Organisational adaptation processes to external complexity

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Abstract

Purpose – Based on a conceptual framework of the linkages between strategic manufacturing goals and complexity, the purpose of this paper is to investigate adaptation processes in manufacturing firms to increasing external complexity.

Design/methodology/approach – Hypotheses are tested with statistical analyses (group comparisons and structural equation models) that are conducted with data from the third round of the International Manufacturing Strategy Survey.

Findings – The study shows that manufacturing firms face different degrees of complexity. Firms in a more complex environment tend to possess a more complex internal structure, as indicated by process configuration, than firms in a less complex environment. Also depending on the degree of complexity, different processes of adaptation to increases in external complexity are initiated by organisations.

Research limitations/implications – Research studies taking into account the dynamics of adaptation processes would be helpful in order to draw further conclusions, for instance, based on longitudinal analyses or simulation studies.

Practical implications – Depending on the level of complexity a firm has been confronted with in the past, different adaptation processes to further growing complexity can be initiated. Firms in high complexity environments have to re-configure their strategic goals; firms in low complexity environments have to build-up internal complexity to cope with demands from the outside.

Originality/value – The paper distinguishes between adaptation processes in low and high complexity environments and provides explanations for the differences.

Keywords Strategic manufacturing, Manufacturing industries, Complexity theory

Paper type Research paper

In many publications about management, one can find a prominent common theme explaining why management has become extremely difficult nowadays. The common theme is "complexity" that is supposed to have increased dramatically over the last years. While many popular publications claim to support management in their struggle with complexity, there exists a variety of assumptions about what are the causes for an increased complexity: globalisation, increased intra-industry competition, substitution between industries, an abundance of data about almost everything, demands for transparency from capital markets, changed expectations of employees, customers, and other stakeholders, etc. These factors, the basic argument goes, increase the complexity with which management is confronted. Consequentially, this apparently ever increasing complexity urges organisations to respond with internal changes in order to maintain their position in the market place and ensure survival in competition.

The notion of complexity in business administration is an ill-defined concept and deviates, for instance, from definitions in complexity science (Lissak, 1999). Nevertheless, findings from the psychological and the economic literature (Dörner, 1996; Rabin, 1998) nurture the assumption that complexity increases the problems of

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making effective decisions and of designing sound policies. In particular, this is true in operations and production management with its highly interwoven arrangement of people, information, machines and material. This paper tries to shed some light on the effects of complexity on manufacturing firms. The study is conducted with the help of empirical analyses. Particularly, we examine how external drivers of complexity influence the internal structure of manufacturing firms and their setting of strategic goals in the manufacturing function.

The paper starts by discussing a conceptual framework of complexity with regard to manufacturing firms. In the course of presenting our conceptual ideas about complexity, we review the relevant literature from production and operations management as well as from strategic management. The second section contains a description of the methodology and the database used, which is drawn from the International Manufacturing Strategy Survey (IMSS-3). In addition, differences between firms competing in a high and in a low complexity environment are analysed. The third section presents statistical analysis on the relationship between external complexity, internal structure and strategic manufacturing goals. The fourth section investigates the practical implications of the findings for management. An outlook on further research closes the paper.

A conceptual framework of adaptation processes to external complexity in manufacturing firms

Definitions of complexity can be derived from business administration literature (Stacey *et al.*, 2000) but also from other fields of science, like philosophy (Mainzer, 1997), mathematics (Mandelbrot, 1977), information science (Sivadasan *et al.*, 2002; Chaitin, 1974), cybernetics (Ashby, 1956), and biology (Ricard, 1999; Holland, 1992). Interdisciplinary work, for instance, of the Santa Fe Institute, is described in Waldrop (1992) or Coveney and Highfield (1995). Following a system theoretic approach (but without delving too deeply into its historical and philosophical roots), we abstractly understand complexity as consisting of detail complexity and dynamic complexity (Senge, 1990; Sterman, 2000). Detail complexity can further be divided into three sub-components: number of elements in a system, number of connections between elements, and types of functional relations between elements (Milling, 2002). The dynamic component of complexity used in this study is composed of the variability of a system's behaviour over time and the variability of a system's structure (assuming that a system can stay the same when its structure changes as long as its underlying goal set is not substantially modified).

We assume complexity to be objective, i.e. in principle it exists and can be measured without reference to subjective perception and cognition. This feature distinguishes complexity from the complicatedness of a situation that depends on characteristics of the human agents involved, like knowledge, experience or intelligence. However, for the following reasons, this distinction is largely only a theoretical one:

- When we measure complexity in the social sciences, we frequently rely on data coming from subjective sources.
- Human beings and their characteristics usually play a major role in organisations; thus, a complexity score depends on subjective factors.

- The system's border, i.e. the variables that are considered relevant and which are included in consideration of complexity, has to be determined by humans and is thus necessarily subjective.

In a similar vein, for instance, Ward *et al.* (1998) reported in an operations management study that seemingly objective measures may not produce data that is more objective than data obtained by measures which are based on – naturally subjective – perceptions and estimations. From a more general, strategic planning point of view, Mintzberg (1994) discusses biases and deviations from objectivity that occur in apparently hard, quantitative data.

The kind of complexity, which is addressed in business administration, can be found outside and inside organisations; we thus speak of external and internal complexity. We assume that there exists a bi-directional influence between the two: external drivers of complexity force the organisation to internally build-up complexity to cope with demands from the outside (Bourgeois and Astley, 1979), in order to comply to Ashby's (1956) well-known law of requisite variety which claims that only variety can absorb variety. Besides this obvious relationship, the other direction of influence is important as well. How organisations are structured, what level of complexity they possess also shapes their environment and its complexity (Milling, 1991; Child, 1972). Thus, although to a certain degree organisations are able to select the environment they want to "live" in depending on its complexity, they will also try to shape the complexity of the environment according to their needs. This process resembles Hayes and Wheelwright's (1984) fourth stage in the development of manufacturing's strategic role: by being externally supportive, manufacturing shapes business strategy and, thus, the competitive environment of the firm.

The amount of complexity absorbed by the company – and, hence, the exact borderline between internal and external complexity – is a matter of management decision (Moldoveanu and Bauer, 2004). A key issue in this respect is the degree of vertical integration of a company. Firms that have outsourced many of their fabrication tasks and concentrate themselves on assembly of components are likely to experience a lower level of internal complexity than a firm that manufactures the same goods with internally fabricated parts, etc. Of course, there are limits to vertical integration. Besides the well-known argument about keeping core competences to stay competitive (Prahalad and Hamel, 1990), it is also a matter of identification of any given system because it has to differentiate itself from the complexity of its environment. If not, the organisation will lose its autonomy and vanish in the larger system of its environment (Gomez, 1993). Our concept of the linkages between internal and external complexity is shown in Figure 1.

If the degree of external complexity increases, an organisation can follow different ways of adaptation. In general, the process of adaptation can be split up into three different routes:

(1) *Adapting explicitly.* When detecting an external increase of complexity, the internal guiding principles (the strategic goal pattern) are adjusted to move the system towards a desired state.

(2) *Adapting implicitly.* In the case of increasing external complexity some built-in flexibility of the system reacts autonomously relieving the management function since explicit guidance is not required.

