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Ubiquitous Convergence : market redefinitions generated by technological change and the Industry Life Cycle

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Abstract

One aspect of industry convergence is redefined market/ industry boundaries. Hence, a deeper understanding of convergence requires an analysis of market definitions. Various theoretical and practical approaches for defining a market and/or industry are reviewed, e.g. neoclassical, industrial organization, anti-trust, RBV, government statistical taxonomies, management practitioners, etc. The convergence phenomena is put into context under a framework provided by the industry life cycle and general purpose technologies. This framework is contrasted with the sparse literature that proposes theoretical definitions of convergence. An alternative definition is proposed: convergence is a market/industry definition generated by technological change.

1 Background

Convergence is a buzz-word. It has been used in the ICT sector to denote all aspects of change generated by digitalization and the introduction of computer technology during the last decade. It could mean anything that had to do with new applications for computers, new IT related technologies and new business models. It has been widely used with little attention to a clear-cut and coherent definition of the term: digitalization of analogue media; the use of IT in telecom; networking of hitherto separate computers; cable TV; internet usage; online banking; the PC used for TV viewing, etc. It could all be termed convergence.

To be able to use convergence as a workable term, a more narrow and clear definition is needed. In this article, convergence is used in the sense of market and industry redefinitions. A working definition is: "a confluence and merging of hitherto separated markets, removing entry barriers across the market and industry boundaries" (Lind 2004).[1] The overlapping terms market and industry will be used interchangeably in this article. Not much has been written about the differences in the definitions of a market and an industry. Steiner (1968) and Nightingale (1978) point out that industry has its focus towards production and the supply side and market has its focus towards the users and demand side of the economy.

From the development in the ICT sector, it seems that the market redefinitions that take place during convergence are closely related to technology and technological change. The term convergence is also widely used in the engineering community to denote pure technological convergence (e.g. between computers and telecom). Separating a technology from the market for the same technology is hard in this context. Technologies and the markets for these technologies mutually shape each other.

A closer examination of industrial history reveals that the well-known convergence in the ICT sector is far from the only convergence. A few other examples are convergence between machine tools and electronics in the 1970s ("mechatronics"), bio-informatics, and convergence between the steam and steel industries in the late 19th century. It seems that convergence is about technology A invading the turf of technology B or that A and B mutually invade each others markets.

There is extensive academic literature dealing with industry dynamics, industry structure, restructuring, market definitions and technological change. This literature has seldom explicitly mentioned the term convergence, analyzed convergence, or tried to put convergence into a general theoretical framework.

The aim of this article is to anchor the convergence phenomena in established theory. This builds on a theoretical framework where the propelling of General Purpose Technologies (GPT) and the Industry Life Cycle (ILC) can be viewed as a causal driver of convergence. A framework where convergences are a ubiquitous phenomena, though often less visible than the ICT convergence in the late 1990s.

The outline of the article is as follows. A theoretical framework is reviewed, followed by a very short case study of the ICT sector. The article concludes with a discussion and some preliminary conclusions of possible ways to relate market redefinitions to the convergence phenomena.

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[1] The convergence definition above does not endorse the popular view among management practitioners during the 1990s; that convergence would fully merge two or more separate industries and create big collapsed merged industries. Rather, convergence create new, ever more specialized sub-industries.

2 Theoretical framework

In this article, convergence is viewed as a discontinuity, a market and/or industry redefinition related to technological change. Hence, market redefinitions generated by e.g. change in consumer preferences are excluded. Convergence is therefore a subset of all market redefinitions. The framework outlined above will build on theories of how markets and industries are defined together with theories of technological change. There are also a small number of articles dealing directly with definitions of convergence (Greenstein & Khanna 1997, Pennings & Puranam 2001, Stieglitz 2003).

2.1 Market/industry definitions

The first major building block in a theoretical framework for convergence is a closer look at how markets and industries are defined. Categorizations and definitions of a market or industry build on theories and concepts that can be utilized to demarcate and define the boundaries of the defined object. The goal of any useful categorization is to find a set of groupings where the similarities within each group is very high, while at the same time keeping the inter-group differences as high as possible.

