Complexity and Complicity in Mobile Telecommunications:
The Effect of Network Externalities and Isomorphic Strategy

Nominated for BEST PAPER AWARD, Strategic Management Society, USA, 2004

Abstract

The new information economy acts as a microcosm where the dynamics of complexity are present through the pervasive effects of increasing returns. Network externalities are the ubiquitous force behind winner-takes-all scenarios where only the strongest firms survive. The effect is evident in cases such as Microsoft's quasi-monopoly and eBay's dominance of the consumer and small business auctions market. Interestingly however, many important industries exhibiting strong network externalities, have emerged with no dominant winner and the competitive environment is preserved.

This empirical study of the UK mobile telecom industry, which tracks an 18-year history of the mobile network operators as well as the strategies and product diffusion patterns of the networks, found firms counteracting winner-takes-all forces.

Results indicate the presence of complex adaptive behavior between competing firms. Strategies are reconfigured to ensure the collective survival of all operators in the industry. The probability that one firm will dominate and that the rest will fail is eliminated. A complex set of isomorphic strategies emerges at the levels of network platforms, technical standards and consumer platforms. Through strategic herding, network externalities are exploited to act for the benefit of the whole industry causing competitors' market shares to converge dramatically to equal levels.

Keywords:
Complex adaptive systems, increasing returns, network externalities, isomorphic strategy

1. Introduction

The new information economy acts as a microcosm where the dynamics of complexity are manifest through the pervasive presence of increasing returns. Network adoption patterns for network products, such as computer operating systems, the internet, software packages and mobile telephones, show strong increasing returns characteristics. The rate of increase in demand exhibits a gradual rate of initial adoption, followed by an exponential increase in demand once a critical mass of users is reached.

In complexity theory, increasing returns such as network externalities are a form of positive feedback reflected in our linguistic expressions such as 'the rich grow richer' and 'success breeds success.' The implication of this concept is that companies with network platforms that are being adopted rapidly will gain even more momentum to diffuse further into the population. Consequently, it becomes almost impossible for other companies to thrive in the market. This 'winner-takes-all' scenario is evident in Microsoft's quasi-monopoly and eBay's dominance of the consumer and small business auctions market.

However, whilst increasing returns predict that network markets should tip in favor of a dominant player, we observe important network industries, such as telecommunications, where the winner-takes-all scenario does not occur and the competitive environment is preserved. The industry players are not seen to exploit the monopolistic consequences of network externalities.

The complex characteristics of network externalities are exploited for the benefit of all the firms in the industry. The mobile communications industry provides a fascinating case of dynamics where interacting forces operate to retain a threshold of power over the outcome of the networks. Interdependence in network industries is a scenario that is unique in terms of theory, but one which is prevalent in the new information economy.

The emerging science of complexity may provide new perspectives in strategy that combine concepts that are under investigated by research in the field (Stacey, 1995). The relevance of complexity to network industry strategy lies in the presence of positive feedback, non-linearity and increasing returns characterized by network externalities.

In the following sections we look at the non-linear dynamics of networks and discuss aspects of complexity latent in the structure of telecommunication platforms.

2. The Power of Network Externalities

Network externalities[1] are pervasive in the new information economy. They are typical of information-based products that are stored, recalled, copied, filtered, seen, transmitted and received (Shapiro, Varian, 1999). Information products become more attractive, more developed and more useful as they become widely adopted by consumers.

This mechanism exhibits a form of increasing returns captured in the work of Arthur (1989) and Metcalfe (1994). Arthur applies network externalities to discuss technology adoption of fax machines, video recorders, operating systems, computer hardware for telecommunications and internet-based technologies. Metcalfe's Law states that, under certain conditions, the utility of a network increases with the square of the number of users.[2]

Liebowitz and Margolis (1995) view network externalities as the increase in the net value of an action that occurs as the number of agents taking equivalent actions increases. Katz and Shapiro (1985) define network externalities as the increasing utility that a user derives from consumption of a product as the number of other users who consume the same product increases.

Network externalities work similarly in language adoption. The number of people speaking a language across different borders is likely to affect which language will be adopted internationally. A decision to adopt a second language is subject to the expected size of the network of speakers. The adoption of the language locks into a positive feedback spiral that increases as the language is adopted by more users.

Indirect network externalities are created by the presence of complementary goods, particularly in the software industry. Indirect network externalities occur when the value of a product is amplified as the number of the complementary goods or services increases. In the computer industry, indirect network externalities are referred to as the 'hardware-software paradigm'. The success of an operating system for personal computers depends on the variety of

[1] Network externalities are also referred to as network effects.

[2] The total utility (U) of a network is equal to N(N-1) where N is the number of people on a network. The values of N(N-1) and N^2 become more equal for increasing values of N. Hence Metcalfe's expression "square the people" as a measure of gauging network utility.

software applications available in the market. The value given to the product may depend more critically on software applications.

Mobile communications networks experience positive feedback on both the demand and supply sides (McGee, Thomas, Wilson, 2005). On the demand side, the value of a system increases with the increase of its usage, and hence the demand for the product increases. The positive feedback generated by the demand side originates from the entire telecommunications network and not just the networks of the individual companies. The value of a mobile platform is that it is linked to competing mobile and landline networks. On the supply-side, the larger a mobile network becomes in terms of its subscriber base, the more flexible it is to lower its tariffs. Its investment costs in infrastructure would be covered faster than that of smaller networks. The lower the tariffs introduced by a network, the more new subscribers will join the network and positive feedback kicks in.