(3) A mixture of implicit and explicit adaptation has to be utilised if some built-in flexibility exists and spontaneously creates adaptive processes but does not lead to a complete absorption of the increase in complexity. In such cases, management has to set new goals to drive the organisation beyond previously defined barriers, for example, to introduce a completely new line of products distinct from the previous range of products.

For the task of a more detailed analysis, both external and internal complexity can be split up into more concrete complexity determinants. For example, we have detailed internal complexity into complexity related to process configuration. On the external side, we distinguish between complexity of products and complexity of customers (for a similar approach but different starting-point, see Kotha and Orne, 1989). Of course, the nature and variety of products is also a matter of internal complexity because it is a management decision, for instance, what range of products is manufactured. However, these internal complexity aspects of products are only indirectly incorporated into the model presented here. Aspects of product complexity that are addressed in the following analysis are derived from market requirements. Thus, they are external to the organisation. Nevertheless, the product range as well as the speed at which new products have to be introduced to the market affects the organisation. After such requirements have been established in the marketplace, by either customer needs or by competitors, they influence internal aspects of manufacturing firms such as process configuration and improvement goals (Hayes and Wheelwright, 1979).

Of course, also other complexity determinants than the ones discussed so far are likely to exist, for instance, inbound/outbound logistics and supply chain issues affecting external complexity (Choi and Hong, 2002) as well as technology and organisational structure influencing internal complexity.

The variables that determine the level of complexity a company faces or builds up internally differ along several aspects. A brief overview of possible variables within the different areas is given in Table I.

The main drivers within the realm of external complexity can be found in a company's customer base and the products demanded by the market place (Berry *et al.*, 1995). The internal complexity of a manufacturing system depends largely on the number and heterogeneity of tasks, processes performed and goods produced within the system (Guimaraes *et al.*, 1999). The basic idea behind our hypotheses is that firms have to react to external complexity with internal means (which is in line with the "law of requisite variety" as stated by Ashby, 1958). At this point of the investigation we do

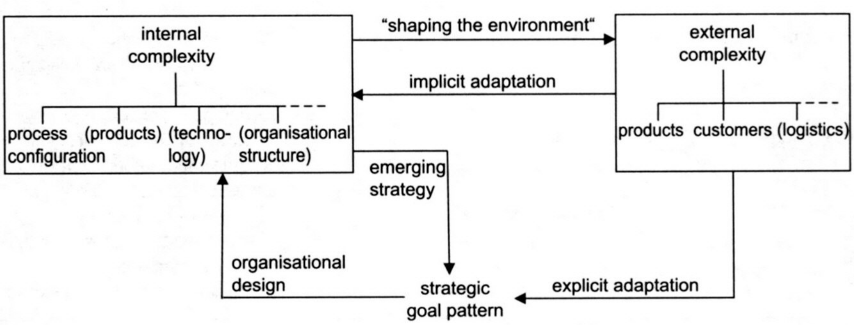


Figure 1. A conceptual framework of complexity in and around manufacturing firms

not distinguish whether this adaptation process was an implicit or an explicit one (compare Figure 1). We just state that high complexity in the environment necessitates a more complex internal system. Thus, our first research hypothesis is:

H1. Plants in a high complexity environment have an on average higher internal complexity than firms in a low complexity environment have.

The fabric of strategic goals or "strategic goal pattern" (sometimes also called "strategic configuration"; Cagliano *et al.*, 2003) can also be considered to possess a certain complexity (Hasenpusch and Grübner, 2002). The set of strategic goals plays the role of a "middle man" between external and internal complexity. It distinguishes explicit adaptation to external complexity from implicit adaptation. In the case of explicit adaptation, the internal structure of an organisation is changed consciously by the management in order to fulfil requirements from the outside and stay competitive. Higher variety in customer base and product range is likely to force companies to strengthen their efforts to meet those requirements. The assumption is that a manufacturing system adapts, when organisational capabilities have to be developed and enhanced by stating clear directions (Ramdas, 2003). Thus, the second hypothesis is stated as follows:

H2. Plants in a high complexity environment intensify their average efforts to improve on the three examined strategic goal dimensions (a) "cost", (b) "quality" and (c) "flexibility" on a higher degree than plants in the low complexity environment do.

By way of formulating strategic improvement goals, the organisation is designed to respond adequately to demands from the environment, thus affecting internal complexity (Beinhocker, 1999). However, the actual structure of and processes and decisions within an organisation (and their complexity) have an influence on the strategic goal pattern, too. This bi-directional relationship represents the phenomenon that Mintzberg and Waters (1985) term "emergent strategy", which means that strategic patterns do not necessarily have to be formulated by a company's management but that strategies emerge from the decisions and the resulting behaviour of members and parts of the organisation.

Similarly, not every adaptation to external complexity is conscious, deliberate or driven by strategic intent. Some changes within the organisation take place without ever being formalised and articulated in the form of strategic goal patterns: because of

Internal complexity	Process configuration	Number of process types Concentration of process types Process layout Order penetration point
External complexity	Products	Breadth of product programme Requirements/specifications Length of product life cycle
	Customers	Number of customers Heterogeneity of customer base JIT requirements Bargaining power of customers

Table I.
Determinants and exemplary factors of internal and external complexity

external complexity, internal structures and processes are adjusted without putting these changes in the context of an explicit strategy. In other words, this means, "action can occur without commitment to act" (Langley *et al.*, 1995). In these cases, the management of a manufacturing company reacts without explicating an overall goal pattern; rather decision-making is guided by what the responsible managers deem to be of benefit for the company. This flexible element in creating emergent strategy is not something that can or should be avoided since it is impossible for senior management to create a manufacturing strategy that covers all possible, but unknown incidences and gives detailed guidance on how to react in these situations (Barnes, 2002).

On a general level, we derive three propositions from our conceptual framework: first, although we assume all relations to exist for any organisation, the strength of the linkages might depend on the level of external complexity a firm faces. Thus, external complexity might be the responsible trigger for developing complexity within organisations; based on its degree, different strategies for adapting to external complexity might prevail (e.g. implicit adaptation or explicit adaptation or a mixture of both). This proposition is the focus of this paper. Second, by the bi-directional linkages inherent in the model we allow organisations to learn. For instance, internal complexity resulting from organisational design influences strategic goal setting by way of emergent strategies. If internal structure and environmental requirements do not fit, adaptive and corrective action can be undertaken. This process can be described as a learning mechanism (Argyris and Schön, 1978, 1996; Mohanty and Deshmukh, 1999). Third, all linkages in the conceptual model are not instantaneous, i.e. more or less strong delays exist until causes lead to an effect. However, delay time of the linkages is different. For instance, while the formulation of new manufacturing goals can happen quite fast once a change in external complexity is detected, organisational design processes take usually a rather long time to realise.

In summary, the conceptual framework shown in Figure 1 adapts and re-interprets the crucial debate about the relation between internal and external influences on firms' success in the context of complexity. It does this in picking up some of the important issues of this debate:

- It combines elements from a market-based (Porter, 1980; Bourgeois and Astley, 1979) as well as from a resource-based view (Wernerfelt, 1984; Penrose, 1959) of strategy, without ignoring one perspective.
- It argues for a "fit" (or at least a balancing process) between internal possibilities and external requirements, in line with an elementary insight from strategic management (Christensen *et al.*, 1982; Selznick, 1957) and cybernetics (Ashby, 1958).
- It describes that organisations try to establish this fit by deliberately crafting policies (Ansoff, 1965) but that they also react in a more unstructured or even unconscious way (Quinn, 1980), resulting in emergent phenomena (e.g. strategies and processes; see Mintzberg, 1978).
- It is based on a feedback oriented view of the structure-agency debate (Ritzer, 1996), i.e. the idea that a system's/environment's structure determines agents'/organisations' behaviour and in parallel agents/organisations are the "designers" of the system/environment in which they exist (Lane, 2002).

