The Effects of Self-Reinforcing Mechanisms on Firm Performance

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Abstract

This study empirically investigates the influence of the market-bound (i.e., interaction and network effects) on the firm-bound (i.e., scale and learning effects) self-reinforcing mechanisms, and their combined effect on product and organizational performance. The findings from a sample of 257 manufacturing firms reveal that interaction effects have a positive effect on network effects. Network effects have a positive impact on the potential for firms to realize scale and learning effects, which in turn, is positively related to their actual realization of these effects. The actual realization of scale and learning effects has a positive effect on product performance, which in turn positively influences organizational performance. These effects are robust across industries and provide ample opportunities for future research.

Keywords:

Self-reinforcing Mechanisms; Increasing Returns; Management; Economics

1. Introduction

Self-reinforcing mechanisms play an important role in many markets and firms. For example, they appear in the emergence of fashions and fads (Abrahamson and Rosenkopf, 1997; Bikhchandani, Hirschleifer and Welch, 1992; Cowan, Cowan and Swann, 1997), in technology adoption and standardization (Arthur, 1989; Church and Gandal, 1992; David, 1985; Katz and Shapiro, 1985), in the production and commercialization of information and knowledge intensive products (John, Weiss and Dutta, 1999; Shapiro and Varian, 1998), and in technological process improvements (Amit, 1986; Arrow, 1962; Hatch and Mowery, 1998; Li and Rajagopalan, 1998). These self-reinforcing mechanisms come in four forms (cf. Arthur, 1988): (1) interaction effects, (2) network effects, (3) scale effects, and (4) learning effects. Of these self-reinforcing mechanisms interaction effects and network effects are market-bound, while scale and learning effects are firm-bound (Den Hartigh and Langerak, 2001). This classification is analogous to the notion of external and internal economies, respectively.

To date, anecdotal evidence and theoretical derivations reveal that presence of these self-reinforcing mechanisms tends to have destabilizing effects on market outcomes, and hence on firms' product and organizational performance (e.g., Choi, 1994; Foray, 1997). These results also suggest that the occurrence of self-reinforcing mechanisms causes winner-take-all situations, lock-in of market outcomes, extreme sensitivity to chance to or historical small events, and market outcomes in which the superior product or technology not necessarily prevails (Arthur, 1989; Besen and Farrell, 1994). Arthur (1996, p.103-104) refers in this context to the *"casino of technology"*, stressing the uncertainty of market outcomes when self-reinforcing mechanisms occur.

Unfortunately, the body of research on self-reinforcing mechanisms has largely omitted to empirically investigate the influence of these mechanisms on market outcomes and firm performance. The purpose of our research is to fill part of this gap in extant knowledge by empirically investigating the influence of the market-bound (i.e., interaction and network effects) on the firm-bound (i.e., scale and learning effects) self-reinforcing mechanisms, and their combined effect on product and organizational performance.

The present study makes two primary contributions. First, our study analyzes the effect of the market-bound self-reinforcing mechanisms on the firm-bound self-reinforcing mechanisms. To our knowledge, no study has investigated empirically the influence of interaction and network effects on scale and learning effects. Second, we examine how the four self-reinforcing mechanisms together influence product and organizational performance. To our knowledge, no study has examined these effects simultaneously and empirically.

The remainder of this article is structured as follows. First, we review the literature on the market-bound and firm-bound self-reinforcing mechanisms. Then, we present our conceptual framework and the hypothesized relationships. Next, we explain the research design and review the findings from a sample of 257 manufacturing firms in The Netherlands. Finally, we explore managerial implications and make suggestions for further research.

2. Market-bound self-reinforcing mechanisms

As previously mentioned the market-bound self-reinforcing mechanisms consist of interaction effects and network effects. These will be discussed henceforth.

Interaction effects: The first market-bound self-reinforcing mechanism is interaction effects. Interaction effects are also known as social network effects (Abrahamson and Rosenkopf, 1997), or social contagion (Burt, 1987; Kretschmer, Klimis and Choi, 1999). Interaction effects occur when a customer's preference for a product is dependent upon the opinions or expectations of other (potential) customers (Bikhchandani, Hirschleifer and Welch, 1992; Cowan, Cowan and Swann, 1997). We refer to interdependence of opinions as 'information exchange' and to interdependence of expectations as 'self-reinforcing expectations'.

Information exchange mainly occurs with high-involvement products that are relatively unknown to customers. Customers can therefore not assess the quality of these products prior to purchase. This means that buying these products entails a large social and/or economic risk for customers. A social risk is the risk of buying a product that is not conforming to the relevant peer or aspiration group. An economic risk is the risk of buying a product that has a very short life cycle or that is based on a technology that does not become accepted as the market standard. As a consequence, customers buying these products run the risk of losing their investment. To assess the social and economic risks customers search for information by consulting opinion leaders and existing product users before making their purchase decision. This information search behavior generates interactions (i.e., information exchange) among customers. Since it is more likely that a customer will find favorable information about a product with a larger market share than about a product with a smaller market share, customers will perceive purchase of the former as less risky and will therefore be more inclined to buy it.

Besides product-specific information exchange customers also exchange non-product related information. Feick and Price (1987) refer to customers who supply this more general market-related information to other customers as 'market mavens'. In the case of network technologies, where the complete network of complementary products rather than a single product is at stake, the influence of market mavens on the purchase intentions of other customers can be substantial.

Furthermore, self-reinforcing expectations play a role when customers have an interest to invest in products that are compatible to a long-lasting technology network that is widely supported and accepted as the market standard. To assess the risk of investing in a technology network, customers form expectations about the size of competing technology networks (Katz and Shapiro, 1985). This expected size is dependent on the number of suppliers and customers who have already invested in this network or who will (soon) do so. When a substantial number of suppliers and customers expect that a particular technology network will dominate the market, they will be more inclined to invest in this network. As a result, the network will grow and thereby fulfill the suppliers' and customers' expectations.

