 1991-1994	178
Table 5.6:	Technical Efficiency for 15 German Machine Tool Firms: Averages over the Period 1986-1994	180
Table 5.7:	Cost Leadership and Product Group Specialization Strategies in the German Machine Tool Industry, 1991 to 1994 (criterion: return on capital after tax in percent)	183
Table A.1:	Orders, Production, Exports, Imports, and Consumption of the West German Machine Tool Industry since 1954 (current prices)	190
Table A.2:	User Industries of Machine Tools for Metal Working in Germany, 1995	192
Table A.3:	Comparison of Real Output (in Units) of Six-Digit Commodity Groups of Machine Tools in West Germany: Average Annual Growth Rate from 1960 to 1989	193
Table A.4:	The Rothenberger Family – Participations in the Machine Tool Industry, 1991 (according to the Holding Companies Pittler Maschinenfabrik AG and Autania AG)	195
Table A.5:	Events in the Development of NC Machine Tools in the United States of America, Europe/West Germany, and Japan	197
Table A.6:	Imports in West Germany for Machine Tools by Countries, 1952-1990 (absolute values and change in percent)	204
Table A.7:	Price Competitiveness of West German Versus Japanese Mechanical Engineering Products (MEP) in Terms of the Real Exchange Rate	205
Table A.8:	Return on Total Capital after Tax (ROC) and Z Values	206
Table A.9:	Return on Total Capital after Tax (ROC, percent)	208
Table A.10:	Return on Equity Capital after Tax (ROE, percent)	209
Table A.11:	Ratio of Shareholder Equity (percent)	210
Table A.12:	Return on Sales after Tax (ROS, percent)	211
Table A.13:	Value Added per Employee (in thousand DM)	212
Table A.14:	NC Machine Tool Imports of West Germany by Machine Tool Type: Average Annual Growth Rates of Units and Unit Value from 1985 to 1990	213