In the following sections, we concentrate on empirically testing the relationships of the conceptual framework and on the question, which kind of adaptation prevails in high or in low complexity environments? Before proceeding with this task, we want to give some information about the context of this paper. Based on the notion of manufacturing organisations as dynamic open systems in changing environments (Lievegoed, 1991), the main assumption of our research is that manufacturing firms can be divided into distinct groups following (consciously or unconsciously) different patterns of dealing with and shaping complexity. Thus, we assume that firms cluster together into groups, each possessing a specific type of complexity. In line with the idea of strategic configurations (Ward *et al.*, 1996; Miller and Mintzberg, 1983), configurations of complexity could be derived from this clustering. These configurations of complexity can be understood as archetypal patterns of complexity factors. Following this argumentation, we hypothesise that only a limited number of such complexity configurations exist. On a principal level, this could imply that complexity configurations are essential classification criteria of manufacturing systems (McCarthy, 1995).

Empirically testing model components

Sample description and analysis methods applied

The conceptual framework of complexity presented here is partially tested against a sample of manufacturing plants. This paper aims to deepen the understanding of how environmental complexity can be determined in an empirical study. Building on this, another objective of this paper is to explore how external complexity affects the internal complexity of manufacturing plants and the set of strategic goals pursued within the manufacturing function, i.e. the configuration of manufacturing strategy. We assume that – depending on the level of external complexity a plant faces – firms differ in their adaptation strategies to complexity. With these research objectives, our paper is embedded in the context of other studies that investigate a kind of "fit between the production core and the organisational environment" (St John *et al.*, 2001, and the literature quoted there).

In contrast to many other papers on complexity and manufacturing (Deshmukh *et al.*, 1998; Frizelle and Woodcock, 1995; Bowman, 1994), the approach described here is not based on a purely functional perspective of production, like order processing with a given sequence of machines and a given number of products. Our approach tries to consider all actually occurring and strategically relevant factors, no matter whether they are "hard" (and easy to quantify) or "soft" (and only a product of subjective judgement). The advantage of this perspective lies in its comprehensiveness and its emphasis on effectiveness ("doing the right things") rather than efficiency ("doing things right"). The main disadvantage is that it misses the mathematical elegance of more operational research type of complexity studies in manufacturing, instead being argumentative and discursive.

Along with calculating descriptive statistics of the sample in question, the empirical analysis includes several methods such as confirmatory factor analysis, reliability analysis and two different path analytic models. Path analytic models provide insights into the causal relationships among different factors, for example, external and internal complexity and manufacturing goals. This method decomposes the empirical co-variances among the measured items and estimates path coefficients that are equivalent to standardised regression coefficients in a standard regression model. This approach has a benefit since it can simultaneously estimate the relationships between factors in a single model and it is capable of computing looped relations between different factors.

To investigate this matter we follow a two-step approach of empirical analysis. After determining statistical factors to be used in the investigation, in the first, confirmatory step we examine whether firms within a high complexity environment also possess a higher internal complexity than firms within a low complexity environment. In the second step, we explore the adaptation strategies of plants within high complexity against firms within low complexity.

The IMSS-3, a questionnaire-based empirical study, provides the data for this analysis. We draw from the third iteration of this study finalised in 2002. The size of the sample is 558 manufacturing plants residing in 14 countries in Europe, South America and the Asian Pacific area. Two different kinds of items are used from this questionnaire: forced choice items and Likert scales. To ensure inter-item comparability all items used in this study have been standardised before analysis.

The plants that participated belong to industries with ISIC codes 381-385, i.e. manufacturing of metal products, machinery, electrical devices, transportation equipment and measuring and controlling equipment. For all plants, only the Director of Production or Operations was asked to fill out the questionnaire. The data collection followed the general recommendation to ask the most knowledgeable person within the company (Venkatraman and Grant, 1986). Since the questionnaire covers many domains of the participating plants, the only person that appears to be competent enough to answer the questionnaire is the Director of Production.

The occurrence of a key informant bias cannot be excluded in principle (Venkatraman and Grant, 1986). Nevertheless, we assume that key informant bias can be neglected in the context of this study. We arrived at this assumption because we do not include perceptual performance data in our analyses, in which case key informant bias is particularly a problem. Anchoring, i.e. the tendency of respondents to rate items systematically low or high, is a typical issue of Likert scales and is therefore possible to occur also in the IMSS sample. However, we did not find any evidence that anchoring had a significant effect on our analysis. To enhance inter-company comparability, all small plants are excluded from further analysis. Ninety-three plants that reported less than 100 employees were discarded, leaving an overall sample of 465 plants to be included in this study.

Drivers of external complexity

Before starting the actual statistical analysis, we construct scales of external complexity using confirmatory factor analysis. The objective of this approach is to determine if the hypothetical constructs like customer complexity, product complexity and product dynamism exist and if they can be derived from the items used in the questionnaire.

Following the theoretical considerations, complexity is measured as a two dimensional phenomenon: detail complexity and dynamic complexity. The complexity demanded by a company's environment is largely determined by the customers and their articulated needs and requirements. These determine the variety of products and services a company is required to offer in the marketplace. The more market segments a company is competing in, the more pressure is on the company to expand its product range (Berry *et al.*, 1995). By an increasing product complexity, i.e. rapidly introducing new products and/or providing a broad range of products, the efficiency of the manufacturing system can be negatively affected and it has to be considered whether the variety that is provided by the system will be appreciated by the market in the form of higher prices (MacDuffie *et al.*, 1996). Serving a broad range of products requires a company to make decisions on different, interwoven levels and over a long time horizon. The effectiveness of product variety decisions may suffer because of historical boundaries created by decisions made in the past and *ad hoc* criteria that arise during the interaction between business partners (Ramdas, 2003). By increasing the range of manufactured products or by increasing the number of variants of a given product, an effect can be observed that occurs besides the technological challenge to produce all different products in one manufacturing system: the number of units per variant will drop over the overall product lifetime. This leads to the problem that the revenue created for each variant is lessened and the base among which the research and development costs and set-up costs can be distributed is smaller as well (MacDuffie *et al.*, 1996).

The pressure of expanding and changing a company's product range may also result from innovative product markets with short product life cycles forcing a company to rapidly and steadily develop and introduce new products to the market (Thun *et al.*, 2000). These two aspects: customers and products are further used to assess the extent of detail complexity a company is confronted with. The dynamic dimension of complexity is being measured by the tendency to change the product offerings. Within the time horizon covered by the analyses, this dimension is much more subject to changes than others are. The changes of, for instance, customer base, structure and market segment are therefore not included in the analysis. In addition, we do not include complexity stemming from suppliers as indicated by the logistics factor in the conceptual model because data in the IMSS sample does not show statistically significant evidence that this factor differs among the companies that participated in this questionnaire.