Network effects: The second market-bound self-reinforcing mechanism is network effects. These occur when the economic utility of using a product becomes larger as its network grows in size (Farrell and Saloner, 1985; Katz and Shapiro, 1985). The difference between interaction effects and network effects is that while interaction effects are mainly associated with information search and preference formation, network effects are associated with the economic utility as a result of *actual* growth in network size (Abrahamson and Rosenkopf, 1997; Cowan, Cowan and Swann, 1997; Kretschmer, Klimis and Choi, 1999). Network size is determined by the number of suppliers and users of products based on a common technology standard. These networks may be physical, as for example, the cable TV network or the telephone network, or virtual, as for example the network of Microsoft Windows users. Network size is important in many markets, but most visible in the markets like telecommunications, computer equipment and software (see Brynjolfsson and Kemerer, 1996; Church and Gandal, 1992).

When a product's economic utility increases as more customers start using it, this is referred to as 'direct' network effects (Farrell and Saloner, 1985; Katz and Shapiro, 1985). Besides, network effects are also present when products are used in combination with complementary products. The increase in a product's economic utility, as more customers start using complementary products, is referred to as 'indirect' or 'market-mediated' network effects (Gupta, Jain and Sawhney, 1999). Examples of indirect network effects are the cellular phone and its network infrastructure, the Internet connection and network protocols, the personal computer and its operating system (cf. Katz and Shapiro, 1994). Compatibility, which is necessary to allow products to function in harmony with complementary products, can be ensured by standardization of the technology infrastructure (Farrell and Saloner, 1992). For example, only if there is a common protocol for communication through the Internet, customers benefit from the continuously growing network of Internet-users and content providers. Therefore, compatibility is one of the most important conditions for network effects to materialize. With a growing number of customers who have bought the standard personal computer with an MS-Windows operating system and Intel microprocessor, it becomes more attractive for other customers to do the same (i.e., direct network effects). For suppliers of complementary products, such as software and peripheral equipment, it also becomes more attractive to accept this standard (i.e., indirect network effects). Consequently it becomes more appealing for potential customers to buy these complementary products. In other words, direct and indirect network effects are mutually reinforcing.

3. Firm-bound self-reinforcing mechanisms

As mentioned before the firm-bound self-reinforcing mechanisms consist of scale effects and learning effects. These will be discussed below.

Scale effects: A first firm-bound self-reinforcing mechanism is scale effects, often referred to as 'economies of scale' or 'increasing returns to scale'. Scale effects imply that the average total cost will decline with growing production volumes. In other words, scale effects are reflected in a downward slope of the average total cost curve (Amit, 1986). A distinction can be made between scale effects with respect to fixed and variable costs. The first entails that the fixed costs of the input factors are spread over as many products (output) as possible. The second relates to the decrease in average variable costs with larger production volumes (Shapiro and Varian, 1998).

Scale effects are related to the specific cost structure of products. Such a cost structure is characterized by high fixed (development) costs and low variable (production and/or distribution) costs. Computer programs are a good example of products that have such a cost structure. These products require high development costs, but very low reproduction and distribution costs. By using the Internet the variable costs of reproduction and distribution can even be reduced to almost zero. The consequence of such a cost structure is that the average total cost curve will descend steeply as the production volume increases. This descent offers the company a unique possibility to improve the product's value proposition for the customer, either by raising the quality of the product and/or by lowering the price. Therefore, the realization of scale effects is often considered the most important driver of competitive advantage (Scherer and Ross, 1990). It is important to note that scale effects are not in themselves self-reinforcing. They may become so when they are embedded in the firm's competitive strategy. Management may, for example, use the cost advantage acquired through scale effects to pursue a cost-leadership strategy in order to lower market prices. Under conditions of sufficient price elasticity, lower prices lead to higher sales, which, in turn, require larger production volumes. This sequence results in even stronger scale effects. In this way, increasing returns to scale may become a self-reinforcing mechanism.

Learning effects: A second firm-bound self-reinforcing mechanism is learning effects. Learning effects imply that there is a positive dynamic relationship between the growth of output of a firm and the growth of productivity (Amit, 1986). Learning results in a more efficient use of input factors as cumulative output grows. In other words, the same output can be produced with less input, reflecting a downward shift of the average total cost curve (Amit, 1986; Day and Montgomery, 1983). Learning may be induced or autonomous (Li and Rajagopalan, 1998). Induced learning is product or process improvement as a result of conscious managerial actions, for example copying best practices, external training of employees, hiring more experienced employees, or using technically improved capital goods. As with scale effects, the efficiency gains of induced learning may become self-reinforcing when embedded into a competitive strategy. Autonomous learning involves 'automatic' improvements as a result of performing production tasks, or 'learning-by-doing' (Arrow, 1962). Learning-by-doing sets another self-reinforcing loop in motion: not only are input factors (e.g., labor, capital, and knowledge) used more efficiently, but the production process may also generate new knowledge as additional output. This additional knowledge output may subsequently be used to improve products or to improve process efficiency. A good example is the market for (cellular) communication networks. The installation of such networks is an activity in which considerable learning effects occur. Each installed network generates new knowledge for improving both the future efficiency (i.e., lower costs) and effectiveness (i.e., higher quality) of the network installation process. Consequently companies that have installed large numbers of such networks are creating a growing knowledge edge over companies that have installed fewer networks. Moreover, as knowledge is time-sensitive (Glazer and Weiss, 1993), the continuous generation of new knowledge becomes an important competitive success factor.

4. Conceptual framework and hypotheses

The review of the literature on market-bound and firm-bound self-reinforcing mechanisms has led to the development of a conceptual framework, shown in figure 1. This conceptual framework reveals a number of relationships. First, interaction effects have a positive direct effect on network effects. Second, network effects have a positive direct effect on the potential for firms to realize scale and learning effects. Third, the potential for firms to realize scale and learning effect has a direct impact on their actual realization of these effects. Fourth, actual realization of this potential has a positive direct effect on product performance. Fifth, the actual realization of scale and learning effects has a positive direct influence on organizational performance. Sixth, product performance positively affects organizational performance directly, which implies that there is also an indirect effect of the actual realization of scale and learning effects on organizational performance. The full lines, shown in figure 1, represent these relationships, which are central to our study. The dashed lines represent the theses that the relationships between the potential and the actual realization of scale and learning effects are moderated by the degree of complementarity and compatibility. We will subsequently discuss the relationships hypothesized in this framework.