What fuels the success of mobile communications is the combination of positive feedback from both demand side and supply-side economics. The result is a double effect in which growth on the demand side reduces cost on the supply side and makes the product more attractive to other users, accelerating the growth in demand even further. The situation creates a new set of dynamics for our traditional industrial economy. New types of economies of scale are emerging and winner takes all strategies have become prevalent (McGee, Sammut-Bonnici, 2002).

2.1 Network Externalities and Market Tipping

Market tipping is a result of the bandwagon effect of consumer demand spurred by network externalities. The first companies to set up their businesses in an information-based market have an advantage over later competitors (Mahajan, Peterson, 1985). Product adoption gains momentum at an increasing rate as more consumers join the platform. The more established markets will benefit from increasing returns to scale and from positive feedback on the demand side. The effect strengthens initial achievements and triggers the early defeat of new entrants (Arthur, 1996). Competing technology may lose ground as the more established technologies continue to grow in strength. A market that moves in favor of a particular product or standard is said to have 'tipped'.

After the tipping point a market could be locked into that product for some time. This is called excess inertia that could persist even when a technologically more advanced standard is put on the market (Katz, Shapiro, 1985; Farrell, Saloner, 1986a). Lock-in effects exist when it is costly to switch from one competing standard to another. There is an investment in skill and competence when switching from Windows to Linux. When an airline switches from flying Boeing to Airbus aircraft it must invest in re-training its crews and engineers, often making existing knowledge redundant. Network theory predicts that network systems will become larger in order to achieve stronger returns to scale.

The rapid progression of market tipping is linked to critical mass. At the critical mass point the utility of the network increases rapidly, and it becomes considerably easier to gain new subscribers. Shy (2000) describes critical mass, as the point at which a network has the minimal number of users needed to induce all potential consumers to adopt the technology. At the critical mass point the profile of the network user shifts from early adopters to a wider market base. The concept of critical mass is derived from physics, where it is used to describe nuclear fission. Schelling's (1978) description of collective behavior, does not address market activities, but it has inspired research in the diffusion of innovation.

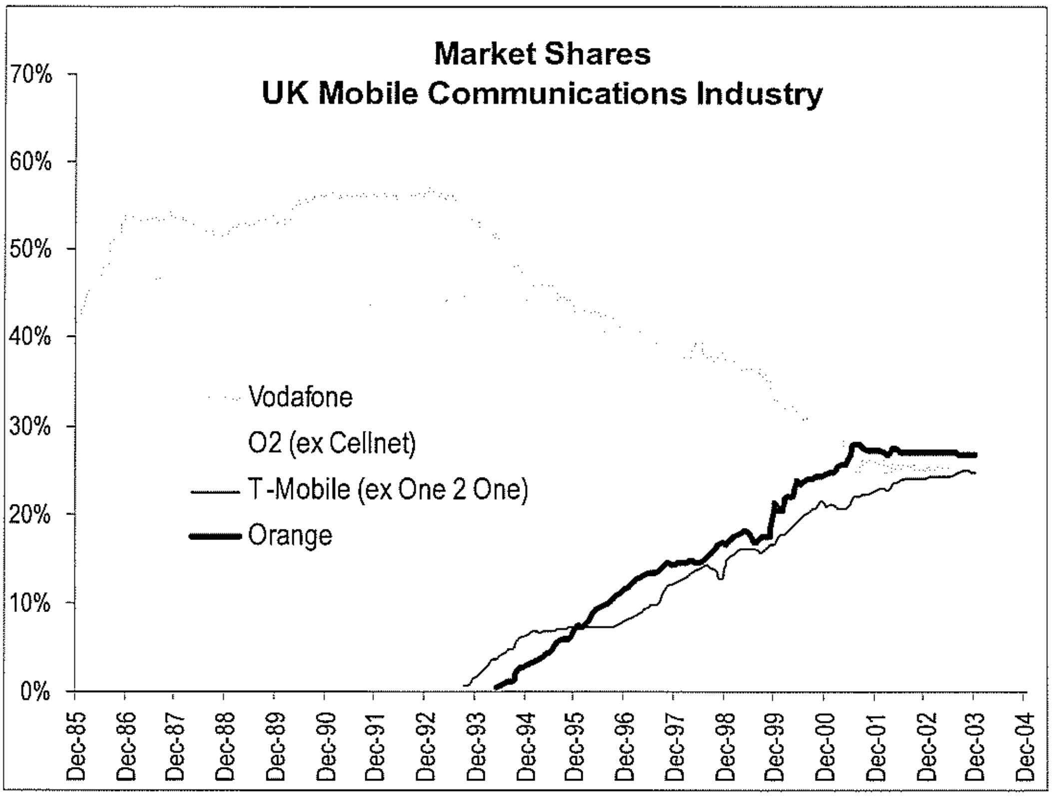
Market tipping and market share dominance are expressed through the models developed by Arthur (1989), Redmond (1991), Clark and Chatterjee (1999). Arthur explains how markets tip in a simple two-product model. The model consists of two types of products. The products are substitutes, which implies that consumers will choose only one of the products. In Arthur's model consumer utility for a product is governed by intrinsic utility and network utility.

$$U_A = A + r\,N_A\,,\ U_B = B + r\,N_B$$

U_A and U_B are the total utilities of products A and B respectively. The constants A and B reflect the intrinsic utility of the products. N_A and N_B are the number of adopters of products A and B. The importance given to network adoption is denoted by 'r'. Consumers will choose A if $U_A > U_B$. A quick calculation with dummy variables will show that for value of $r > 0$, the equation would always lead to lock-in as N grows large for one of the two products.

