KNOWLEDGE AND SECTORAL INNOVATION SYSTEMS: THE MOBILE COMMUNICATIONS INDUSTRY EVOLVED LARGELY BY GETTING THINGS WRONG

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SUMMARY

This paper examines the role of knowledge (technical, strategic, and environmental) in the evolution of sectoral innovation systems. The analysis of the evolution of the Mobile Communications Innovation System highlights the importance of Knightian uncertainty and the paradoxical construction of 'false knowledge' in shaping the evolutionary path of the sector. It is suggested that this is typical of sectoral innovation system evolution.

> “rational choice relies on a comparison of the consequences of all available alternatives, without deigning to explain how these consequences can be known, or even how all the alternatives can be shown to be available. If we wish to do economics in the spirit of Knight and Shackle, we must do it in another way: we must switch our emphasis from closed to open systems, and from proofs to process.” Loasby, 2001, p. 396-397.

> “The past cannot be changed, but it can, in part, be known; the future cannot be known, but it can be imagined, and by acting on that imagination it can, in part, be changed. Imagination is shaped – though not determined – by the interpretation of environment and experience. However, most of what is imagined turns out to be impossible; and so progress depends on both the variety of imagination and some process for selection among this variety – the essentials of evolution.” Loasby, 2001, p.397.

CONCEPTUALISING KNOWLEDGE

Even in evolutionary economics we frequently use a utilitarian, instrumental conception of knowledge. ‘Knowledge’ is often conceived of as a substance capable of generating more and better output. Although conceptually distinct from ‘capital’ and ‘labour’ (and with different, though also troubling, measurement problems), from a utilitarian, instrumental perspective knowledge is seen as playing a similar role to capital and labour as an input in the process of producing innovation and output. Clear policy implications are drawn: in our so-called Knowledge Economy a major issue relates to the improved production and use of knowledge. Knowledge, in short, is seen as an indispensable tool to be used in the production of a greater, and better output.

But what is this 'knowledge' that plays such a useful functional role in the so-called Knowledge Economy? In rational choice theory, as Loasby (2001) makes clear in the above quotation, knowledge is implicitly embodied in the central concept of the (closed) choice set. A 'rational choice' requires knowledge of all the alternative courses of action as well as knowledge of all the consequences of these alternatives. The alternatives, and the consequences, depend on the 'state of knowledge' existing at the time. Over time, as the stock of knowledge expands, so the set of alternatives and the set of consequences will expand. However, the fundamental problems with rational choice theory begin to emerge, as Loasby notes, when we start questioning the assumptions that are implicitly made in assuming that the choosing agents come to possess all the knowledge contained in the (closed) choice set.

Evolutionary economists have, understandably, reacted against the omniscience implied in rational choice theory. One of the responses has been interest in the concept of 'bounded rationality' originally developed by Herbert Simon. However, it will be argued here (although without the supporting chapter and verse) that many evolutionary economists have tended to retain the utilitarian, instrumental conception of knowledge, of knowledge (including its tacit dimensions) as a relatively well-defined tool used in the production of innovation and output.

Few evolutionary economists have followed Loasby, in word and deed, down the road towards a fundamentally different conception of knowledge, one intimately tied up with the processes of imagination, interpretation, trial *and error*, and the "fallible process of making connections". (Loasby, 2001, p.398) What emerges down this road is a less firm, less clear-cut, more ambiguous concept of knowledge, one that admits the contradictory notions of uncertain knowledge, fuzzy knowledge, ambiguous knowledge, and even wrong knowledge.

However, once we accept that we can never know with certainty, that knowledge and uncertainty are not opposite states at alternative ends of a polarity, but rather are intimately and inevitably bound up with one another, and once we acknowledge that one person's 'knowledge' is often another's 'ignorance', then a very different world opens up, one considerably less explored, even in evolutionary economics. In order to explore this world I have preferred to drop the word knowledge – with its potentially confusing black or white connotations of being in a superior state of knowing, as opposed to an inferior state of not knowing – in favour of a conceptualisation of *knowledge as belief*.[1] Thinking of knowledge as belief emphasises the relativeness and openness of knowledge, and makes it easier to understand *knowledge as a process* rather than as a state of affairs, knowledge constantly being transformed as an inherent part of the evolutionary process itself, constantly becoming other than what it was.