<< Figure 1 about here >>

The effect of interaction effects on network effects: Social interaction effects were defined in terms of information exchange and the formation of expectations that occur when customers face social and economic network risks. Through social interactions customers try to reduce these risks, by interpreting other customers' opinions and preferences. For individual customers, the formation of opinions and preferences will precede their actual behavior (Katz and Shapiro, 1986; Rosenberg, 1976). The actual behavior of customers subsequently causes the network effect, because the economic value of the network increases as more customers adopt a product based on the same technology. Therefore we hypothesize that:

H_1 *The greater the interaction effects, the greater the network effects.*

The effect of network effects on the potential of scale and learning effects: The first consequence of network effects is the existence of multiple possible equilibria in the market. These equilibria are often characterized by a very asymmetrical division of market shares (Arthur, 1989; Besen and Farrell, 1994), also known as 'winner-take-all'. This means that the sponsor of the winning technology acquires the largest technology market share, and hence obtains market dominance. This creates the possibility to realize the largest scale of production for the products based on this technology, enabling scale effects. The second consequence of network effects is the tendency for the winning technology to gain ever-increasing popularity once it has gained an initial edge in the market (Abrahamson and Rosenkopf, 1997; Katz and Shapiro, 1994; Besen and Farrell, 1994). The fast-increasing popularity means that not only the scale of production for products based on the technology can be quickly increased, enabling scale effects, but also that the cumulative production of these products fastly increases, enabling learning effects. Together, the consequences of network effects suggest that:

H_2 *The greater the network effects, the greater the potential to realize scale and learning effects.*

The effect of the potential to realize scale and learning effects on the actual realization of scale and learning effects: The fact that there are multiple equilibria in the market and that there is a very asymmetric distribution of market shares, does not automatically mean that all individual firms will be able to increase their production volume. On the contrary, in a winner-take-all market there is only one winner and many losers. To be successful in winner-take-all markets, firms can follow different strategies. They can choose to follow a 'shaper' strategy by developing an own proprietary technology in order to appropriate all the returns (Besen and Farrell, 1994; Shapiro and Varian, 1999). However, such a strategy is both costly and risky, which means that only a few firms can afford to develop and implement such a strategy. An alternative, known as an 'adapter' strategy, is to join the winning technology by acquiring a license for developing products based on this technology. In this way, firms can profit indirectly from the potential to realize scale advantages created by the winning technology. Therefore we hypothesize:

H_3 *The greater the potential to realize scale and learning effects, the greater the actual realization of (a) scale and (b) learning effects.*

The effect of the actual realization of scale and learning effects on product performance: As previously explained, scale and learning effects only become self-reinforcing mechanisms when they are embedded in the firm's competitive strategy aimed at making optimal use of the acquired efficiency gain (Amit, 1986; Day and Montgomery, 1983). Firms may use the realized efficiency gain in different ways, for example for the pursuit of a cost-leadership strategy with low-priced products, or for the pursuit of a differentiation strategy with products that deliver superior customer value. Either way, such a strategy will improve product performance versus the performance of products of competitors that do not realize scale and learning effects to the same extent. Besides, learning-by-doing may result in product improvements, thereby better tailoring products to specific customer needs, and realizing superior customer value relative to other firms. Thus we hypothesize that:

H_4 *The greater the actual realization of (a) scale and (b) learning effects, the higher the level of product performance.*

The effect of the actual realization of scale and learning effects on organization performance: Analogous to the effect on product performance, realizing scale and learning effects may become self-reinforcing when used for achieving organization-wide process improvements (Hatch and Mowery, 1998). Through better efficiency and higher effectiveness, these improvements result in better market outcomes in terms of sales growth, market share (Makadok, 1999) and new products. This in turn causes higher operational cash flows, higher profits and better returns on investment. Hence we hypothesize that:

H_5 *The greater the actual realization of (a) scale and (b) learning effects, the higher the level of organizational performance.*

The effect of product performance on organizational performance: For many firms organizational performance is, to a large extent, determined by the performance of a few primary products (i.e., products with a high market share). The rationale is that there is a positive relationship between the market shares of the firm's primary products and organizational performance. Market share as an antecedent of organizational performance is consistent with the profitability models proposed in numerous empirical studies (see Capon, Farley and Hoenig, 1990 for an overview). The relationship is grounded in: (1) efficiency theory, i.e., the cost efficiencies for firms with higher market shares through a downward sloping cost experience curve; (2) market power theory, i.e., firms with higher market shares exercising market power to set prices, obtain inputs at lower costs, and extract concessions from channel members, and; (3) product assessment theory, i.e., customers use market share as a signal for product quality and a product's widespread acceptance as an indicator of superior quality. Although the organizational performance impact of primary products may not hold universally, a meta-analysis performed by Szymanski, Bharadwaj and Varadarajan (1993) reveals that on average market share has a significant and positive effect on organizational performance. That primary products with high market shares are typically more profitable than those with lower market shares is also one of the more robust findings from the PIMS-project (Buzell and Gale, 1987). Accordingly, we hypothesize:

H_6 *The higher the level of product performance, the higher the level of organizational performance.*

The moderating effects of complementarity and compatibility: The effect of the potential to realize scale and learning effects on the actual realization of scale and learning effects depends on the nature of the firm's products and the product technology upon which these products are based. Complementarity and compatibility are product or product technology characteristics that are proposed to affect the linkages between the potential to realize scale and learning effects and the actual realization of scale and learning effects.

First, we consider complementarity, which is the extent to which customers use the firm's product and/or product technology together with complementary products and product technologies (Gupta, Jain and Sawhney, 1999). In a situation where the firm is not a sponsor of the winning technology, the firm may choose to profit from the potential to realize scale and learning effects created by the winning technology in another way. That is to compete not with the dominant product or the dominant technology (i.e., not focusing on substitution), but instead to focus on products or technologies that are complementary to (i.e., are used together with) the dominant product or dominant technology. In this way these firms may capitalize on indirect network effects and realize scale and learning effects by offering complementary products or technologies (Katz and Shapiro, 1986). Thus we hypothesize that:

H_7 *The higher the degree of complementarity, the stronger the (positive) relationship between the potential to realize scale and learning effects and the actual realization of (a) scale and (b) learning effects.*