Several items from IMSS-3 were used to construct statistical factors with regard to the three different drivers of external complexity. To quantify customer complexity a measure is computed using question A5 from the questionnaire. In this question, the plant managers are asked to state the distribution of annual sales among different customer segments, i.e. component manufacturers, product assemblers, distributors and end-users. From this question, two different aspects of complexity can be derived. At first, the span of customer segments served is considered. Each of the customer groups requires to some extent different ways and processes of marketing, sales and logistical distribution. In some industries, even a different product design is required. The more segments that are served by a company the more complexity is being required from the market. The number of different customer segments that can be served ranges from one to four.

Another facet of complexity is related to the degree of concentration or focus on certain customer segments. If a company serves two different customer segments, the amount of business done within each segment plays an important role in defining the degree of complexity. If, for example, a company does 99 per cent of its sales within one segment and only 1 per cent of product sales within a different customer segment, the company will most likely install special processes to conduct business with the first customer segment. In contrast to this, the small amount of business conducted with the second customer segment will not be processed by specially designed and implemented processes. Hence, the complexity is considered lower for companies with a higher degree of concentration (Hill and Duke-Woolley, 1983). The degree of concentration can vary from 100, i.e. all sales are done in only one customer segment, to 0 in the case of equally distributed sales in all four segments (Ettlie and Penner-Hahn, 1994).

The items are tested on their general capability to be represented by a single factor. Cronbach's α is therefore used to assess construct reliability (Nunnally, 1978). Since the scales constructed for this study are newly developed, they are required to reach 0.60 as the measurement error (Sakakibara *et al.*, 1997). The results depicted in Table II show that the factors customer complexity and product dynamism fulfil this standard; product complexity comes very close to that limit. We accept all three factors based on the small number of items from which they are constructed, which could be shown to be a major cause of the relatively small values of Cronbach's α[1].

The results of the factor analysis (Table II) support the idea that different items – subject to empirical measurement – can be traced back to an underlying variable of external complexity. The different factor solutions satisfy commonly accepted reliability criteria for the overall model acceptance as well as for the sub-model components.

To gain more insights into how complexity relates to internal settings it is necessary to distinguish different profiles of complexity requirements demanded by the environment. Factor values are calculated from the results of the factor analysis above. In order to apply a single value to measure the overall complexity a plant is confronted with, the three factor values are summed up for each plant in the sample. It has to be considered that by an additive connection of the three complexity factors an arbitrary relationship between those factors is implicitly assumed. Since there does not exist a reference to any better way of building up a single scale from these factors, the

Complexity factor	Item (Item number from IMSS-3 questionnaire)	Cronbach's α	Factor loading
Customer complexity	Number of different customer segments (A5)	0.66	0.79
	Degree of concentration on customer groups (A5)[a]		1.00
	Customer focus (A72)		0.22
Product complexity	Product design and quality (A62a)	0.59	0.34
	After-sales-service and technical support (A66a)		0.28
	Wider product range (A67a)		0.53
	New product frequency (A68a)		0.76
Product dynamism	Changes in product design and quality (A62b)	0.60	0.44
	Changes in after-sales-service and technical support (A66b)		0.30
	Changes in product range (A67b)		0.59
	Changes in new product frequency (A68b)		0.77

Notes: All model parameters are significant with an error probability of $p < 0.05$; goodness-of-fit indices: GFI=0.95; AGFI=0.93, REMSEA=0.089; [a]construction of concentration measure explained in the text

Table II. Factors of external complexity (original questionnaire items in the Appendix) proposed way is comprehensible and free of any questionable weights applied to each factor. To ensure that the factor values are comparable with their underlying scales, all values were normalised on the interval (0; 1) and summed up to the overall complexity scale with the interval (0; 3). The summed factor values show that the amount of complexity differs considerably across the sample. Not all plants operate in an environment of the same complexity. Some companies are facing very complex market requirements while others are operating in relatively simple and stable market conditions. Therefore, the total sample was divided into two groups according to the total value of factors depicted in Table II.

With the help of the overall complexity value, the sample was separated into plants facing a relatively high degree of external complexity and plants facing a relatively low degree of external complexity. On the overall interval, the line of separation was drawn in the middle (1.5) of the interval plus/minus an additional 0.10 step to enhance the strength of separation that left the hard to distinguish middle valued plants aside. Setting the line of separation this way, leads to bigger between-groups differences. Naturally, sensitivity analysis shows an average complexity value increase/decrease in each of the remaining groups when the 0.10 step is changed. For example, the between-groups difference is worsened by 10-19 per cent depending on which factor is being considered when the separation line is set precisely to 1.5, i.e. no companies "in the middle" are left out. This means that differences in external complexity would be blurred in this case. In contrast, a further increase of the step slowly produces higher differences between groups. However, a substantially greater between-groups difference can only be achieved at the cost of small group sizes.

After exclusion of missing values, only 357 plants could be used for this analysis. The following groups of plants resulted:

- a high complexity group consisting of plants affected by a relatively high degree of external complexity ($n = 136$); and
- a low complexity group consisting of plants having to deal with only moderate external complexity ($n = 175$).

As has been discussed above, in order to avoid classification difficulties, all plants lying at or close to the separation line were omitted from further analyses ($n = 46$). In the rest of this paper, we compare plants in the high complexity group with plants in the low complexity group.

Assessing internal complexity and manufacturing improvement goals

The assessment of a plant's internal complexity is based on a plant's process configuration within manufacturing. The main objective during construction of this factor can be found in the argument that the amount of different tasks that have to be performed in a manufacturing system are responsible for its complexity (Guimaraes *et al.*, 1999). The implementation of a manufacturing system capable of providing large amounts of product variety results in more complex internal structures whereas variety creation and variety implementation creates additional costs within the system (Ramdas, 2003).

To capture this information, the heterogeneity of the process landscape within the manufacturing system is being addressed by the number of different process layouts and the degree of concentration on specific process layouts (i.e. job shop, line or cellular production). The heterogeneity of products being manufactured by an organisation is represented by the number of different lot sizes employed in manufacturing and by the concentration on certain lot sizes. However, the number of different lot sizes did not load in a statistically significant way on the process configuration factor. Another factor that is capable of raising process complexity is assumed to be the depth of the order penetration point. Again, analysis showed that the influence of this item was not statistically significant for the overall sample. The variables of which process configuration consists are depicted in Table III together with factor loadings. Information about organisational structure and technology, the two other factors of internal complexity according to our conceptual model, could not be derived in consistent and comprehensive form from IMSS data. Thus, in the rest of this paper, process configuration is assumed a proxy of internal complexity in general.

Regarding the construction of concentration measures for the degree of process focus and concentration on lot sizes, the same method of computation is used as in the case of concentration on customer groups in Table II. If a plant does not focus on one process type (line production, job shop layout or cellular design) and on one lot size (mass production, small batches or one-of-a-kind production), its process configuration is presumably more complex than when concentrating on only one specific way of manufacturing. This heterogeneity of the manufacturing system design leads to an increasing number of processes and tasks that have to be performed simultaneously, binding scarce resources and creating conflicting relationships within the plant.