Clark and Chatterjee (1999) build on the modeling approach of Arthur (1989) and Redmond (1991) to include variation in the strength of network externalities and their effect on market shares. Dominant market shares can arise from network effects. The level of probability of this occurring depends on the characteristics of the consumer decision-making process in the market. However, Arthur, Redmond, Clark and Chatterjee's models do not explain how some markets fail to tip even in the presence of strong network externalities.

Figure 1: Market Shares in the UK Mobile Communication Industry



2.2 The Absence of Marketing Tipping in Mobile Telecommunications

In spite of the monopolistic consequences of network externalities, several network industries fail to tip preserving the competitive environment. The UK mobile communication market did not move towards a dominant player. By the end of 2003 the UK market shares in terms of network users converged to 24%, 24%, 25% and 27% for Vodafone, O2,[3] T-Mobile[4] and Orange respectively (Figure 1). The company with the largest market share was the last to enter the market. The four companies represent the full population of mobile network operators servicing over 50 million subscribers (Figure 2).

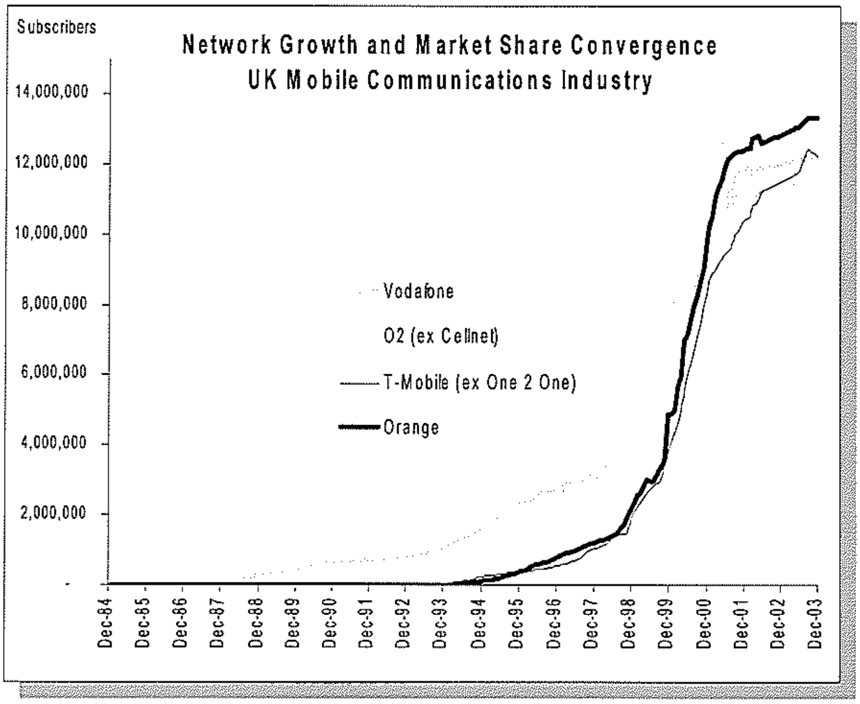
In view of the existing knowledge on network externalities, we develop our research question regarding the nature of consumer adoption of competing interconnected networks: How is the competitive environment preserved in network industries despite the monopolistic consequences of network externalities?

Whilst the theory of network externalities points us towards an interesting journey to unravel increasing returns dynamics, it does not pose questions on what may be the cause of the preservation of the competitive environment. There is a need for a more critical conceptual approach to study market development that captures the complexity of the development processes (Sammut-Bonnici, Wensley, 2002).

We look at complexity theory to introduce the dynamic perspective in this research. Complexity endorses the underlying mechanism of non-linearity in network externalities, whilst recognizing the presence of self-organizing mechanisms. Complexity sheds light on the processes of co-operation, adaptation and outcomes as factors that create change and transformation. We investigate patterns of adaptive behavior which dampen the monopolistic consequences of network externalities.

[3] O2's previous brand name was Cellnet.
[4] T-Mobile's previous brand name was One 2 One.

Figure 2: UK Mobile Market Development over 18 years



3. Complexity and Telecommunications Networks

Telecommunications networks reflect the original Greek roots of the word 'complexity', which means 'entwined together as in a piece of woven cloth' (Battram, 1999) . Physical platforms in mobile communications are the technical networks connecting mobile phones, base stations, mobile exchanges and landline exchanges. The system extends from local, to national and to an international level (Figure 3). In mobile network the end nodes representing the users would be 'fuzzy' because of the movement of the end user.