There are a number of overlapping and partly conflicting approaches to handling market & industry definitions. Practical and theoretical contributions to this problem area have come from neoclassical economics and industrial organization; from theories developed for government anti-trust rulings; from government statistical industry classifications; from the Resource Based View in management theory; from academics in the field of marketing; and from empirical market researchers in industry. One dimension that is left out in this article is market boundaries based on geography (e.g. Brooks 1995).

2.1.1 Industry classifications, SIC, and NAICS

Significant hands-on practical work with classifications and definitions of markets and industries has been done over the years by government statistical agencies. Official industry statistics in the US have been based on SIC (the Standard Industrial Classification) since the late 1930s (Pierce 1957). SIC was revised 1946, 1958, 1967, 1972 and 1987 but the main structure had been kept intact. The government statistical agencies in North America devoted considerable resources during the 1990s to developing a new industry classification system to replace the SIC nomenclature. In 1997 the NAICS (North American Industry Classification System) replaced SIC (Ambler 1998). A significant change in NAICS is the expansion of categories for professional and service industries compared with the SIC, which reflected an early 20th century industry structure. At the same time, outdated industries have been removed. In the old SIC, almost half (459) of all industries represented manufacturing, while this sector is less than 20 percent of GDP today.

The top level in the NAICS hierarchy consists of 20 broad industry sectors (up from 10 in SIC), in which manufacturing of products is only one sector on the NAICS top level (Ambler 1998). Some of the new top sectors are Utilities, Information, Professional services, Administrative support, Education, Health care, and Entertainment. In total, there are 358 new industries in NAICS, of which 250 are service industries.

The NAICS classification builds on grouping around the production process and the supply side of the economy. Firms using similar production methods are grouped together (US Census Bureau, *internet resource*). One example is the sector Information, which covers software, film production, and theaters. The common denominator is that all industries in this sector use intellectual property rights in their "production process". The strict production and supply side focus in NAICS will of course make the classifications less useful for the categorizing of markets on the demand side, but is a way of avoiding ambiguities about classifications. However, official industry classifications are built to help government agencies with a clear, hierarchical and unambiguous taxonomy. They are not intended to be a decision tool for analysts or managers in the industries themselves.

New industry classifications seem to come around twice per century (1939 and 1997). The classifications seem to take place some 20 – 30 years after the changes in the real economy that triggered them. The industrial economy had already been established for decades in 1939. The same applies for the service and knowledge economy when the 1997 reclassification finally took place.

Other classification systems are ISIC from the United Nations and NACE from the EU. The United Nations introduced the global classification system ISIC (International Standard Industrial Classification) in 1948. The purpose of ISIC was to cover economic activities globally and is therefore not specifically adapted to the needs of industrialized countries. The European classification system NACE is compatible with ISIC, and has 17 categories on the top levels. In spite of a number of smaller revisions, NACE and ISIC seem less adapted to the emerging service and knowledge economy than NAICS. Thus far, NAICS is the only classification system strictly built on production processes. Its predecessor, SIC, as well as NACE and ISIC, have taken a more pragmatic approach and have sometimes grouped industries around markets or customer segments.

Though more conceptually elegant, it remains to be seen if NAICS will provide a better or worse mapping of industries compared to the more pragmatic taxonomies. One study has analyzed how well 235 different SIC industries would map on a pure market, versus a pure production oriented industrial taxonomy (US Department of Commerce, 1994). In the study, experts from the categorized industries were brought in. The SIC industries were evaluated and categorized as – more or less – production oriented versus market oriented. An example of a production oriented SIC industry could be "Potato Chips, Corn Chips, and Similar Snacks" (SIC 2096). Here, the frying and oil cooking in the production process defines the industry. The industry (SIC 2064), "Candy and Other Confectionery," is an example of a market defined industry, as it includes candies made of various ingredients and with different production methods. Some industries are conceptually “ideal”, in that they can be fully defined by both a unique production process and a single market segment. An example is “Ball and Roller Bearings” (SIC 3562).

The results showed that a pure production oriented taxonomy would map onto around 60% of the industries in manufacturing and around 70% in the service sector. If a pure market oriented taxonomy had been used, around 70% in both the manufacturing and service industries in SIC could be mapped. This is hardly conclusive evidence in favor of either conceptual model as the favored principle. It might even be the case that a pragmatic taxonomy would provide the best overall match.