The statistical analysis distinguishes between three different manufacturing strategy dimensions that firms want to achieve in the future: cost, quality and flexibility. The fourth strategic factor from Skinner's (1969) original set of priorities, dependability/delivery, is not examined separately in this study. Rather it is subsumed under the quality heading. There are two reasons for this:

(1) Conceptually, dependable deliveries – with some justification – can be interpreted as a sign of quality. Thus, rather than distinguishing between the two, quality and delivery are seen as the basis for the more distinct priorities cost and flexibility, following Ferdows and De Meyer's (1990) notion of a "sand cone model" of strategic capabilities. In our understanding, quality and delivery act more as "qualifiers" in Hill's (1993) terminology and are therefore subsumed into one category (an assumption which is supported by the following statistical analyses).

Complexity factor	Item (Item number from IMSS-3 questionnaire)	Cronbach's α	Factor loading
Process configuration	Number of different process layouts (PT2)	0.72	0.78
	Degree of concentration on specific process layouts (PT2)[a]		1.00
	Number of different lot sizes (PT3)		ns
	Degree of concentration on lot size (PT3)[a]		0.29
	Depth of order penetration point (PC4)		ns

Notes: All model parameters are significant with an error probability of $p < 0.05$; goodness-of-fit indices: GFI=1.00; AGFI=0.99, REMSEA=0.033; [a]construction of concentration measure explained in the text

Table III. Factors of internal complexity (original questionnaire items in the Appendix)

(2) Empirically, a strong correlation between items of the two constructs was found so that a separate examination was not expected to yield substantial results[2].

A confirmatory factor analysis approach is chosen to extract the three strategic dimensions out of ten items covering different goals that are pursued in the plants of the IMSS study. The results of the factor model satisfied all common criteria. They are highly significant and depicted in Table IV.

Empirical analysis of adaptation processes to external complexity

Differences between high and low complexity groups

In the first step of the statistical analysis, we test whether the high complexity group differs from the low complexity group concerning process configuration. We test this hypothesis (*H1*) with *T*-tests comparing the two different groups (for a summary of results see Table V). The average value for process configuration differs between both groups. The group operating in a high complex environment shows an average value for process configuration of 0.27 while the low complexity group accounts for an average value for process configuration of −0.11 on a standardised scale. Although the difference can be considered as being rather small, it is nevertheless statistically significant. Hence, *H1* can be accepted. A reason for the small difference could be the fact that during the separation of the two groups only a small part with a medium complex environment was omitted from the sample. Hence, the amount of divergence between both groups might not be strong enough to lead to more robust differences between the

Strategic goal	Item (Item number from IMSS-3 questionnaire)	Cronbach's α	Factor loading
Cost	Enhancing labour productivity (C113)	0.64	0.60
	Enhancing turnover rate of material in stock (C114)		0.60
	Improvement of capacity utilisation (C115)		0.68
Quality	Improvement of manufacturing conformance (C11)	0.66	0.63
	Improvement of product quality and reliability (C12)		0.60
	Increasing delivery reliability (C19)		0.49
Flexibility	Increasing product customisation ability (C13)	0.68	0.50
	Improvement of volume flexibility (C14)		0.70
	Enhancing product mix flexibility (C15)		0.69
	Reducing time to introduce new products (C16)		0.50

Notes: All model parameters are significant with an error probability of $p < 0.05$; goodness-of-fit indices: GFI=0.98; AGFI=0.96, REMSEA=0.074

Table IV.
Strategic dimensions – statistical factors (original questionnaire items in the Appendix)

Hypothesis	*T*-value	Degrees of freedom	Significance level $p <$	Average high complexity group	Average low complexity group
H1	3.380	303	0.01	0.27	−0.11
H2a	2.511	293	0.01	0.18	−0.11
H2b	1.906	293	0.05	0.13	−0.09
H2c	4.447	293	0.01	0.29	−0.23

Table V.
Summary of *T*-test results

two groups. However, methodological requirements regarding the number of cases demanded for further analysis restricted the number of cases that could be omitted from the sample.

The next step of the analysis tests the aspect that the set of manufacturing goals pursued within a plant depends upon the level of external complexity a plant is confronted with. The results of the *T*-test conducted to test *H2* show that in the high complexity group all manufacturing improvement goals are rated on a higher level. The highest differences can be found in the set of flexibility goals. The high complexity group rates their importance at 0.29 compared to the low complexity group rating at -0.23 with an error probability less than 0.01. Rated on the same significance level is the aim to improve on cost performance with an average of 0.18 for the high complexity group and -0.11 in the low complexity group. Fewer differences can be found with respect to the set of quality goals where the high complexity group rates its importance at 0.13 compared to -0.09 with an error probability less than 0.05. Thus *H2* can be accepted for all three strategic dimensions. The finding that quality is only weakly different between the groups can be an indication that the competence of a plant to produce quality is being perceived as a qualifier in the market (Hill, 1993). Thus, quality might be required in both situations, no matter what level of complexity is being projected from the market.

The level of vertical integration might be confounded to these results because one can assume an influence on the degree of internal complexity of a firm, expecting that the degree of complexity is positively correlated with the number of different operational tasks that have to be performed (represented by the degree of vertical integration). Thus, for controlling purposes, we tested the relationship between the level of vertical integration (item number PT1 from IMSS-3 questionnaire) and process configuration. While the two variables correlate significantly for the total sample of companies (0.312, $p < 0.000$), no statistical differences between the high and the low external complexity group concerning vertical integration can be reported. We interpret these results in the following way: although management's decisions about vertical integration influence the process configuration (and, thus, the internal complexity) that a firm possesses, these decisions do not seem to be consistently related to a firm's adaptation process to external complexity.

As a preliminary result of this study it can be stated that the level of external complexity goes along with different configurations within the plants examined. The acceptance of *H1* and *H2* leads to the conclusion that both the actual structure of manufacturing processes as well as the definition of manufacturing improvement goals – the content of manufacturing strategy – are subject to external complexity influence. However, the strength and direction of influence within the two groups and possible differences between both groups are still unknown. The analysis presented in the next section aims to give some answers to that question.

Structural equation models of adaptation processes

In the second step of the statistical investigation, we concentrate on different adaptation strategies within high and low complexity environments. With the help of structural equation models, the dependencies between external complexity, internal complexity and strategic goal pattern are investigated separately for the two groups. The approach chosen for this study is utilizing the structural equation model in an exploratory manner. A stepwise modification procedure is used to extract a structural model from the empirical data that provides sufficient goodness (Jöreskog, 1977).

The three main aspects of the analysis presented here are external complexity, process configuration and the goals pursued within the manufacturing system. With regard to Figure 1 several ways exist to adapt to external complexity. A system can adapt implicitly by autonomous changes of the system as a response to external complexity. Another way of reacting to external complexity can be assumed in a more explicit form by changing the goal pattern in order to adjust the system's capabilities and structure in the future. The third way of reaction can be found in an emergence of goals from within the system. All three possible ways of adaptation will be examined in the following, considering different patterns of adaptation depending on the degree of complexity. Figure 2 shows the overall model tested here. This figure is different from the overall conceptual model (Figure 1); it represents a part of the overall model and concentrates on the relationships that are tested within the empirical study. Furthermore, the theoretical constructs are detailed to show how constructs can be operationalised.

Path analytic models are used to examine these relationships. All complexity areas are represented by the factors that have been explained in the previous section. Before presenting the results of this study, it has to be stated that only little empirical evidence can be found in the literature to guide the set up of model specifications with regard to the setting presented here. Hence, the nature of this study is considered exploratory.