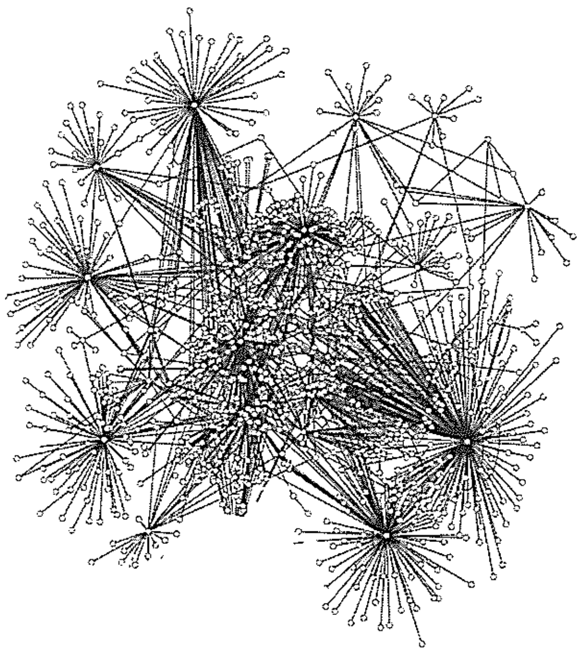
Linguistically, complexity is equivalent to 'complicatedness': a system with several nodes and interconnections. Systems are complex not just because of its different components but because of its interconnectedness. The complexity within mobile telephone networks lies in the ability of each free moving end node to connect to any other node via a plethora of connecting exchanges, across multiple layers of technical platforms and compatible standards.

3.1 Complexity and Network Interconnectivity

Telecommunications platforms have had to cope with the complexity of interoperability among different systems, and to master the agility required to shift rapidly to newer standards. Interoperability exists between platforms of different mobile network operators in the same country, or different platforms in different countries. Physical platforms have evolved from the simple structures such as the older regional railway systems, to a complex structure of interconnected sub-platforms.

Complex networks such as telecommunications are the subjects of a new field of research that applies graph theory (Buchanan, 2002). Networks are mapped as graphs that are composed of a collection of dots and connecting lines. The dots are associated with the elements of the system. The lines correspond to the interactions or connections between pairs of elements. A similar approach is adopted in network economics (Economides, 1996; Gottinger, 2003).

Figure 3: Telecommunications Networks – Nodes and Interconnections



Telecommunications networks fall under an 'integrative class' of complex networks, because of their tendency to integrate information from a large number of sources. Other networks that form part of this class are air traffic control and management systems, military command and control systems and electricity network sharing. The integrative class is characterized by: a large number of diverse information sources; the need to interoperate and integrate both equipment and information; the need to detect events in a complex network of connections; the need to operate across techno-socio barriers; and the need to operate as an open system which includes interoperability, portability, scalability and the need to evolve.

The aspect of interconnectivity in the mobile communications industry creates a more homogenous market environment: network services from any firm provide largely the same function.

Interestingly models of market development of interconnected products are a very recent addition to the literature on network industries, even though most ICT products run on interconnected platforms. By adding converter technology to achieve compatibility, Gottinger (2003) produces interesting changes to Arthur's model (1989) discussed earlier. Parameters k and c are introduced assuming values from 0 to 1, which represent the compatibility of platform A and B and the reciprocal compatibility of B and A, respectively. The value of 1 represents perfect compatibility and 0 reflects total incompatibility. Gottinger's formula can be collapsed to Arthur's formula when k=c=0.

$$U_A = A + r\,N_A + kN_B\,,\ U_B = B + r\,N_B + cN_A$$

According to this model the introduction of a partial two-way converter will prolong the time required for a market to tip in favor of one network or the other. The introduction of a perfect two-way converter where k=1 will prevent any technology from emerging as the standard. The value 1 leads network externalities to be effectively eliminated from the situation as independent forces on the respective network. The elimination of network externalities from Gottinger's formula throws light on the conundrum of market share convergence in the UK mobile phone industry, but it does not reflect the real mobile communications environment. Network externalities remain strong and real as the adoption by consumers will fuel further adoption. What the formula suggests is that in the UK mobile communications industry network externalities act equally on the competing firms based on the number of users on the whole industry's network platform.

In view of the concepts of network connectivity, the research question regarding the preservation of competition, which we framed earlier is reflected in the following hypothesis:

HYPOTHESIS 1: *Network externalities derived from the platform of the whole industry, are expected to be similar to those derived from a single constituent network.*

The scenario reflected in the hypothesis implies that the decision of a new user to connect to a mobile platform is influenced by the number of users on the whole industry's platform, rather than the number of users on the individual firm's platform.

3.2 Complex Adaptive Systems

The mobile communications network acts as a complex adaptive system. It comprises several interacting agents and components. The behavior of each agent is generally definable. However, the behavior of the system is emergent and shows signs of intelligence in the way it learns, reacts and adapts to changes in the larger network. For example, technological capability is in constant evolution. Different parts of the communications system around the globe are updated with these technologies. Over the years the telecommunications industry has acquired collective knowledge of how to introduce new technologies whilst retaining the compatibility of its sub networks. Other forms of adaptive behavior appear in the continuous development, selection and coordination of communication protocols. Similar complex adaptive systems are everywhere in the economy and in the natural environment in the form of stock markets, consumer markets, social groups, cities, the brain, swarms, and rainforest systems, among many others. (Gell-Mann, 1995)

A complex adaptive system starts with simple rules and goals for the individual, which create an organized complex formation. The result is a configuration that seems to have its own life, which is capable of moving in harmony without a leader or external control. The process is bottom up starting with a few simple rules for individuals, which create a complex system. A random variation process of generating rules and tendencies usually activates self-organization. The process creates an organized formation referred to by von Foerster (1962) as the 'order from noise' principle and the 'order through fluctuations' mechanism by Prigogine and Stengers (1984). Self-organization requires continuous adaptation and the presence of a powerful interrelationship between entities in a system. Capra (1983, p. 516) asserts: 'Detailed studies of ecosystems over the past decades have shown quite clearly that most relationships between living organisms are essentially co-operative ones, characterized by co-existence and interdependence.'