It is not hard to find a number of articles with critique against the official industrial classifications taxonomies and the quality problem arising when they are used as input data (Andrews & Abbott 1988; Kahle & Walking 1996; Jacobs & O’Neill 2003; Bhojraj, Lee & Oler 2003; Clarke 1989; Ackerman & Morris 1993; McKie 1985). This critique is an indication that the official “industries” are too coarse to be used as industry definitions by practitioners working in the industries themselves. Additionally, this is does not aid in understanding convergence.

Further studies of how SIC/NAICS industries have been redefined during the recurrent reclassifications could possibly be used as input data for an analysis of convergence, though the coarseness of the data will most likely limit their usefulness.

2.1.2 Industry taxonomies developed in industry

In addition to the official industry classifications there are some taxonomies developed in the private sector. The financial industry has developed an alternative classification system, GICS (Global Industry Classification Standard). GICS is developed by Morgan Stanley together with Standard & Poor's. The GICS is adapted for listed companies and its structure consists of 10 top level sectors, 24 broad industry groups, 62 industries and 132 sub-industries.

The news provider Factiva (former Dow Jones and Reuter Business Briefing) did extensive work around the year 2000 in developing an industry taxonomy for classifications of articles in the business press. The goal was to make the large archives of news articles searchable by industry segment. Their taxonomy was built on earlier (and partly incompatible) taxonomies developed by the partners Reuters and Dow Jones.

2.1.3 Market definitions in neoclassical industrial organization

In orthodox neoclassical theory the scope of a market is defined by goods with very high mutual cross-elasticity, or as an alternative by high elasticities of substitution. Elasticities are difficult to measure and observe. What is, for example, the correct market boundary based on elasticities between beverages? Between soft drinks and juices, or between soft drinks and beer? An alternative and more operational definition is that the scope of a market is defined by the space where the same price holds and where all intra-market arbitrage opportunities have been closed (Geroski 1998).

Within neoclassical economics, more operational concepts and methods for defining markets and industries have been developed by Industrial Organization theorists. An important user of these analyses has been anti-trust authorities who want a theoretically founded market definition (Geroski, 1998). The purpose is to make rulings in merger cases where the critical issue is whether a dominant firm has a monopoly or not. This issue is entirely dependent on how the market is defined. With a narrow market definition a given firm will be a dominant monopolist while a more wide market definition will show that the same firm is a smaller and less dominant actor on the larger market in which it is operating. The definition used in anti-trust cases is that a market is defined by a "... product or a group of products and a geographical area in which it is sold such that a hypothetical, profit maximizing firm, not subject to price regulation, that was the only present and future seller of those products in that area would impose a 'small but significant and non-transitory' increase in price above prevailing or likely future levels" (US Department of Justice, 1984). That is, the area where it is possible for a dominant firm to permanently raise prices without losing market share is the scope of the market.

2.1.4 Market definitions in marketing science

The academic discipline of marketing has made contributions to the market definition discourse. Levitt (1960) pointed out that products on a market are building blocks in a means-ends hierarchy. The products and services on a market are always a means to fulfill some more abstract end, which in turn fulfill some even higher end, etc. An air-ticket is a means to a holiday, which is a means to new experiences, which is a means to self-fulfilment, etc. Railway companies were not in the "railway market" but in the market for transportation services. The implication is that the observable market – the first sight market definition, (e.g. the passenger air transport market) must be understood by a deeper analysis of the intrinsic real needs of the customers.

2.1.5 Subjectivists and the Resource Based View

Most of the theories and classifications mentioned above; implicitly assume that it is possible to identify and empirically observe a "correct" market definition. A well known problem with this perspective is the bias caused by the reliance on statistical aggregations of observable quantitative data. Local knowledge about differences in product quality, buyer preferences, production processes, and other proprietary local conditions is hard to observe. Markets are created by individuals who make their decisions based on local, partly tacit, and unarticulated knowledge. These are individuals with subjective and incoherent preferences (Hayek 1945, Polyani 1967).

There are several approaches that can be utilized to tackle these problems. The Resource Based View (RBV) in management theory recognizes the issue and they view the firm as a unique bundle of resources, knowledge, and internal capabilities (Penrose 1959, Wernerfelt 1984, Teece, Pisano & Shuen 1997, Grant 1996, Kogut & Zander 1992). The capabilities (or resources) are defined as proprietary, partly tacit and inimitable. RBV views the market as a group of buyers and sellers entangled with one another, while the vendors offer value by exploiting their unique capabilities. In their articles on convergence definitions, both Pennings & Puranam (2001) and Stieglitz (2003) favor the Resource Based View of the firm as the theoretical perspective under which to analyze convergence.