Second, we consider compatibility, which is the extent to which a product and/or product technology functions in harmony with complementary products and product technologies (Farrell & Saloner, 1992). Making a product or technology compatible with the dominant product or technology means making a connection to the dominant technology network (Brynjolfsson and Kemerer, 1996; Church and Gandal, 1992; Gandal, 1995). It is a strategy to realize part of the potential of scale and learning effects generated by the dominant technology network. Therefore we hypothesize:

H_8 *The higher the degree of compatibility, the stronger the (positive) relationship between the potential to scale and learning effects and the actual realization of (a) scale and (b) learning effects.*

5. Methodology

Sample and data collection: The initial sampling frame consisted of 2934 Dutch manufacturing firms with independent R&D, production and marketing/sales departments. Through a telephone pre-survey 998 firms were identified with a knowledgeable marketing manager in a position to generalize about patterns of behavior related to the content of inquiry. To ensure the suitability of the marketing managers we adopted a self-assessment of their knowledgeability through the telephone calls. A total of 283 (9,6%) knowledgeable marketing managers was willing to cooperate with the research and was interviewed by phone using a standardized questionnaire. In answering the questions we asked the respondents to focus on their primary product in their principal served market segment.

Our efforts yielded 257 usable responses, for a final usable response rate of 8.8% (25.8% of those who were approached). A routine check for respondent bias indicated that no significant differences existed in the mean responses on any construct across respondents with different levels of education and different durations of employment. Moreover, no industry and firm size effects existed in the mean responses on any construct. A time-trend extrapolation procedure was used to test for non-response bias. We divided the data set into quartiles based on the number of minutes it took to complete the questionnaire. The underlying rationale is that slow respondents are more similar to non-respondents than fast respondents. In comparing fast (1^{st} quartile) and slow (4^{th} quartile) respondents, no significant differences emerged in the mean responses on any of the constructs. Together these results suggest that respondent, industry, firm, and non-response bias were not a major problem. Sample characteristics are shown in table 1.

<< Table 1 about here >>

Measure development and pre-testing: We generated a pool of items for measuring each of the study's constructs using literature search and extensive interviews with academics and practitioners. Pretests of these items occurred in three phases: (1) face-to-face interviews with 10 academics, (2) face-to-face interviews with 15 managers, and; (3) a test of substantive validity involving 21 managers (Gerbing and Anderson, 1991). At each stage, participants identified items that were confusing, tasks that were difficult to respond to, and any other problems they encountered when filling out the questionnaire. We revised or eliminated problematic items, and developed new ones. By the end of the third phase of pre-testing the practitioners reported no concerns, and the questionnaire was therefore ready for final administration.

Level of analysis: Our study responds to a call by Drazin and Schoonhoven (1996) for cross-level research. These scholars argue that using a cross-level perspective leads to enhanced understanding of the factors leading to higher organizational performance. Therefore, we examine the potential and actual realization of scale and learning effects and organizational performance at the organizational level. Product performance is examined at the product level. Interaction effects and network effects are examined at the market level.

Measures: We measured all constructs with multiple items on a seven-point rating scale. To measure interaction and network effects (both related to the product and to the product technology upon which the product is based) 8 items were used respectively. The potential to realize scale (with regard to fixed and variable costs) and learning effects was measured using 3 items. The actual realization of scale and learning effects was measured using 3 items. Product performance was measured using 10 items adapted from Griffin and Page (1996). Organizational performance was measured using 7 subjective items adapted from Naman and Slevin (1993) and Slater and Narver (1994). Subjective measures of organizational performance are frequently used in strategy research and have been shown to be reliable and valid (Dess and Robinson, 1994). Complementarity and compatibility (related to the product and to the product technology upon which the product is based) were measured using 2 items respectively. The scale items are shown in the appendix.

Unidimensionality and reliability: We computed the inter-item correlations and corrected item-to-total correlations for each item, taking one subscale at a time, to obtain unidimensionality (Steenkamp and Van Trijp, 1991). We eliminated items for which these correlations were not significant ($p<0.01$). The unidimensionality of each purified scale was explored with principal axis factoring using an eigenvalue of 1.0 and factor loadings of 0.40 as the cut-off points. We explored the reliability of each purified, unidimensional scale by computing the reliability coefficient. In case where the coefficient alpha was smaller than 0.7, we removed the item with the lowest corrected item-to-total correlation until the requirement of 0.7 was met (Nunnally, 1978). This procedure resulted in the elimination of 7 items.

Convergent validity: Convergent validity of the scales was investigated by estimating three confirmatory factor models using Maximum Likelihood estimation in LISREL 8.3. This approach was selected in order to fit the constraints of a five-to-one ratio of sample size to parameter estimates (Baumgartner and Homburg, 1996). The first model contained the items pertaining to interaction and network effects. The results indicated that the absolute (i.e., GFI and NFI) and incremental (i.e., NNFI, CFI and IFI) fit indices were above the threshold value of 0.90 (GFI=0.92.; NFI=0.91; NNFI=0.92; CFI=0.93; IFI=0.93). The parsimonious fit measure (χ^2/df) was below the recommended threshold of 2.0 (1.89), and the root mean square error of approximation (RMSEA) was at the recommended 0.08 level (0.08). Convergent validity was indicated by the fact that all items loaded significantly ($t>2.0$) on their corresponding latent construct structures (Bagozzi, Yi and Phillips, 1991). The second model included the items measuring the potential and actual realization of scale and learning effects, complementarity and compatibility, and provided a good fit to the data (GFI=0.98; NFI=0.96; NNFI=0.92; CFI=0.97; IFI=0.97; χ^2/df=1.73; RMSEA=0.07). Convergent validity was indicated by the fact that each item loaded significantly ($t>2.0$) on its corresponding latent construct. The third model encompassed the items pertaining to product performance and organizational performance. The estimated model produced a good fit to the data (GFI=0.93; NFI=0.91; NNFI=0.92; CFI=0.94; IFI=0.94; χ^2/df=1.94; RMSEA=0.07). Again, convergent validity was indicated by the fact that each item loaded significantly (t>2.0) on its corresponding latent construct.