At the level of technological standards and physical platforms, adaptive behavior arises from competition and co-operation among the system agents. In this environment competition becomes the driving force behind co-operation. Competing firms are observed to spontaneously forge alliances and symbiotic relationships in order to increase the industry further. The larger the industry, the more space for all players, and the higher the probability that more companies would survive and flourish. Competition and co-operation are closely interrelated: alliances emerge at every level and in every kind of complex adaptive system, from biology to economics to politics (Axelrod, 1997).

Moore (1996) urges businesses to adopt a co-operative ecosystem model. He describes how Intel developed a co-evolving network of businesses to become a major supplier of microchips. The feedback loop in co-evolution is towards more complexity. There is also the possibility of a decline in diversity, as we will see in the case of the mobile communications industry. When environments are competitive and aggressive from the start up phase, co-operation emerges between the parties for the benefit of all.

Cohen and Stewart (1994) explain the process through the concept of 'simplexity' and 'complicity'. 'Simplexity' is the tendency of a single, simple system to generate highly complex behavior. This leads to 'complicity', which is when two or more systems interact in a mutual feedback that changes them both, leading to behavior that is not present in either system on its own. This is also a characteristic of emergence through co-evolution, which is the interdependence between a system, or an organization and its environment. Lewin et al (1999) look at strategic and organization adaptations as co-evolving with fluctuations in the environment, population and organizational forms. Examples of such fluctuations would be competitive dynamics, technological and institutional changes.

Our next hypothesis is developed in view of the theory of complexity, which encompasses both dynamics of interacting agents, system rules, and co-operation in the form of complicity.

HYPOTHESIS 2: *Market shares of interconnected networks converge as a result of complex adaptive behavior of competing firms, whereby the industry is configured for the collective benefit of the constituent firms.*

4. Methods

The above hypotheses represent two models. The first hypothesis pertains to the relationship between complex increasing return dynamics (in the form of network externalities) and the platform performance of the respective firms. The second hypothesis pertains to the relationship between complex adaptive behavior and platform performance. Performance is defined in terms of the number of users who adopt the network platform, in accordance to network diffusion and network economics theory.

The basis of network economics provides a sound point of departure for our research on network externalities. It leads the investigation into the nature and extent of the power of network effects and exponential mechanisms of demand. Whilst the theory of network economics points us towards an interesting journey to unravel network externality dynamics, it does not pose questions on how the competitive environment is preserved. As a positive theory, network economics does not encompass other modes of change. We look at complexity theory to introduce a dynamic perspective in this research.

In revealing patterns of complex behavior within an industry, a dynamic vocabulary must be adopted. By bringing in the language of complexity we gain a broader terminology. The choice of terms in previous work on industry evolution (Nelson, Winter, 1982) implies that some absolute level of a particular mode of evolution can be measured or graded in a positivist manner. This is similar to Rumelt's (1974) concept that the language in research on strategy content implies that strategy can be measured or graded in a positivist manner. Complexity evolutionary theory has a more dynamic view of the development of systems. It acknowledges both self-reinforcing increasing returns and self-balancing mechanisms as agents of change and development.

4.1 Sample selection:

The UK mobile communications industry was chosen as the site for the investigation of market development in the presence of network externalities. The UK was selected as an industry base because it is the country which shows the strongest preservation of the competitive environment in the mobile communications industry in the European region. The companies were chosen to maximize on the organizational dimensions of endogenous and exogenous factors that the companies had faced during the founding period. The selection of the complete population of firms is critical to eliminate alternative accounts of patterns in corporate emergence. The companies under review: Vodafone, O2, T-Mobile and Orange, constitute all the network providers in the mobile telephone industry for the country. The study covers the history of the UK mobile communications industry from its inception date in 1985 to 2002.

4.2 Data Collection

"History is the version of past events that people have decided to agree upon." This quotation by Napoleon Bonaparte (1769-1821) represents the key difficulties in collecting historical information. The issues of interpretation and recollection of past events was a major concern when designing the research process. In order to build a comprehensive history of strategies and outcomes the data source had to be free from these challenges. We looked at historical research methodologies in order to construct a robust set of data that is not modified by the lag between the time of occurrence of the event and the time of collection. The information source had to consist of information that was compiled in real time as the events were occurring. The source of information we selected was the Lexis Nexis online database. The electronic catalogue offered the facility to look for industry specific commentaries from major journals and newspapers from the UK and internationally. Data was mined using standard search conditions which controlled the period under review and the frequency of incidence of the company names.

We obtained both quantitative and qualitative information in order to construct a longitudinal history of the strategic events initiated by the industry players. The time series for the four companies were compared. The industry's historical date was channeled into two key databases: the Subscriber Database and the Events Database.

The Subscriber Database contained information on network diffusion, and how the consumer market adopted the mobile communications networks. The investigation of network externalities required quantitative data on the demand function of the industry. For this purpose we constructed a subscriber database containing numeric information on the acquisition of new customers by the mobile network companies on a monthly basis. The database helped us build a clearer picture of patterns in the development of the industry's demand. The database consists of over 200 records with 2,420 data elements with fields for units of time, industry network size, and firms network size on a monthly and on a cumulative basis.