To capture different adaptation patterns with regard to the degree of external complexity the complete model is tested against the data of the high complexity group; then, the same model is tested against the low complexity group. The model tested for the two sub samples consisted of all possible relationships, i.e. linkages were hypothesised between the three components of external complexity and the three components of the strategic goal pattern (resulting in nine linkages for explicit adaptation) as well as from the three components of external complexity to process configuration (which makes three linkages for implicit adaptation). Furthermore, three linkages were assumed from process configuration to the three components of the strategic goal pattern (for emerging strategy). However, only a selection of these relationships proved to be statistically significant. Thus, we used the method of

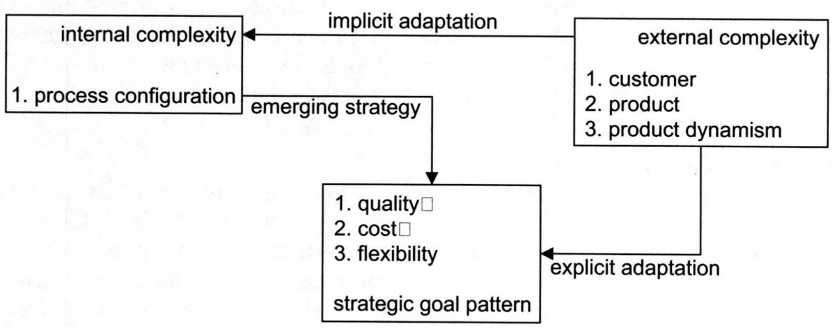


Figure 2.
Adaptation mechanisms to external complexity tested in this study

stepwise elimination of linkages using modification indices to derive a statistically satisfactory structural equation model with only significant links between variables (Jöreskog and Sörebom, 1982). In the following presentation, we concentrate on the relationships that constitute the best statistical fit to the empirical data.

The first model is run with the high complexity group. After exclusion of all missing value cases, an overall of 107 plants are examined in this model. These plants are operating in highly complex environments and therefore have already developed a highly complex internal system structure that can perform a broad range of manufacturing tasks. Around 35 per cent of their processes are organised by highly flexible cellular design. It can be assumed that these plants are aware of the large variety they have to cover as well as the capabilities their system provides to deal with highly diverse market demands. Therefore, these plants rely on their actual resources with only little need to develop additional capabilities in the future. This assumption is supported by the fact that the plants in the high complexity environment state that their manufacturing strategy is on average more resource driven than market driven. This group is therefore expected to have a strong relationship between its process configuration and its goal pattern. The adaptation to complexity within the system is of a kind that leads to the formation of a resource orientated manufacturing strategy. Along with this goes the argument that there will only be relatively weak forms of implicit or explicit adaptation since internal capabilities already provide sufficient support for even higher levels of complexity.

The results of the complete path analytic model support these assumptions; they are shown in Figure 3. The strength of relationships has to be read as follows: a positive sign indicates that the depending variable increases as the independent variable increases and vice versa for negative sign. From Figure 3 it can be concluded that in a highly complex environment a further increase in complexity does not affect the

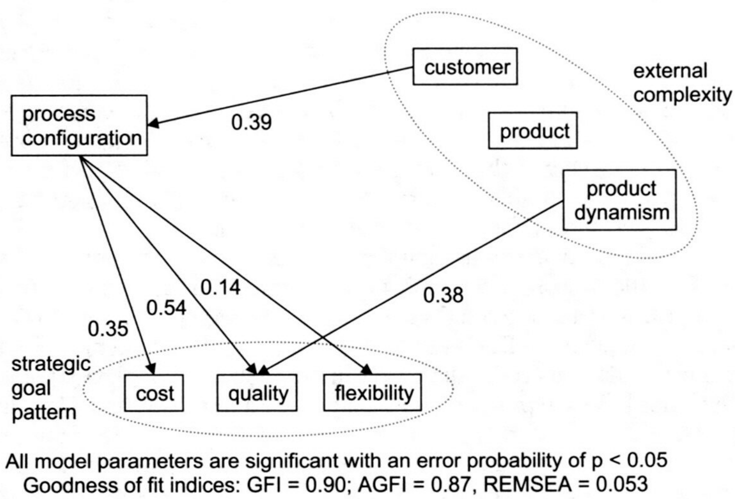


Figure 3. Structural equation model of adaptation relationships within the high complexity environment

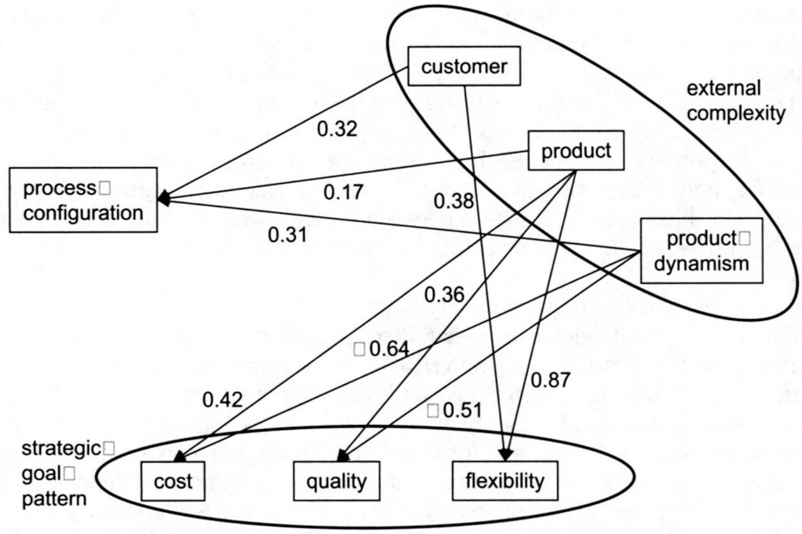
strategic goal pattern. The response to an external complexity increase is generated from within the manufacturing system.

Only little influence has been detected from the external complexity factors to the strategic goals pursued. The explicit adaptation is very weak, only dynamism within the product segment leads to higher emphasis on quality issues. Extending product range and introducing new products when already operating under heavy market pressure requires quality issues to be addressed in the future. These plants have already invested in programs to accelerate product development processes and they rely much more on platform strategies and implemented concepts of modularity in the past, average 0.202 compared to -0.251 of the low complexity group. There seems to be no need for the complexity of process configuration to rise further along with an increase of external complexity. The only factor that showed significant influence is the customer base. If additional customer groups are to be served, there will be necessary changes to enhance process configuration.

The strategic goal pattern is much more affected by process configuration. When the complexity of process configuration rises – and along with the problems that will occur with it – the overall emphasis on manufacturing strategy rises as well. In the case of high external complexity, the plants respond to increasing complexity by a weak implicit adaptation. Simultaneously, the formulation of a strategic direction is strongly affected by internal forces, pushing management to permit emergent patterns in favour of centrally planned strategy formulation (Mintzberg and Waters, 1985). This might lead to the conclusion that the internal quest to manage a highly complex system drives strategic goal formation.