Discriminant validity: Discriminant validity among the scales was assessed in two steps. First, we estimated a two-factor model for each possible pair of scales. Discriminant validity was indicated when the variance-extracted estimates for the two scales exceed the square of the correlation between them (Bagozzi and Yi, 1988). The results revealed that without exception the assessment supported the discriminant validity of the scales. Second, we examined the confidence intervals around the correlations between the scales to determine whether they encompassed one. Discriminant validity was obtained because none of the 95% confidence intervals (plus or minus 1.96*standard errors) around all pairwise correlations encompassed 1.0 (Bagozzi and Phillips, 1982).

Together the results of the tests for unidimensionality, reliability, convergent validity and discriminant validity provided sufficient evidence of the validity of the scales. Provided with this evidence the constructs were formed by averaging the responses to each item in a particular scale. Means, standard deviations, number of items deleted, number of items retained, inter-construct correlations, reliability coefficients, composite reliabilities and average extracted variances are reported in table 2.

<< Table 2 about here >>

6. Results and discussion

The hypotheses were tested using causal modeling by means of LISREL 8.3. We used the constructs created for the estimation of the model to obtain a favorable ratio between our sample size and the number of parameters to be estimated (Baumgartner and Homburg, 1996). The analysis resulted in a good fit to the data (χ^2/df=1.98; GFI=0.97; AGFI=0.93; NFI=0.93; NNFI=0.92; CFI=0.96; IFI=0.96; RMSEA=0.07). Table 3 presents the unstandardized estimates and t-values associated with the direct effects. The discussion of the results is organized around the hypothesized relationships shown in figure 1.

<< Table 3 about here >>

The effect of interaction effects on network effects: The findings support H_1, as interaction effects have a positive significant ($p<0.05$) direct effect on network effects (b=0.68). This finding is consistent with previous theoretical evidence that suggests that interaction effects enhance the creation of network effects (Katz and Shapiro, 1986).

The effect of network effects on the potential to realize scale and learning effects: The results support H_2, because network effects have a positive and significant *direct* effect on the potential to realize scale and learning (b=0.23) effects. The results, shown in table 4, also reveal that interaction effects have a significant and positive *indirect* effect on the potential to realize scale and learning (b=0.15) effects, through the positive and significant effect of interaction effects on network effects. Together these direct and indirect effects show that interaction and network effects are a significant factor in creating a potential to realize scale and learning effects.

The effect of the potential to realize scale and learning effects on the actual realization of scale and learning effects: The results support H_{3a} and H_{3b}, as the potential to realize scale and learning effects has a significant and positive direct effect on the actual realization of scale (b=0.23) and learning (b=0.18) effects. This finding is consistent with literature that has illustrated that firms can exploit the potential to realize scale and learning effects through the pursuit of alternative competitive strategies (Besen and Farrell, 1994).

The effect of the actual realization of scale and learning effects on product performance: The findings provide support for H_{4a} and H_{4b}, because the actual realization of scale (b=0.06) and learning (b=0.12) effects both have a positive and significant effect on product performance. These findings confirm prior research that suggests that the actual realization of scale and learning effects are the most important drivers for competitive advantage, and hence superior product performance (cf. Scherer and Ross, 1990).

The effect of the actual realization of scale and learning effects on organizational performance: The results support H_{5b}, as the actual realization of learning effects has a significant and positive *direct* effect on organizational performance (b=0.11). This result confirms previous findings that show that learning effects have a positive effect on organizational performance (Hatch and Mowery, 1999). The findings provide no support for H_{5a}, because the actual realization of scale effects has no significant *direct* effect on organizational performance. The results shown in table 4 reveal, however, that the actual realization of scale effects has a positive and significant *indirect* (b=0.03), but no significant total effect on organizational performance. This is remarkable because prior (empirical) research has shown that the actual realization of scale effects is important to achieve superior organizational performance (Makadok, 1999).

The effect of product performance on organizational performance: The results provide support for H_6, as product performance has a significant and positive (b=0.50) effect on organizational performance. This finding is consistent with prior empirical research that has demonstrated the importance of primary product performance for organizational performance (Szymanski, Bharadwaj and Varadarajan, 1993).

The moderating effect of complementarity and compatibility: To test hypotheses 7 and 8 we used the following procedure. We split the sample into two subgroups for the moderating variables using the median for complementarity and compatibility respectively. For each subgroup the path model used to test the hypotheses 1 through 6 was estimated. We conducted a pairwise comparison of the estimated parameters between the two subgroups. More specifically, the pairwise comparisons were based on the χ^2-difference ($\Delta\chi^2$) between the two models, in which one model constrained the parameters to be equal (i.e., an equality constraint model, in which the relationships between the potential to realize scale and learning effects and the actual realization of scale and learning effects are constrained to be equal across the subgroups), and the other model left the parameters free to covary (i.e., a free model in which the relationships between the potential to realize scale and learning effects and the actual realization of scale and learning effects are allowed to be different across the subgroups). The significance of the $\Delta\chi^2$ between the two models was used as a test for the equality of the parameters, i.e., whether the equality constrained model produced a better fit than the free model. The $\Delta\chi^2$-statistics for the subgroups are shown in table 5.

<< Table 5 about here >>

The first pairwise comparison was between low (group 1) and high (group 2) complementarity. The χ^2 was 141.78 for the equal-parameter model and 128.91 for the free-parameter model. The $\Delta\chi^2$ was 12.87 (Δdf=2). The critical value of $\Delta\chi^2$ with 2 degrees of freedom is 9.21 at the 1% level. Thus, the $\Delta\chi^2$ is significantly different. The results, summarized in table 6, reveal that for low degrees of complementarity the potential to realize scale and learning effects has a significant and positive effect on the actual realization of scale (b=0.19) effects, but no significant effect on the actual realization of learning effects. The results also reveal that for high degrees of complementarity the potential to realize scale and learning effects has a positive significant and stronger effect on the actual realization of scale effects (b=0.25) and also a significant and positive influence on the actual realization of learning effects (b=0.23). Together these results imply that we find support for H_{7a} and H_{7b}.

<< Table 6 about here >>

The second pairwise comparison was between low (group 1) and high (group 2) compatibility. The χ^2 was 96.68 for the equal-parameter model and 94.73 for the free-parameter model. The $\Delta\chi^2$ was 1.95 (Δdf=2). Thus, the $\Delta\chi^2$ is not significantly different. This means that we find no support for H_{8a} and H_{8b}.