Another closely related theory is the markets-as-networks view (Axelsson & Easton 1992), which views – primarily – business to business markets as a network of buyers, sellers, and other players embedded in a social context. An even further step back into (sociological) theory is offered by the social constructionists (Callon 1998), who do not deal at all with ways of making a better correct market definition, but instead study how social agents are shaping and constructing the concept of a market.

2.1.6 Market researchers and business practitioners

In managerial practice, corporate strategists and market researchers define markets and market segments all the time in their day to day activities. Their work is based on the proprietary local knowledge about products, competitors, and customer needs. This is knowledge that the players in the industry possess about their own business environment. Their own conceptual understanding of their business environment is the point of departure for segmentations and empirical data collections of sales volumes, market shares etc. As insiders in their respective industries, their segmentations and empirical data would presumably be more accurate and up-to-date than official industry statistics.

There is often an inherent vendor and producer bias in this kind of analysis. Another bias is caused by the reliance on statistics and empirical quantitative methods, which can overlook qualitative and unarticulated knowledge about the market and user preferences. To counter these problems, some market researchers spend considerable resources on qualitative data gathering such as interviews. This is to better understand buyer needs and preferences. Once produced by corporate analysts, consultants or market research firms, these market analyses are kept internal as jealously guarded business secrets. The knowledge is kept local and is not easily observable.

2.1.7 Market/industry definitions put in perspective

The various theories and methods about market and industry definitions reviewed above offer little direct help on the issue of market redefinitions and convergence. They provide frameworks for taxonomies and classifications. An implicit feature of these taxonomies is that the boundaries can be moved and redefined. Though they provide a functional framework for a better understanding of the phenomena, they are seldom explicitly dealing with the process of how and why markets are redefined.

One lesson that can be learned from the recurrent official industry reclassifications is to draw attention to the evolving nature of economic activity. It shows how the last centuries have witnessed an ongoing restructuring of the economy from an agricultural economy, via an industrial manufacturing economy to a service and knowledge economy. As stated by Adam Smith in the Wealth of Nations, in a growing economy, the economics of scale will give room for increased division of labor and specialization (Stigler 1951). Over time, these will produce an ever-increasing number of new sub-industries and markets. This process of constant restructuring and fragmentation will generate constant re-definition of markets/industry boundaries, of which some are convergences.

Whether a market is viewed as an objective empirical phenomena or a subjective tacit social construction does not contribute much to the understanding of market boundary redefinitions. A change in method and theoretical model will of course generate a new set of market definitions. However, the focus of this article is on longitudinal redefinitions generated by technological change, not redefinitions generated by a shift in theoretical perspective. Of the two theoretical perspectives, the RBV and subjective view of markets and industries fits somewhat better with theories of ILC, GPT, and techno-economic paradigms reviewed below.

2.2 Technological change and the Industry Life Cycle

The other major building block in a theoretical framework for convergence is a closer look at technological change and the Industry Life Cycle. Innovations and Technological Change are major forces of market and industry restructuring. Theories about General Purpose Technologies (GPT), Industry Life Cycles (ILC), and diffusion of innovation are relevant points of departure for an analysis of convergence (Greenstein & Khanna 1997). Theories that examine how new technologies emerge, grow, become dominant, and eventually become ubiquitous in almost all sectors of the economy. Examples of general purpose technologies forming long-term industry life-cycles could be the steam engine, steel, railways, electricity, telephony, automobiles, plastics, mass production, computers, and the laser. During the long-term process when the new technology goes from being used nowhere to everywhere, it will at some point disrupt and enter almost all other industries in the economy. These moments when penetration into a new industry or market occur is a convergence – and a discontinuity.