The group of plants operating in relatively low complex environments is employing systems of fewer capabilities that cannot easily comply with increased complexity in the market place. If external complexity rises, their internal systems will implicitly change as well since their capabilities are limited much more than the ones of the high complex group. The manufacturing systems are largely relying on line manufacturing processes (39 per cent) that provide less flexibility to cope with increased product variety. Their process configuration does not provide enough built-in flexibility that can handle high demand of complexity. It might be the case that they have occupied more simple market segments on purpose and try to avoid high variety markets with highly dynamic changes. If the segments of less complexity are to be abandoned this will require a shift in the strategic goal pattern in order to develop enhanced system capabilities. Therefore, it can be assumed that both implicit adaptation and explicit adaptation are of higher relevance in this scenario. Figure 4 shows the supporting results from a path analytic model for the low complexity group.

Interpreting the results shown in Figure 4 it can be stated that implicit adaptation occurs strongly in the case of a low complexity environment. The relatively low level of complexity of process configuration does not provide enough capabilities to deal with further market complexity. The system has to adapt by winding up its own complexity. Further data analysis shows that in the past, low complexity plants have invested significantly less in programs such as process automation and TPM. In order to comply with higher external complexity the system has to adapt and the corresponding strategy has to reflect that. Their strategic goal pattern is less resource orientated compared to the high complexity group (-0.22-0.10) and especially product



All model parameters are significant with an error probability of $p < 0.05$
Goodness of fit indices: GFI = 0.91; AGFI = 0.89, REMSEA = 0.055

Figure 4.
Structural equation model of adaptation relationships within the low complexity environment

complexity appears to play a major part in that. Higher product variety leads to much more concentration on cost, quality and flexibility goals. An interesting result can be found in the influence that the dynamism of product complexity has on cost and quality goals. One explanation for the negative signs could be that if dynamism grows these goals have to be lessened in order to provide new products or a wider product range: if cost and quality were too rigorously pursued an expansion of product offerings would be prevented. If an organisation operates in a low complexity environment and is confronted with more demanding market requirements (in terms of customer groups served and product range offered), a strong push is required to guide the system towards the desired direction. Hence, both ways of adaptation, explicit and implicit, are utilised in order to generate enough momentum and commitment to initiate change processes.

The models presented above are drawn from a sub sample of 311 plants. The plants that have been omitted from the sample are located within the "middle" area of complexity and represent 12.9 per cent of the overall sample. Omitting these plants can influence the validity of the results that are derived from the structural models. To control for this effect, the model structure was tested against the whole sample with a separation of the high from the low complexity group at 1.5 of the external complexity measure, thus incorporating the whole sample for purposes of sensitivity analysis. The results of this analysis show that the findings of the structural equation models (factor loadings and β-coefficients) differ only to a minor degree. The algebraic sign is retained for all coefficients whilst the coefficients' values are decreasing slightly for the less discriminative whole sample analysis (average drop in coefficients value for the high complexity group is 13 per cent, the low complexity group drops on an average of 10 per cent). At the same time the overall fitness indices of the models are decreasing showing a less significant model (high complexity group: GFI = 0.89, AGFI = 0.86, REMSEA = 0.53; low complexity group: GFI = 0.89, AGFI = 0.86, REMSEA = 0.45). This leads to the conclusion that the separation between high and low complexity groups has influences on the discriminative power of the models but does not yield substantially different model specifications and interpretations. However, for the sake of stronger effects we decided to keep the original distinction between the high and low complexity groups at 1.5 ± 0.1, on which all results reported so far are based.

Summary and interpretation of empirical results

The findings of the two models imply that alternative forms of adaptation to external complexity work in the presence of different levels of complexity. Figure 5 shows a schematic model for high (a) and low (b) complexity environments. The strength of the adaptation forms is depicted by the thickness of the corresponding lines.

In a high complexity environment, firms are already adapted to external complexity by a variety of internal measures: flexibility in process configuration, technology and organisational structures. They are able to utilise different process types and layouts; their production technology allows them to produce small lot sizes; the machines they

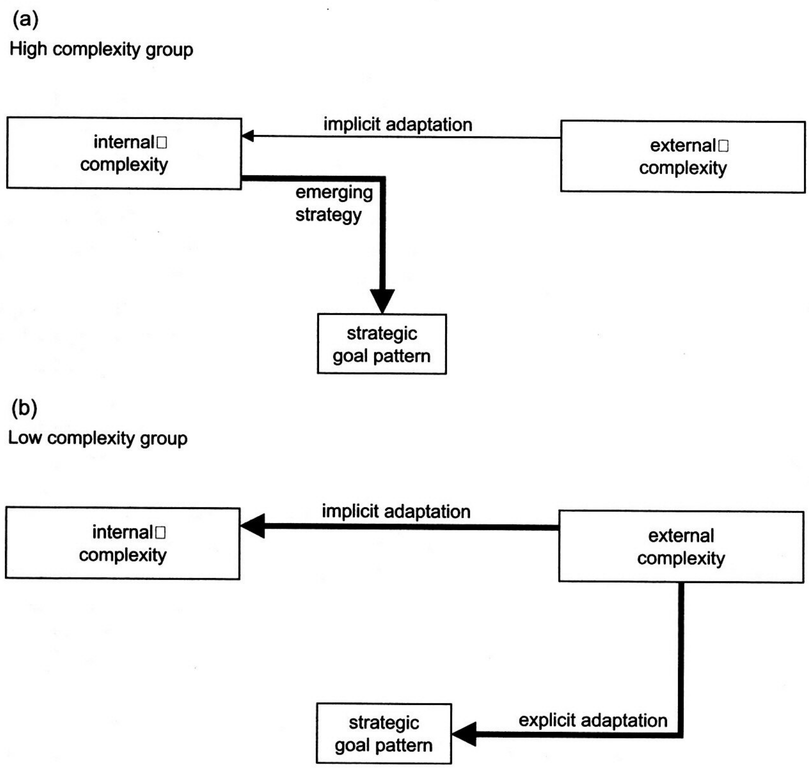


Figure 5.
Alternative ways of adaptation to external complexity

use are capable to manufacture a large variety of different products; the people working on the shop floor are highly skilled to permit flexibility in routines and plans. In other words, organisations surviving in high complexity have already built up the necessary internal variety in order to cope with external pressure. If this external pressure is stronger than on average in this group, these organisations do not need a substantially higher internal complexity. Their internal structure is to a high degree already capable of absorbing external complexity demands; only some small, implicit adaptation processes are necessary. Explicit adaptation processes are not necessary because these organisations are already adjusted to high complexity and management does not seem to perceive an increased complexity as problematic. However, resulting from actual internal processes, not from explicitly formulated policies, changes emerge in the manufacturing strategy of these companies.

The case is quite different for companies in a low complexity environment. In this case, if external complexity pressure is relatively high, firms are forced to adapt strongly in order to survive. The reason for this is that – having lived under low complexity – they did not face the necessities to adapt their internal structures to high complexity demands in the past. For instance, they concentrate on specific production layouts and types; they use highly automated but inflexible machinery; production is aligned to produce with large lot sizes; shop floor personnel are specialised in the given task but rather limited in the ability to do something different. Thus, when complexity is relatively high they must adapt implicitly and explicitly, i.e. a higher outside complexity leads to higher internal complexity and management becomes aware of the increased complexity and changes the organisation's strategic goal pattern as well.

In summary, organisations react differently to higher external complexity depending on whether the absolute level of complexity is rather high or low. That is, adaptation processes to external complexity in high complexity environments are distinct from adaptation in low complexity environments. Primarily, different levels of internal complexity are a reason for this, which allow for a different degree of absorption of external complexity by organisational structures.