7. Management implications

Our results have important implications for managers. The theoretical and practical inferences drawn from our results are based on the documentation of existing practices of manufacturing firms. We cannot assert that these inferences are necessarily appropriate, but rather that they represent the norms in a sample of manufacturing firms across different industries in the Netherlands. Our aim is to help managers to understand the relationships between the different self-reinforcing mechanisms and their influence on product and organization performance. In this way, managers will be able to consciously act upon these relationships and will be able to exploit opportunities when they arise. The discussion of the implications is, again, organized around the hypothesized relationships of figure 1.

The effect of interaction effects on network effects: For managers, the findings that interaction effects precede network effects means that firms with a 'shaper' strategy planning to catalyze the market-bound mechanisms should focus on: (1) managing customer and competitor expectations, and; (2) initiating information exchange among market participants. Subsequently they should focus on creating direct and indirect network effects around their technology. They can induce direct network effects by assembling a group of suppliers that can be persuaded or is already willing to accept the firm's technology as the market standard. They can create indirect network effects by assembling a group of suppliers that will commit themselves to supply complementary products or technologies. Firms with an adapter strategy should enter the market either by connecting themselves to the group of suppliers that accepts the shaper firm's technology as the market standard (e.g., by buying a license), or by linking themselves to the group of firms that commits to supplying complementary products or technologies.

The effect of network effects on the potential of scale and learning effects: The finding that network effects lead to a potential to realize scale and learning effects, means that there is the possibility that in the market an asymmetric division of market shares arises. For managers, this means that the shaper firm supplying the dominant technology, has the largest potential to realize economies of scale and learning effects for the products based on this technology. For firms following an adapter strategy the asymmetrical division of market shares implies that the potential to realize scale and learning effects is smaller. Moreover, for these firms the decision which group of suppliers to join is essential to avoid a lock-out situation, i.e., a situation in which the technology that the firm has invested in or committed to does not become the market standard. To avoid a lockout situation, adapter firms should postpone the decision to commit themselves to a technology until it becomes clear which technology of the shaper firms will dominate the market.

The effect of the potential to realize scale and learning effects on the actual realization of scale and learning effects: The positive relationship between the potential to realize scale and learning effects and the actual realization of this potential, means that firms are generally able to exploit this potential. Firms with a shaper strategy do this through selling licenses, protecting their acquired position, leveraging the installed base into new markets, and offering customers migration paths to new and updated products (Shapiro and Varian, 1999). Firms following an adapter strategy are able to exploit this potential of scale and learning effects through maintaining a healthy market for complementary products or technologies.

The effect of the actual realization of scale and learning effects on product performance: The finding that the extent to which firms are able to realize scale and learning effects significantly influences their product performance, reveals that firms, regardless of their strategy, are capable of embedding the realized economies of scale and learning effects in their product strategy. Managers can improve customer satisfaction and acceptance by improving on product quality and innovativeness and/or by lowering cost prices. This will raise sales and extend the firm's market share.

The effect of the actual realization of scale and learning effects on organizational performance: For managers, the finding that learning effects influence organizational performance reveals that learning effects are not restricted to a specific product. This means that learning effects allow firms to realize product and process improvements and spread best practices throughout the organization. The result that the realization of economies of scale has no effect on organizational performance shows that scale effects are restricted to specific products. This reveals that firms are not capable of realizing economies of scope (Teece, 1980). Therefore, managers should concentrate the firm's resources on a small portfolio of products based on the same product technology instead of diversifying into unrelated markets or technologies.

The effect of product performance on organizational performance: The result that the performance of the firm's primary product has a significant influence on organizational performance, reveals that firms are able to convert the advantages of a large market share of their primary products into organizational success. This shows that managers are capable of exercising sufficient market power to be a price-setter and to extract concessions from suppliers and other channel participants in their principal served market.

The moderating effects of complementarity and compatibility: We find that the degree of complementarity of products or technologies strengthens the relationship between the potential, and the actual realization of scale and learning effects. This implies that for firms following a shaper strategy it is favorable that a wide range of complementary products and technologies is available in the market. For firms with an adapter strategy, offering products or technologies that are complementary to the dominant product or technology allows them to better exploit the potential of scale and learning effects created by the shaper firm. These finding re-emphasize the importance to link up with the technology that will become the market standard.

Finally, we find that the degree of compatibility does *not* influence the relationship between the potential, and the actual realization of scale and learning effects. The finding runs counter to existing literature (Brynjolfsson and Kemerer, 1996; Church and Gandal, 1992; Farrell and Saloner, 1992; Gandal, 1995), that points to the importance of compatibility in markets where network effects play an important role. This finding also runs counter to our intuition, which leads us to assume that in situations where complementarity has a significant moderating effect, the closely related concept of compatibility would also be of influence. A possible explanation for this finding may be that the majority of products and product technologies in our sample are highly compatible to other products in the firms' principal served markets.

In summary, managers have to recognize that self-reinforcing mechanisms exist both in their market as well as within their firm. The interrelationships between the market-bound and firm-bound mechanisms can generate complex, often unexpected, and sometimes unpredictable market outcomes. Our results shows that self-reinforcing mechanisms are present across different industries and not just in high-tech or software industries as is often assumed (Arthur, 1996). Therefore, the strategic and tactical implications resulting from our study may be important to managers across different industries.

8. Limitations and further research

This study is limited by several factors that should be addressed in future research. First, although the study included data from manufacturing firms in different industries, the hypothesized relationships should be tested with other independent samples. Second, data for this study were collected using the key informant approach, which precludes a thorough analysis of validity and measurement error issues. It would be interesting to use multiple respondents at different positions within the organization in future research. This would enable us to use multi-level modeling techniques to test the hypotheses. Third, because of the cross-sectional nature of our study, causal inferences need to be confirmed by longitudinal studies, because self-reinforcing mechanisms are dynamic by nature. Fourth, this study focused on the moderating effects of product and product technology related characteristics (i.e., complementarity and compatibility). Future research should consider including also firm (e.g., firm strategy and size) and market (e.g., market turbulence and competitive intensity) as moderating variables. Fifth, this study focused on the market-level influence of interaction and network effects on the potential to realize scale and learning effects. Given that other factors at both the firm level and the market level are also likely to influence the potential and the actual realization of scale and learning effects, there might be some over-estimation bias in the parameters. Finally, this study looked at interaction and network effects from the perspective of the manufacturing firm. Future research may consider investigating interaction and network effects from another market participant's perspective.