KEY BELIEFS IN THE EVOLUTION OF THE

[1] The philosopher Dretske (1982) notes that in philosophy knowledge is conventionally defined as 'justified true belief'. However, the problematical nature of this conception of knowledge becomes apparent when we ask about the conditions that must be met for a belief to be 'justified' and become 'true' and when we examine the history of 'knowledge' in any area of human thought and see the changes over time in what is commonly accepted as justified and true.

MOBILE COMMUNICATIONS INDUSTRY

In this paper some key aspects of the evolution of the mobile communications industry (henceforth referred to as the mobile industry) will be examined, paying particular attention to the role of changing knowledge/beliefs. It will be shown that many of the central beliefs of those that shaped the evolution of this industry, held at different points in the industry's evolution, subsequently turned out to be wrong. However, both the actions undertaken in the light of the beliefs held, as well as the different responses of others in the system, were important determinants of the evolutionary path followed by this industry.

BELIEF 1 (circa 1970s – early 1980s):

Mobile communications are unlikely to become a high-growth area of activity largely because the mobile method of transmission is inherently inferior to other alternatives

Incredible as it may seem from today's perspective when almost everyone in developed countries seems to own a mobile phone, until the early-1980s it was widely believed that mobile communications would not become a high-growth mass-consumption part of the telecommunications industry. Modern mobile communications are based on a cellular concept that allows the carrying capacity of the mobile network to be considerably expanded by re-using frequencies in non-contiguous cells, thereby economising greatly on scarce spectrum. The first proposal to use cellular systems in the field of mobile communications was put forward in AT&T's Bell Laboratories in 1947 and discussed subsequently in a number of internal memoranda. The first publication on cellular communications emerged from Bell Labs in 1960.[2] Only a decade later, in 1970, the first civilian standard for modern cellular telephony began to be specified in Scandinavia, leading to the Nordic Mobile Telephony (NMT) standard that was introduced in 1981.[3]

However, despite the advance of the technology and the possible uses it created, the general view in the 1970s and early 1980s was that mobile communications were unlikely to become a high-growth segment. In part the problem was believed to be inherent in the technology itself. Depending on radio waves transmitted through the outside air between the handset and base station, mobile communications were believed to be based on an inferior transmission technology resulting in relatively high levels of interference and relatively low capacity and speed. In order to improve transmission performance, frontier research at the time focused on 'waveguides' and later optical fibre that would guide light, rather than electro-magnetic radio signals, more efficiently thus providing levels of capacity and speed far in excess of what could be achieved using mobile cellular communications. Furthermore, complementary technologies and assets also presented problems from the users' point of view. For example, the handsets were large, heavy and with limited battery-power.

It was largely for these reasons that Bell Labs downgraded the importance of research on mobile communications in the late 1970s and early 1980s.[4] Bell Labs was by no means alone in holding this belief. Kurt Hellstrom, later President of Ericsson, remembered clearly that "When I joined Ericsson in 1984 Radio Communications was something odd happening on

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[2] The publication was by H.J. Schulte and W.A. Cornell (see Millman, 1984, p.235 for further details).

[3] See McKelvey, Texier and Alm, 1998.