The second database, the Events Database, provided detailed information on the nature and timing of the marketing activities of the companies in our sample. The database took the form of a case study archive, which catalogued all the events happening in the industry over eighteen years. The database supported a detail case history of some 3,000 events, which were identifiable through the date of occurrence and coded by type of activity. The database provided a solid basis for data mining and supported several analytical configurations. Elements of the industry's history were rapidly searchable. Through the codification of longitudinal data we were able to build a history of the mobile communications industry based on multiple levels of temporality and the role of the various players in the industry.

The methodology we applied improved on the traditional case study methodology of building a fixed case history and then proceeding with extracting inferences from it. We have developed a case study in the form of an events database, which catalogues all the events in the industry's life cycle from inception to the present date. This innovative approach to developing comprehensive case studies has significant advantages over the traditional method. Firstly, the case study database supports a more detailed case history that is not limited by the context of a condensed case study, as found in most research projects. Secondly, since the case history is retained in its complex state, we reduce the issue of researcher bias. Bias occurs because what is included or excluded from the case study would inevitably be influenced by the researcher's perspective of what is important. Thirdly, since the database is coded by event title, date, and event type it provides a basis for data management and enables many useful configurations of analytical possibilities. Elements of the case study are rapidly searchable. Fourthly, we retain the ability to build a traditional descriptive case study at any time from the case study database. Through this technique we were able to efficiently build traditional case studies on corporate ownership and supply chain history, based on multiple levels of temporality. The fifth advantage of the database is the opportunity it provides for interlinking events and time frames for a more detailed multilevel form of analysis.

4.3 Quantitative Data Analysis

The research looked at a complex chain of events over time. Through pattern matching, we compared patterns with theory-based predictions and uncovered mechanism of a self-reinforcing and self-balancing nature. The process was completed through application of standard quantitative and qualitative techniques.

A cross-correlation method of analyzing time series was applied to gauge the presence of network externalities by looking at the correlation between subscriber acquisition in period (t) and the total size of the industry networks in (t-1). The correlation function provides a measure of the similarity between the time series data we were analyzing. This method had a number of strengths. Firstly, the approach did not require the summing of data over time and hence met our requirement of preserving the time component of the data. Secondly, by measuring the degree of similarity over a continuous range of time frames it identified where the degree of similarity was strongest. Thirdly, the measure of similarity could be selected according to the nature of the data, and hence can be applied to the data sets.

The research process necessitated the identification of critical mass, which was evaluated in terms of inflection points on the demand function. An inflection point occurs when the rate of change, or the gradient of the curve, changes in magnitude and direction. A typical diffusion of innovation curve has an s-shape with a first-order inflection and two second-order inflection points (Valente, 1995).

Through another set of correlation analysis we searched for marketing effects by correlating the occurrence of marketing activities and the increase in the subscriber population. Dichotomous variables were applied to preserve the temporal component of the data. Data of the type 0/1 reflected the presence or absence of a particular strategic marketing action. This type of analysis has been used in a number of fields (Brock, Le Baron, 1996). The technique is applied in the natural sciences, in particular signal processing which deals with typical 0/1 type events.

The research hypothesis developed from the complexity framework required us to identify cross industry patterns of strategy over time of the network operators. In order to achieve this we obtained longitudinal data to construct time series of the strategic events initiated by O2, Vodafone, Orange and T-Mobile. The time series for the four companies are compared. The accomplishment of Miller and Friesen (1984) and Meyer et al (1993) in creating rich time series from archival data, was used as a basis for the data collection methodology.

In order to separate firm attributes from those of the strategies being pursued we needed to investigate multiple types of strategy which were relevant to the consumer decision making process when choosing a network. Hence marketing strategies were chosen as the relevant set of strategies. The marketing typology needed to be categorized using a set of standard descriptors. Such a typology had to be well supported by the existing conceptual framework. The key areas of strategic marketing: product, price, distribution, and promotion, were selected and sets of further subgroups were created.

5. Results

5.1 Cross Correlation Time Series Analysis

In order to address the first hypothesis we apply a cross correlation time series analysis on the increase in subscribers and the size of the existing network platform. The time frame of the correlation data is set to period (t) for new subscribers and period (t-1) for the number of subscribers on the existing network. We establish whether network externalities are present and measurable at the level of the whole industry. We then investigate the strength of these externalities by analyzing the correlation coefficients for new subscribers per network against the existing number of subscribers at the level of: (i) the same network; (ii) the competitors' networks; and (iii) the total industry network. Table 1 summarizes the correlation coefficients for new subscribers and network size.

The first inference from the results is that all combinations of the matrix are positively related. Network externalities are deemed to be present at the level of the whole industry, exhibiting a correlation coefficient of 0.8 for subscriber growth and the network size of the industry.

(i) The correlation coefficients show a positive relationship between the number of new subscribers per network and the existing number of subscribers on the same network. O2 has the highest correlation at 0.8 and Orange has the lowest at 0.5. Orange has moved from being the smallest network in 1993 to being the largest network in 2004. The shift in its position and the rapid growth in its subscriber base affect the value of the coefficients. To achieve such rapid growth it would have been gaining new subscribers over and above the effects of network utility. The growth rate of Orange's network was faster than the growth rate of the industry platform.