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Figure 1: Conceptual framework

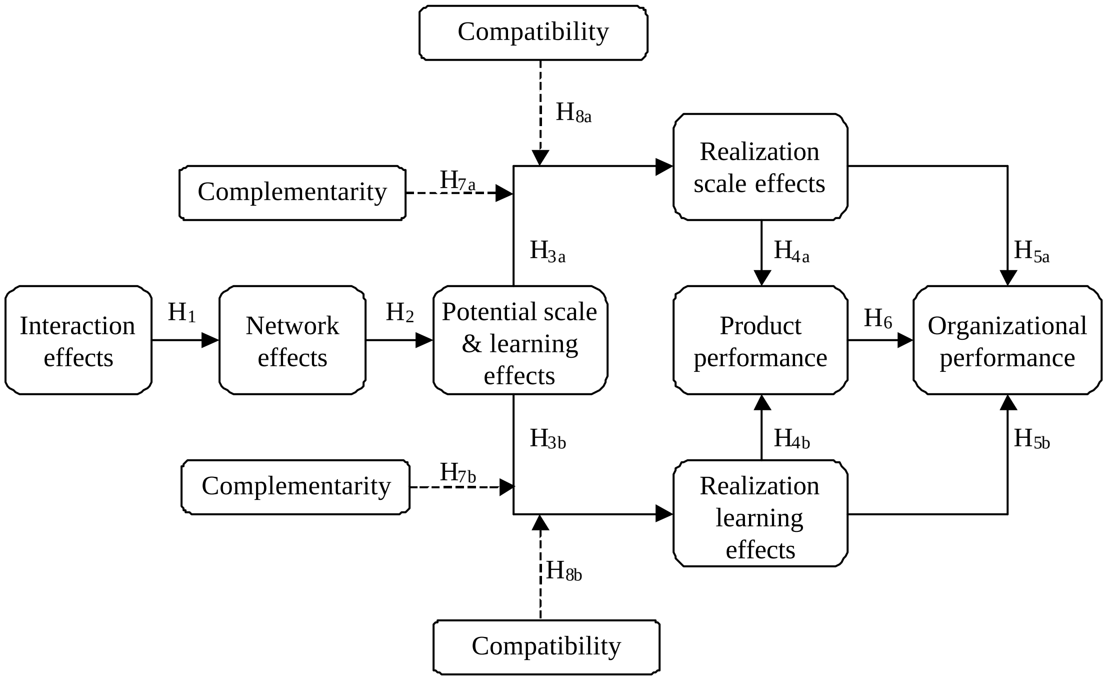

Table 1: Sample Characteristics

Industry:		Firm size in no. of employees:		Respondent duration of employment:		Respondent education:	
- Metal products	31.9%	= 25	10.9%	0-1 years	15.2%	University	19.3%
- Machinery	33.9%	26-50	33.5%	2-3 years	20.7%	Higher vocational	53.1%
- Office machinery and computers	0.4%	51-100	32.7%	4-7 years	23.9%	Intermediate vocational	13.8%
- Electrical machinery and supplies	3.1%	101-200	13.6%	8-14 years	17.2%	Other	13.8%
- Audio, video and telecommunication	1.2%	>200	9.3%	15-22 years	13.2%		
- Medical instruments	6.2%			> 22 years	9.8%		
- Cars, trucks and trailers	5.1%						
- Transport (not cars, trucks or trailers)	5.1%						
- Computer service and IT agencies	13.1%						
	+		+		+		+
	100.0%		100.0%		100%		100%

Table 2: Psychometric Properties of the Scales

	Mean	SD	Item deleted	Items retained	1.	2.	3.	4.	5.	6.	7.	8.	9.	Composite reliability	AEV
1. Interaction effects	4.70	1.61	2	6	*0.86*									0.87	0.53
2. Network effects	4.48	1.51	2	6	0.75	*0.81*								0.82	0.58
3. Potential scale and learning effects	4.72	1.41	0	3	0.18	0.19	*0.70*							0.73	0.48
4. Actual realization of scale effects	4.49	1.81	0	2	0.11	0.09	0.20	*0.89*						0.91	0.78
5. Actual realization of learning effects	4.91	1.72	0	1	0.21	0.18	0.15	0.27	*n.a.*					n.a.	n.a.
6. Product performance	5.65	0.86	3	7	0.11	0.08	0.08	0.13	0.20	*0.72*				0.75	0.49
7. Organizational performance	4.91	1.17	0	7	0.15	0.15	0.06	0.14	0.23	0.36	*0.89*			0.89	0.53
8. Complementarity	5.30	1.73	0	2	0.03	0.02	0.15	0.05	0.22	0.12	0.11	*0.72*		0.73	0.49
9. Compatibility	6.23	1.30	0	2	0.01	0.02	0.11	0.03	-0.00	0.12	0.05	0.41	*0.71*	0.72	0.58

Note: - Reliability coefficient is shown *in italics* on diagonal
- SD = standard deviation; AEV = average extracted variance
- n.a. = not available

Table 3: Direct Effects (unstandardized estimates and t-values between brackets)

Path from: \ Path to:	Network effects	Potential scale and learning effects	Actual realization of scale effects	Actual realization of learning effects	Product performance	Organizational performance
- Interaction effects	**0.68 (16.36)**	--	--	--	--	--
- Network effects	--	**0.23 (3.83)**	--	--	--	--
- Potential scale and learning effects	--	--	**0.23 (2.90)**	**0.18 (2.39)**	--	--
- Actual realization of scale effects	--	--	--	--	**0.06 (2.13)**	0.03 (0.80)
- Actual realization of learning effects	--	--	--	--	**0.12 (3.81)**	**0.11 (2.61)**
- Product performance	--	--	--	--	--	**0.50 (6.21)**
- Organizational performance	--	--	--	--	--	--

Model fit: χ^2/df=1.98; GFI=0.97; AGFI=0.93; NFI=0.93; NNFI=0.92; CFI=0.96; IFI=0.96; RMSEA=0.07).

Note: T-values above 1.96 ($p<0.05$) are shown in **bold**.