2.2.1 Techno-economic Paradigms, GPT, and ILC

There are a number of partly overlapping theories that address how fundamental new technologies create new industry sectors and how these industries form S-curve shaped life-cycles spanning up to a century. The Schumpeterian economic historian Dahmén introduced theories about Development Blocks (Dahmen, 1950, 1988). A new technology needs a number of complementary supporting technologies in order to reach its potential. Once they are in place, a development block can be formed. This is a cluster of firms, focusing on exploiting the new technology, complementary technologies, or supporting functions. As the development block grows, division of labor creates opportunities for even more specialized firms and a full eco-system of new related industries in a cluster around the new technology. In this growing sector of the economy, a number of new business opportunities are created. To exploit the potential from electricity, a number of complementary technologies had to be put in place. The electricity development block required power generators, a power-grid, equipment producers, service providers, household equipment and a compelling "killer application" - the light bulb. An example using the automotive industry could include car manufacturers, repair garages, gas stations, car resellers, tire manufactures etc.

The evolutionary economist Dosi introduced the related term Technological Paradigms (Dosi 1982). This term was later developed by Perez to Techno-Economic Paradigms (Perez 1985, 2002). The term Techno-Economic Paradigms is the totality of technology, economy and supporting institutions. A closely related term is Large Technical Systems, introduced by Hughes (1983, 1987). These terms are similar in scope to Development Blocks, though the Development Block put more focus on the early phases of the ILC. From Growth Theory within neoclassical economics, theories about General Purpose Technologies (Helpman 1998) have been developed over the last decade. It builds on formal modeling of when a new technology penetrates the entire economy, forming a long-term S-curve.

The S-curve – the logistic or sigmoid curve – was introduced in economics by Mansfield (1961) in an article about diffusion of new technologies. Diffusion theory built on the sigmoid curve was also used to develop the Product Life Cycle (Rogers 1962). The S-curve has since been widely used in management and economic theory (Foster 1986).

The term Industry Life cycle was introduced in the literature as an analogous metaphor to the product life cycle model from the 1970s. The concept was introduced in the academic discourse by usage and its origin can not be traced to a formal definition by a specific author (McGahan, Argyres, Baum 2004).

Empirical support for ILCs and GPTs is collected from industrial and economic history. Freeman & Louçã (2001) present an overview of the five major techno-economic paradigms since the Industrial Revolution. The first wave was generated by cotton, iron and water power starting in the 1770s. The second wave was triggered by railways, steam power and mechanization in the 1830s. Electrification, steel and heavy engineering drove the third wave from the 1870s and onwards. The fourth wave took off around 1910 and was driven by oil, automobiles and mass production, and the current wave is driven by computers and telecommunication.

One aspect of the ILC is the increased specialization and industry fragmentation within the techno-economic paradigm. As the cluster of firms centered on the new GPT grows, economics of scale will make it viable to sustain ever narrower and more specialized business models. "The division of labor is limited by the extent of the market" (Stigler 1951). When an emerging industry such as the computer industry grows, the initial market definition will fragment and create an increasing number of new sub-markets and supporting industries, e.g.: software, hardware, systems integration, application software, operating systems, resellers, chip design firms, contract manufacturers, etc.

2.2.2 Dominant Designs, growth and Product Architectures

The industry focused theories reviewed above are on a macro or meso level. They note how new GPTs evolve from inception to ubiquitous penetration of the entire economy. However, they are not particularly detailed about the exact process and they often do not put the penetration events – the discontinuities – in a theoretical framework. In order to do that, we need help from theories about performance and technological trajectories, product innovation, product architectures, and dominant designs.

During the ILC, products and technologies typically show exponential performance growth. That is, exponential growth – as in Moore's Law – is not an exception but just a highly visible case where there is rapid growth. Even in the traditional industrial economy, growth is exponential - though significantly slower. The exponential growth curves can continue over a number of successive technology generations. Nordhaus (2001) showed that the performance/price for computers has been growing 55 percent annually since around 1940. This closely matches Moore's law, where a doubling in performance every 18 months translates into an annual growth of 59 percent. Even low growth figures provide remarkable gains over long periods of time. The real price of illumination has been falling by 3.6 percent annually for 200 years. This exponential path has been valid through the shift from candles, town gas lamps, kerosene lamps, and electric light bulbs, to fluorescent light. The real price today for one lumen-hour is below 0.1% of what people had to pay 200 years ago (Nordhaus 1997).

Closely related to the exponential performance growth is the learning curve or experience curve, stating that prices typically fall between 20 and 35 percent for each doubling of accumulated production volume. The learning curve was first observed in the 1930s during aircraft manufacturing. Since then, it has proven to be valid in a number of different technologies and over very long time periods. A study of 108 different technologies by Argote & Epple (1990) show the learning curve to be valid in most cases.