Conclusions and further research

This paper puts focus on the influence of external complexity on the internal structuring of manufacturing plants. The empirical analysis shows that different ways of adaptation to external complexity exist and that they appear to be relevant under different circumstances only, depending on the degree of external complexity. To change a system's structure in response to external forces, there exists an adaptive relationship consisting of implicit adaptive means built in the structure of the organisation and the pattern of goals guiding the direction of the organisation. However, the importance of each component of the adaptation structure depends upon the status quo of the system and the strength of the external complexity to which a system has to respond. In general, both implicit and explicit adaptation processes enable an organisation to maintain its position within the environment (Mintzberg, 1978). However, under complex market conditions the self-regulating mechanism of emergent patterns is of more relevance than explicitly crafted policies. In contrast to this, if external complexity is low and begins to rise, explicit adaptation plays the major role to design an internal structure that is able to respond with higher variety and dynamism.

From a conceptual point of view, a managerial implication of this research is the depiction of different possibilities to adapt to external complexity. Firms should be aware that not all adaptation processes are based on explicit and arbitrary management policies, but that implicit decisions and emerging strategies play an important role. These, more "soft" ways of adaptation must be considered and can be influenced, similar to the "conventional" way of explicit adaptation and organisational design.

However, managing implicit adaptation and emerging strategies is a difficult task. Starting points for this endeavour can be found, for instance, in the literature on organisational learning (de Geus, 1988; Fiol and Lyles, 1985; Daft and Weick, 1984), complexity science (McCarthy, 2004; Lissak, 1999; Stacey, 1995), organisation science (Ethiraj and Levinthal, 2004; McKelvey, 1999) or behavioural economics (Camerer, 1998; Sterman, 1994). To elaborate the connection to these lines of research is one issue of further work within this research project.

The major managerial implication from the empirical study is a warning to firms that have not faced substantial external pressure in the past. If external complexity increases for these firms, they need to take powerful action because, most probably, their internal structures are insufficiently prepared to deal with higher complexity. By way of explicit and implicit adaptation, these organisations need to adapt: manufacturing improvement goals must be re-formulated to be in line with changed demands, elasticity in process layout needs to be enhanced, more flexible machinery is required and the workforce must get prepared for changes in daily routines. In other words, major restructuring processes are likely to be necessary for firms in low complexity environments when complexity increases.

Such is not the case when firms already have to deal with high external complexity. These firms can handle increases from the capabilities of their internal system. However, as a slight drawback, the internal structure of such firms is apparently not efficiently adapted to the level of complexity (i.e. they possess too much internal complexity), because they can deal with higher demands without effort, just from their structure. By way of an emerging process, they also routinely adapt their manufacturing goals to the changed environment.

Another point that will be considered in future studies is the use of more and different scales to assess adaptation processes statistically. For instance, we concentrated our empirical study on customers and products on the external, and on process configuration on the internal side. Other factors, for example, technology, organisational structure and logistics were excluded from our statistical analysis. By employing these and other scales, more emphasis can be put on dynamic complexity, besides the well-investigated detail complexity.

The main remaining issue concerning the empirical study is the need to consider dynamic systems and, thus, to apply dynamic research methods. In particular those linkages of the conceptual model that are prone to strong time delays need a dynamic treatment, in order to derive valid explanations. In the same way, only dynamic research methods allow derivation of real cause-and-effect statements, for instance, in the form: "when external complexity of a firm has increased, the level of its internal complexity increases as well by producing with more and different process layouts." Longitudinal studies (Goldstein, 1979) in combination with dynamic modelling and simulation techniques (Sterman, 2000) might be suitable for this task.

Notes

1. Since Cronbach's α is very much affected by the number of variables pooled together into one factor, a sensitivity analysis is performed to examine the influence of the relatively small number of items (Nunnally, 1978). To evaluate the strength of this influence, the number of items required to meet certain reliability levels can be calculated. In the case of product complexity, the impact of the small number of items can be considered quite high. For instance, if only 4.169 items instead of four items of the same reliability level are used to represent a common scale, the criterion level would be met. Furthermore, if the items were doubled, leaving the correlation constant among all the variables, Cronbach's α would reach 0.82. The influence of the small number seems to play a major role for the relatively low values of Cronbach's α, not the measurement error of the items considered. The factors are therefore accepted and used in further analysis.
2. In fact, we tried to represent all four strategic priorities separately in the structural equation model, however, without achieving interpretable results due to under-specified models. For an overview of other combinations of manufacturing dimensions used in empirical studies see Minor *et al.* (1994); for a discussion and a critique of the strategic priority concept see Swink and Hegarty (1998) and Swink and Way (1995).

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Appendix

Items from IMSS-3 questionnaire used to construct "external complexity" (Table II), in original order

A5. Please identify to what extent do you sell your products to

Components manufacturers	_____ per cent of total sales
Product assemblers	_____ per cent of total sales
Distributors	_____ per cent of total sales
End-users	_____ per cent of total sales
	100 per cent

A6. Consider the degree of importance of the following goals to your major customers (please circle all appropriate alternatives). Compared to your competitors, you win orders from your customers by aiming to:

	Not important				Very important	Has goal priority changed in last three years?
Offer superior product design and quality	1	2	3	4	5	No Lower Higher
Have superior customer service (after-sales and/or technical support)	1	2	3	4	5	No Lower Higher
Provide a wider product range	1	2	3	4	5	No Lower Higher
Offer newer products more frequently	1	2	3	4	5	No Lower Higher

A7. How would you describe the market aims of your business unit in terms of customers, market segments, product attributes and geographical markets? (Please indicate on scale by circling all the appropriate alternatives).

Customer focus	Few customers	1	2	3	4	5	Many customers

Items from IMSS-3 questionnaire used to construct "internal complexity" (Table III), in original order

PT2. Please indicate to what extent your activity is organized in the following layout categories (indicate percentage of total volume):

Process layout	
Job shop	_____ per cent
Cellular layout[a]	_____ per cent
Dedicated lines	_____ per cent
	100 per cent

Note: [a]A "cell" is a grouping of equipment dedicated to support the production of families of parts sharing similar process operations

PT3. Please indicate to what extent your activity uses one of the following process types (indicate percentage of total volume):

Process type	
One-of-a-kind	_____ per cent
Batches	_____ per cent
Mass production	_____ per cent
	100 per cent

PC4. What proportion of your customer orders are:

Designed/engineered to order	_____ per cent
Procured to order	_____ per cent
Manufactured to order	_____ per cent
Assembled to order	_____ per cent
Produced to stock	_____ per cent

Items from IMSS-3 questionnaire used to construct "strategic goal structure" (Table IV), in original order

C1. Please indicate the importance of the following improvement goals for your manufacturing function for the next three years:

	Not important				Very important
Improving manufacturing conformance	1	2	3	4	5
Improving product quality and reliability	1	2	3	4	5
Increasing product customization ability	1	2	3	4	5
Increasing volume flexibility	1	2	3	4	5
Increasing mix flexibility	1	2	3	4	5
Reducing your time to market	1	2	3	4	5
Increasing delivery reliability	1	2	3	4	5
Increasing labor productivity	1	2	3	4	5
Increasing inventory turnover	1	2	3	4	5
Increasing capacity utilization	1	2	3	4	5

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