Table 1: Correlation of New Subscribers and Network Size

Correlation Matrix [a,b,c]

	Network Size in month (t-1) from Installed Base				
New Subscribers in month (t)	Industry (1)	O2 (2)	Vodafone (3)	T-Mobile (4)	Orange (5)
1. Industry	0.8 **	0.8 **	0.8 **	0.7 **	0.6 **
2. O2	0.7 **	0.8 **	0.8 **	0.7 **	0.7 **
3. Vodafone	0.6 **	0.7 **	0.7 **	0.5 **	0.5 **
4. T-Mobile	0.7 **	0.7 **	0.7 **	0.6 **	0.6 **
5. Orange	0.6 **	0.6 **	0.6 **	0.6 **	0.5 **

[a] Number of new subscriber to network size correlations represent 648 observations.
[b] N=216 for columns 1, 2 and 3.
[c] N=112 for column 4 and N=104 for column 5.
** = $p < 0.01$

(ii) Interestingly the correlation coefficients for a company's new subscribers and the size of competitors' networks show positive relationships. For example Orange's coefficients are similar whether new subscribers are compared to the company's own platform or to that of its competitors: Vodafone, O2, and T-Mobile. The same results are obtained for the other mobile network operators.

(iii) The correlation results for the subscriber growth of the individual networks and the industry network is 0.8. The correlation results of the respective firms are in the same range. O2 and T-Mobile have a correlation of 0.7. Vodafone and Orange show a correlation coefficient of 0.6 for the utility of the network size of the whole industry.

The empirical results support the first hypothesis. The subscriber increase of one company is influenced by the size of the total industry. The increase in subscribers is interdependent with the utility of the whole network as well as with the utility of competing networks. The utility of other networks has a similar effect on new subscribers to a company's own utility. The implication in mathematical terms is that pervasive network externalities dampen the mechanism of positive feedback on the firms' separate demand functions, and prevents the market from tipping in favor of the larger networks.

We can start to understand why market shares become similar in the UK mobile communication industry: network externalities have a positive indiscriminate effect on the different networks in the industry. Competing firms benefit from industry wide network externalities arising from the combined network size of the whole industry.

5.2 Patterns of Adaptive Behavior

The second hypothesis is tested through an analysis of the nature of firm activity and the effect on the increase in network subscribers. The empirical analysis utilized the subscriber database and the events database. In 18 years of history, there is no visible leader in the UK mobile communications industry. Neither is there evidence of a visible strategy initiator. Analytical mapping of strategy types shows that the network operators were following several steams of activity driven by new technological opportunities and traditional marketing tactics. The findings uncover patterns of co-operative and adaptive behavior aimed at reducing any strategic advantage that arises among competing firms.

The deduction of patterns of strategic behavior required context with regards to what was happening in the industry's environment . We explored industry leadership patterns in terms of constant market share leadership. A second search was conducted for strategy initiators, with the objective of uncovering firms that may not have lead the industry, but may have been a source of innovative strategic action.

We searched for patterns of market leadership in terms of network size and market share. In the period under analysis there is no overall industry leader in the mobile communications industry. O2 held the highest market share from the start of the industry up to 1986 when it relinquished its lead to Vodafone. O2 never regained the pole position but came close to having the same market share as Vodafone in 1996 and in 2001. The O2 story defeats the idea of 'first mover advantage', and the concept of a seed value from the innovations diffusion literature. Vodafone and O2 held their positions at a stable level, until the entry of T-Mobile and Orange in 1993 and 1994. At that point the market share of the older companies diminished as the new companies rapidly increased their hold on the market. Vodafone is seen to have held the longest lead, from 1986 to 2001, yet Orange's meteoric rise is equally significant.

The industry shows evidence of shifting patterns of leadership. Orange's dramatic growth moved it to the top position as from 2001. As the last entrant to the market, and the current market leader, Orange provides another exception to the concept of first mover advantage.

As the search for a visible industry leader yielded negative results, the next line of inquiry searched for companies that were initiating strategic actions. Although industry leadership was absent in terms of network size, there could still be the possibility that a particular company would be the source of innovative actions. The results show that there was no consistent initiator of strategic action in terms of type or volume of initiatives.

The analysis looked into the relationship between performance and strategic activity as well as the nature of strategic behavior. The analytical process to investigate performance looked at consumer demand and the correlation to strategic marketing activity. We assessed the four typologies of activity at the level of product, price, distribution, and promotion.

The empirical analysis finds no correlation between new subscribers and strategic marketing activity, in terms of occurrence and frequency. The data on marketing events was identifiable to precise launch dates, whilst the data on subscriber population was available at monthly intervals. In order to smooth out noise in the data we summed the periods in quarters and correlated the resulting figures.

Whilst the frequency and volume of strategic marketing activity had no correlation to network growth, there were clear occurrences of highly effective strategic actions. A case in point was the introduction of pre-paid telephone cards and the distribution of phone and service packages through supermarkets and high street shops. The effect was to catapult the industry towards its critical mass. The industry entered a period of rapid exponential growth leading to the capture of 80% of the total subscriber market in just three years.