The exponential growth curves and the learning curves are closely related to each other. For exponential growth to continue at the same annual rate, the total market has to grow to keep up with the doubling rate of the cumulated production volume (BCG 1968). As a result, the exponential price fall will continue until saturation when the end of the S-curve is reached. The implications for the convergence issue are that over the ILC there is continuous price fall of orders of magnitude for a technology or product. This price fall will be an important trigger for entry into new industries. Note that the growth paths can generate price fall, higher performance, or a mixed performance/price increase. Entry into new industries can be generated by increased performance as well as by lower-prices.

During the course of a full life cycle, products, technologies, and product architectures undergo a number of transformations. When a life-cycle leaves the early experimental stages and enters more main-stream market, design variety is reduced and the Product Architecture (PA) settles around a Dominant Design (DD), (Abernathy & Utterback 1978, Utterback 1994). Well-known examples of establishment of DDs are the QWERTY typewriter keyboards, the PC industry when the Intel/Microsoft DD was established, and variations in early aircraft design before the DC 3. When a DD is prevalent, the nature of innovation slows down and changes character. Innovations on the DD itself become confined to incremental improvements that do not overturn the established DD and destroy the accumulated competence around the DD.

The high visibility of QWERTY as an example of a DD does not imply that once a DD is established it will exist forever. Over a full life-cycle, the first DD is often replaced by new DDs several times. The DD in electronics built around vacuum tubes were replaced by transistors and the transistors were subsequently replaced by integrated circuits. Propeller aircraft were replaced by jet planes, etc.

While a DD is freezing the overall PA, radical innovations in sub-systems are possible in the incremental phase. As long as the accumulated competence and network effects embedded in the DD is kept intact, innovations in sub-systems can be discontinuous. The shifts between phases of incremental and discontinuous innovation are central in theories about technological innovations (Tushman & Andersson 1997).

The section above has presented a somewhat simplified model that puts too much emphasis on the overall PA. This section will show that discontinuities exist on a scale from small to very large and that they can affect different parts of PA and value network. Henderson & Clark (1990) introduced a model with innovations in the subsystems as an additional dimension to innovation in the PA. They developed a 2*2 matrix, where the two axis are innovations in sub-systems vs. innovation in product architecture. They introduce a taxonomy with four categories: incremental, modular, architectural, and radical innovations.

This model is further developed by Afuah & Bahram (1995). The innovation categories introduced by Henderson & Clark have different impacts on different parts of the industry eco-system. An architectural innovation by the product manufacturer can be radical for the customers, incremental for component suppliers, and modular for complementary players in the value constellation. An example is the potential impact from a future electric car. For end users and tire manufactures, the electric car would be an incremental innovation, while it would be a radical innovation for traditional car manufacturers. For taxi fleet companies, the electric car would most likely be a modular innovation. Another example from Afuah & Bahram could be the impact of abandoning the QWERTY keyboard and replacing it with the DSK keyboard. For keyboard manufacturers it would be an architectural innovation but for the customers it would be a highly competence destroying radical innovation. For component vendors it would just be an incremental innovation.

The more elaborate models introduced by Henderson & Clark (1990) and Afuah & Bahram (1995) add new perspectives to the problem of change in DD and PA. Instead of the simple dichotomy between incremental innovations under a DD or totally disruptive discontinuities, it is possible to keep the dichotomy but apply it on different levels of magnification. Discontinuities can enter on many levels, from small disruptions on peripheral subsystems over to macro discontinuities on entire technological paradigms. What at first glance may look like an era of incremental innovations in one PA, can disguise a number of smaller discontinuities in subsystems on lower levels. The cross-fertilization across technologies and PAs even enables incremental innovations in one PA to induce larger discontinuities in other PAs or technologies. Or vice versa.

Some implications for the convergence analysis can be drawn from the arguments above. A point of departure is the fact that technological change can be viewed as incremental evolution, punctuated by discontinuities – and that these disruptions come in all sizes. Combine this with the observation that convergence events are discontinuities related to technological change. It seems that it is possible to use the theories around PA and DD to analyse convergence as a "discontinuity" under the PA and DD framework. This line of argument is a topic for further research and will be elaborated in forthcoming papers.