Table 4: Indirect and Total Effects (unstandardized estimates and t-values between brackets)

Path to:	Network effects		Potential scale and learning effects		Actual realization of scale effects		Actual realization of learning effects		Product performance		Organizational performance	
Path from:	Indirect	Total	Indirect	Total	Indirect	Total	Indirect	Total	Indirect	Total	Indirect	Total
- Interaction effects	--	**0.68 (16.36)**	**0.15 (3.72)**	**0.15 (3.72)**	**0.04 (2.29)**	**0.04 (2.29)**	**0.03 (2.01)**	**0.03 (2.01)**	**0.01 (2.15)**	**0.01 (2.15)**	**0.01 (2.06)**	**0.01 (2.06)**
- Network effects	--	--	--	**0.23 (3.83)**	**0.05 (2.31)**	**0.05 (2.31)**	**0.04 (2.03)**	**0.04 (2.03)**	**0.01 (2.17)**	**0.01 (2.17)**	**0.01 (2.07)**	**0.01 (2.07)**
- Potential scale and learning effects	--	--	--	--	--	**0.23 (2.90)**	--	**0.18 (2.39)**	**0.04 (2.64)**	**0.04 (2.64)**	**0.04 (2.47)**	**0.04 (2.47)**
- Actual realization of scale effects	--	--	--	--	--	--	--	--	--	**0.06 (2.13)**	**0.03 (2.01)**	0.06 (1.52)
- Actual realization of learning effects	--	--	--	--	--	--	--	--	--	**0.12 (3.81)**	**0.06 (3.24)**	**0.17 (3.88)**
- Product performance	--	--	--	--	--	--	--	--	--	--	--	**0.50 (6.21)**

Note: T-values above 1.96 ($p<0.05$) are shown in **bold**.

Table 5: Test for the Moderating Effect of Complementarity and Compatibility

Moderator:	Equality constraint model:	Free model:	Chi-square difference:*
- Complementarity	χ^2=141.78 (df=45)	χ^2= 128.91 (df=43)	$\Delta\chi^2$= 12.87 (Δdf=2)
- Compatibility	χ^2= 96.68 (df=45)	χ^2= 94.73 (df=43)	$\Delta\chi^2$= 1.95 (Δdf=2)

* Critical $\chi^2_{(2)}$ value is 9.21 at the 1% level.

Table 6 Estimates of Free Model for Complementarity (unstandardized estimates and t-values)

		Low complementarity:		High complementarity:	
Path to:	From:	Estimate:	T-value:	Estimate:	T-value:
- Actual realization of economies of scale	- Potential to realize scale and learning effects	**0.19**	**2.31**	**0.25**	**3.05**
- Actual realization of economies of learning	- Potential to realize scale and learning effects	0.08	1.01	**0.23**	**3.11**

Note: T-values above 1.96 (p<0.05) are shown in **bold**.

Appendix: Items

Instruction:
Please use the following scale to indicate your extent of agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

Product-related interaction effects:
In the market the attractiveness of our primary product will increase if:
… it becomes known that opinion leaders among customers use this product.
… it becomes known that lead suppliers offer this product.
… it is expected that more customers will start to use this product.
… it is expected that more suppliers will start to offer this product.

Technology-related interaction effects:
In the market the attractiveness of our primary product 's technology will increase if:
… it becomes known that opinion leaders among customers use products based on this product technology.
… it becomes known that lead suppliers offer products based on this product technology.
… it is expected that more customers will start to use products based on this product technology.*
… it is expected that more suppliers will start to offer products based on this product technology.*

Product-related network effects:
In the market the attractiveness of our product will increase if:
… more customers use this product.
… more suppliers offer this product.
… more customers use complementary products.
… more suppliers offer complementary products.

Technology-related network effects:
In the market the attractiveness of our primary product's technology will increase if:
… more customers use products based on this product technology.
… more suppliers offer products based on this product technology.
… more customers use complementary products based on this product technology.*
… more suppliers offer complementary products based on this product technology.*

Note:
* Item deleted

Instruction:
Realization of economies of scale means that through a higher sales volume in units your firm is able to:
- lower the fixed costs per unit volume.
- lower the variable costs per unit volume.

Realization of economies of learning means that your firm is able to increase efficiency through increasing knowledge and experience. Here: 1 = very low potential, 7 = very high potential.

Potential to realize scale and learning effects:
What is the potential for your primary product to:
… realize economies of scale with regard to fixed costs.
… realize economies of scale with regard to variable costs.
… realize economies of learning.

Instruction:
Please use the following scale to indicate how well your firm utilizes the potential to realize economies of scale and learning. Here: 1 = very poor utilization, 7 = very good utilization.

Realization of scale and learning effects:
To what extent has your firm been able to utilize the potential to realize:
… economies of scale with regard to fixed costs.
… economies of scale with regard to variable costs.
… economies of learning.

Instruction:
Please use the following scale to indicate your extent of agreement about how well your primary product has performed on each of the performance indicators mentioned below. Here: 1 = very poor and 7 = very good.

Product Performance:
- Customer acceptance.
- Customer satisfaction.
- Unit sales volume.
- Sales growth.
- Market share.
- Contribution margin.
- Price/quality ratio.
- Development costs.*
- Integral cost price.*
- Product innovativeness.*

Appendix (continued)

Instruction:
Please use the following scale to indicate your extent of agreement about how well your firm has performed over the last year relative to competitors on each of the performance indicators mentioned below. Here: 1 = very much poorer and 7 = very much better.

Organizational Performance:

- Sales growth.
- Market share
- New product success.
- Sales share new products (i.e., products introduced last 5 years).
- Operational cash flow
- Profitability
- ROI or IRR.

Note:
* Item deleted

Instruction:
Please use the following scale to indicate your extent of agreement about the extent to which customers use your primary product and product technology together with complementary products?
Here: 1 = very small extent, and 7 = very large extent.

Complementarity:
To what extent:
… do customers use your primary product together with complementary products?
… do customers use your product technology together with complementary product technologies?

Instruction:
Please use the following scale to indicate your extent of agreement about the extent to which your primary product and product technology is compatible with complementary products and product technologies.
Here: 1 = very small extent, and 7 = very large extent.

Compatibility:
To what extent:
… is your primary product compatible with complementary products?
… is your product technology compatible with complementary product technologies?

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