The empirical findings concerning UK mobile communications uncover patterns of homogenous strategic behavior aimed at reducing unfavorable outcomes within the industry. Interestingly strategies were remarkably similar, both in their nature and in the time frame in which they were executed. Each time one of the firms attempted to implement an innovative or merely a different marketing tactic its competitors copied the move within a matter of weeks or months. Efforts towards strategic differentiation were met with a counter mechanism in order to reduce the risk of one competitor succeeding more than the others. Product lines, pricing policies, distribution strategies, and promotional activity were copied by the firms. This leads to very low strategic differentiation between the network operators.

The assessment of the degree of strategic differentiation among the network operators was based on an assessment of their product packages characteristics. The product offering in terms of physical attributes was almost identical, since all the networks were selling products created by the larger global equipment producers such as Nokia, Ericsson, Motorola, and Siemens.

The commercial environment in which the product offering for each company was marketed showed no significant differences in customer cohorts and segments, media advertising and critical distribution activities. Pricing strategies were also very similar, as any innovative pricing policy which had any bearing on the market was quickly adopted as a standard industry practice.

New products and services were typically introduced nationwide in the UK within the same time period. The isomorphic policy of concurrent launches reduces the risk of technological adoption deviation and ensured that competitors remained within similar performance levels.

The low strategic differentiation corroborates concepts that the greater the extent to which the industry's trajectory is uncertain, the greater the rate of isomorphic change (DiMaggio, Powell, 1983). This dynamic is seen in the choice of similar standards as well as the timing of the introduction of new strategies and technologies. The mobile network operators move towards similar marketing network interdependence, standardization of technology and the limitations imposed by regulation. The three factors initiate a constraining process of isomorphism that forced the firms in the industry to resemble each other.

6. Discussion

What is outstanding about the dynamics uncovered in this research is that the UK mobile communications industry operates very differently from a branded oligopoly. The complicity element in the model emerges through the tacit intent of the players to grow the market to its full potential: the larger the market, the larger the market shares of the competing firms. Network externalities become even more powerful as all members of the industry are able to benefit from them through network interconnectivity and isomorphic strategies. These amplify the effect of externalities by stepping up the level of interconnectivity in the system from the perspective of the consumer platform.

In the research sample, the complexity of interrelationships and strategic complicity, as defined by Cohen and Stewart (1994) became embedded in the system as the rules of competition become survival through complicity in order to grow the market collectively. The firms could not afford to be left behind on any new strategic initiative. This initiated a close watch on competitive action followed by a subsequent competitive reaction. The degree of innovation in the strategic reaction was strongly moderated by the limitations of interconnectivity and regulation, as well as by fact that successful strategies were copied. The mechanism effectively eliminated any strategic advantage of individual firms, which would arise from different strategic actions. The competitive system thereby entered into a self correcting, negative spiral of variation reduction in strategic initiatives. Firms' individual strategies became less and less bold as the payback on strategic advantage was only temporary. Major changes in the industries, such as the launching of new standard generations had to be introduced by collaborative efforts across the industry. The homogenous demand patterns for the networks imply that consumers perceive the characteristics of the mobile network operators to be fundamentally similar. The model of strategic mimicry that we detect in the UK mobile communications market is also present in the German market (Nattermann, 1999). Isomorphic strategies or strategic herding has strong appeal because of its risk reduction properties, which ensures the survival of more firms in the industry.

The moderation of strategic variation, as observed in the UK industry, partly reflects Kaufmann's 'order for free' concept in NK Boolean networks. When the simulation is switched on, such a network would quickly settle to relatively few simple states, rather than explore the millions and trillions of variety of states which are mathematically possible. Furthermore, the complex adaptive behavior of the UK mobile market has some similarity to Reynolds' boids simulation (1987). There are clear rules and limitation of interconnectivity, standardization and regulation. The boids in the simulation are given rules of distance, velocity and direction. In both situations, the systems show no sensitivity to initial conditions. First mover advantage has no bearing in the UK mobile communications industry. Both systems exhibit a herding or swarming effect, and both have no real leader. In fact leadership shows signs of periodic change. The last entrant can lead the flock, as in the case of Orange, and the first entrant can lag behind. The emergent behavior of market leadership continues to fluctuation as long as the complex adaptive nature of the system is retained through its rules and the collective identity of its members.

7. Conclusion

Although the results provide compelling evidence, there is a need to expand this stream of research to encompass network usage and revenue indicators such as average revenue per user. Investigation into multiple levels of network and strategic effects may yield even more complex cycles of network externalities across interdependent platforms.

The empirical findings of this research shed light on complex adaptive behavior and isomorphic strategies in the mobile communications industry. The similarity of the organizations reduces their differentiation from the consumers' perspective and keeps market shares on the path of convergence. In contrast to other research on network industries (Arthur 1989, Redmond 1991, Clark and Chatterjee 1999, Shy 2000) we take a dynamic view that incorporates the implications of interconnected and interdependent networks. This perspective raises a number of important issues regarding the emergence and development of interconnected networks. It complements Gottinger's (2003) econometric approach to understanding interconnectivity by introducing the dynamics of strategic mimicry and undifferentiated consumer adoption.

The concept of strategic complicity sheds light on a chaos-reducing mechanism that eliminates the risk of failure of the majority of firms. Network externalities are exploited collectively and winner-takes-all scenarios are eliminated. Complicity implies that the firms create a single interdependent network, bound together by adaptive mechanism of evolving technology and strategy. The research findings conceptualize the process dynamics of strategic development in network industries as a new integrative theoretical and practical phenomenon.

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