2.3 Types of convergences

There are a few articles that explicitly examine Convergence and possible ways of defining the term. Langlois & Robertson (1995) don't mention convergence but discuss industry restructuring. Their perspective is the dynamics of the boundaries of the firm. They put firm dynamics in a theoretical framework provided by transaction costs theory, capabilities, vertical integration, modularity, and technological change. Industry redefinitions are mentioned as the merger of two adjacent industries into one, and fragmentation of one into two – though the term convergence is not used. The redefinitions are typically generated by change in technology and/or firm boundaries. Most examples are taken from the early automotive industry.

Greenstein & Khanna (1997) suggest a model with two types of convergences. The first is convergence in substitutes, when one technology can replace another. The second is convergence in complements, when two technologies work better together than separate. Pennings & Puranam (2001) develop this typology for convergence by adding a second dimension to the Substitute – Complement dimension. They introduce the categories Supply Side and Demand Side convergence and construct a 2*2 matrix with four categories.

Stieglitz (2003) uses the same 2*2 matrix but re-labels the Supply-Demand dimension to Technology vs. Product based convergence. This gives Stieglitz's taxonomy four cells. On the technology side there are two categories. The first is technology substitution, which covers technology replacement, (e.g. transistors replacing vacuum tubes). The second type of convergence is technology integration or inclusion. This covers cases when technology A and B merge and create a new converged technology C (= A + B). Examples could be mechatronics, bio-informatics, cell phones/handheld computers, and IT/telecom.

On the product or demand side there are two additional types of convergence. Product based substitution covers cases when increased cross-industry completion between products from industry A and B leads to an industry merger and creation of a new merged industry. C. Stieglitz notes that this convergence is typically accompanied by technological convergence between technology A and B, and that the merger often generates a number of new market segments rather than one large merged industry C. The example Stieglitz gives of this convergence type is the mainframe and minicomputer industries in the 1970s. Initially, they were two separate industries, but over time the increasing market overlap caused the industries to partially merge. Pennings & Puranam have a different definition and call this cell Substitution on the Demand Side. They view it as convergence of consumer preferences and their examples are globalization and homogenization of markets. Stieglitz's fourth type of convergence is product complementarity or product functionality extension. This occurs when product A and B mutually can deliver the services of the other product without the need to incorporate the other underlying technology. An example is the convergence between the PC and the telephone. Pennings & Puranam define the same cell as when different (but related needs) are met by bundling products together. Their examples are the bundling of hardware and software and the bundling of consumer of investment banking.

The typologies reviewed above are interesting, but for the purpose of this article, the demand side (or product side) convergences are less helpful. In line with Lind (2004), it is important to keep the definition of a term reasonably narrow to retain its analytical clarity. A wide definition of convergence that encompasses all instances where "two entities merge into one" is less useful. Although Stieglitz and Pennings & Puranam give examples of convergences on the demand side, they fall outside the convergence definition proposed by the author. In the definitions reviewed above, the technology side convergence seems easier to handle than the attempts to define convergences on the product/demand side. The problem seems to be the close entanglement between products and the underlying technologies inside the products. It is hard to envisage a demand side convergence without any reference to the underlying technology. The example given by the authors with convergence between the PC and the telephone overlooks the massive convergence in underlying technologies. However, the distinction between technology replacement (substitution) convergence, and technology inclusion (complementarity) convergence is useful in the further analysis.

3 Industry case: the ICT convergence

The most visible and well-known industry case is the convergence between telecom, IT, media and consumer electronic devices during the 1990s. The convergence between computers and telecom networks was envisioned in the late 1970s (Lind 2004) but it was not until the 1990s that it really took off. In the convergence vision, computers would be connected to each other over the telecom network and the telecom networks would be digitalized and fully rely on computers for switching. One dimension of the ICT convergence vision was that media would be digitalized and transformed into multi¬media. This would be a new converged medium where text, sound, and pictures are merged and carried over digital networks built by computers. Another vision was that the traditional telecom networks would be replaced by datacom networks and the Internet. In retrospect, some of the early visions of ICT convergence did not turn out. The idea that the three or four separate industries would merge into one bThe scope of this article only allows for a few selected illustrations of the industry turmoil during the 1990s. The industries ex ante – telecom, computer, media, and consumer electronics – are still around after the ICT-convergence, though they were fundamentally transformed by the event. The telecom industry relies on computer (datacom) technology for its networks and has been relegated to a background role as infrastructure provider. The computer industry has fully embraced networking technology. At the same time, the traditional computer industry has seen its role diminished to an equipment vendor industry. The traditional media industry has seen its role radically transformed. If the media industry is defined as creation of content, it is still around. Now with a number of new distribution channels. If on the other hand, the media industry is defined by its physical manifestations, the industry has seen a significant restructuring. The "old media" such as film, TV, newspapers are now sharing the market with new actors such as portals, bloggers, communities, and console games. Most of the old media have now embraced the new opportunities and created new distribution channels and content built on the Internet and multimedia.

During convergence the number of industries did not fall but increased. Rather, the output of the ICT revolution the last decade is a large number of new or re-defined markets. Each with its own narrow business logic and its own set of players. There are few indications that the barriers to entry between these new sub-markets – once established – in the post-convergence marketplace are lower than in traditional markets. The capabilities and unique resources needed to compete in each of the sub-markets are highly proprietary. Amazon has no chance in entering the market for local access provision or compete with Vodafone. Ebay can't compete with Cisco and Nokia can't compete with Microsoft.

4 Discussion: the terms market, industry, technology, and convergence

According to the theory review and industry cases above, convergence turns out to be an elusive and multi-faceted concept. Convergence takes place in the intersection of change between technologies, industries, products, and markets.

It seems that attempts to define convergence as a pure market or industry phenomena – without references to technology – encounter problems. The same problems arise if convergence is defined as a Technology phenomena, without reference to Market or Industry.Even if Market, Industry, Product, and Technology are separate terms with their respective definitions and scope, there is a considerable overlap (Steiner 1968, Nightingale 1978, Geroski 1998). They are entangled with each other and each term requires the others for its definition.

One way to develop a typology of the terms is to concatenate them in a "value chain" as: technology-product-industry-market, going from the producer side to the consumer side.

The term Industry has a bias towards the producer and supply side of the economy, while Market has a twist towards users and the demand side. They are, to a large extent, overlapping and there is no clear-cut obviously accepted definition that clarifies how to separate them (Nightingale 1978). A technology with buyers will define a market for that technology. A product is always building on one or more technologies and a technology has to be embodied in products. An industry is formed around a technology and this industry defines a market, etc.

The point is not that technology-product-industry-market is the same thing. Rather, it is that each term highlights certain aspects of a multi-faceted phenomena. In particular, if the object of study is a phenomena such as the broad techno-economic paradigm formed around a general purpose technology such as, for example, ICT. The propelling of a techno-economic paradigm will generate a number of convergence restructurings in the intersection of technology and markets.

5 Conclusions

The initial view of convergence in this article is as a confluence of hitherto separate markets and industries (Lind 2004). (A perspective that does not omit the strong connections to technology.)

That two separate industries merge (converge) does not imply that the number of industries fall – rather the opposite. The increased division of labor will give room for an ever growing number of specialized markets and industries. An example from the case study above is how the merging of machine tools and electronics increased the number of industries from two to at least three: the mechanical industry, the electronics industry, and the new industry cluster built around mechatroncis.

The article has shown how convergence can be viewed as a discontinuity in product architecture, technological subsystems, industry structure, or market definitions. These discontinuities occur when one technology A, enters the domain of another technology B. Either to replace B, to merge with B, or to enhance B. Discontinuities that redefines market and industry structure.

With a liberal definition of the term technology, this can encompass the entry of new products, distribution channels, or business methods. As was illustrated above, discontinuities come in all sizes, from large and highly visible convergences down to very small. Hence, we are surrounded by discontinuities/convergences, though most are below the horizon of attention. Does anyone remember when wooden clothespins were replaced by plastic ones? These discontinuity events can have a number of triggers.

Among them are lowered prices of technology A or improved performance of A, all which push A over a threshold and make it possible to enter B.

The causal drivers are the propelling of ILCs and GPTs along their technological and performance trajectories. Over its ILC, a GPT will go from its first entry in a market to successive penetration of most sectors of the economy, forming a band of pearls of Convergence events.

If at any time a number of simultaneous ILC S-curves are in progress, they will form an entangled n-dimensional space of mutual Convergences into each other. Convergences are ubiquitous.

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