[4] This downgrading was later perceived as one of the more important mistakes made in Bell Labs. (Author's interviews in Bell Labs.)

the outskirts of Stockholm".[5] As McKelvey, Texier and Alm (1998) have noted, Ericsson's focus at the time was dominated by its new digital AXE switch and the priority accorded the company's switching division crowded out the fledgling mobile division. In the early-1980s, AT&T asked the consultancy company, McKinsey, to predict how many cellular phones would exist at the turn of the century. The answer of 900,000 compared with the more than 400 million mobile phones that existed in 2000. Indeed, it was only in 1993 that AT&T entered the mobile field by merging with McCaw Cellular Communications in an agreement worth $12.6 billion.[6]

However, 'knowledge' that there were limited opportunities for gain in the mobile industry was not shared by everyone. The choice set was not closed but open; moreover, it contained a significant degree of ambiguity. Two companies in particular drew different inferences from the 'knowledge' available and moved faster and further than the rest of the pack in seeking to take advantage of the new commercial opportunities opening in the slowly-growing mobile industry. These were Vodafone, started by Racal a well-known British defence equipment company, which began mobile operations in 1985, and AirTouch, the spun-off mobile subsidiary of the Baby Bell, Pacific Telesis (acquired by Vodafone in 1999). Vodafone went on to become the world's largest global mobile operator.[7]

Clearly, to return to the broader knowledge issues of concern in this paper, the 'choice set' such as it existed until the early-1980s provided little clear-cut knowledge regarding whether consumers would be willing to put up with inferior transmissions (resulting at times in no-signals and interference) and initially cumbersome handsets in return for the advantages of being able to communicate while on the move. However, as we have seen, different individuals and organisations responded in different ways to the ambiguity that existed and came up with a variety of imaginative solutions. It was this variety that was subsequently put to the selection test, with results with which we are now familiar.

<u>BELIEF 2 (circa mid-to-later 1990s)</u>

The 'GSM Model' provides the basis for the future evolutionary trajectory of the mobile industry

The first pan-European standard for digital mobile communications (GSM[8]) created a major success story for the global mobile industry. While GSM created a unified mobile

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[5] Financial Times interview, 26 July 1999.

[6] AT&T's main long-distance competitor, the new entrant MCI-WorldCom, was even slower to realize the importance of mobile communications. For a long time arguing that mobile was unimportant for WorldCom, Bernie Ebbers, the company's CEO, only changed his beliefs in 1999. This led WorldCom to attempt to enter the mobile market through the acquisition of Sprint. This acquisition was thwarted, however, by both the US and European regulatory authorities. (Fransman (2002), p. 97)

[7] Care should be taken, however, not to conclude from this account that Vodafone had superior 'foresight' compared to its competitors as a result of having derived knowledge about the mobile industry more effectively than its rivals. "That Vodafone got these things right, however, may be as much due to the company's specialization and scope as to 'visionary foresight' on the part of Sir Gerald Whent, the man who was responsible for many of Vodafone's key formative decisions in the late 1980s and early 1990s." (See Fransman (2002), p. 118 for an elaboration.)

[8] GSM (Global Systems for Mobile Communication) is a European standard for digital mobile communications formally adopted in 1992. Commonly spoken of as a second-generation (2G) mobile standard – the first-generation referring to analogue mobile communications – GSM emerged out of collaborative European work starting in the early 1980s aimed at creating a pan-European standard for digital mobile

communications system for Europe as a whole, including the ability to 'roam' from one company's network to another's, in the US – where the belief was held that standards should be developed by markets not by government-influenced co-ordination – there were three incompatible second-generation standards.[9] Japan made the decision to develop its own incompatible standard.[10]

The 'GSM Model' facilitated effective coordination between European mobile operators and competing mobile equipment suppliers and dynamic increasing returns soon propelled these companies (and their customers) to the forefront of the global mobile communications industry, the outstanding examples being Ericsson and Nokia. By the late-1990s the GSM standard had significantly more subscribers globally than any other standard, having been widely adopted in many developing countries. To the glee of many Europeans – stung by the mounting evidence that the US was forging ahead in almost all the other 'high-tech' areas, particularly computing, software and semiconductors – America lagged behind in mobile. GSM allowed Europeans to hold their heads up in international forums, even if not particularly high.[11]

It was not surprising, therefore, when many in Europe suggested that the GSM Model provided the evolutionary way forward for the global mobile industry. The immediate need was to replace second-generation mobile networks with higher-capacity higher-speed networks that would overcome the threat of congestion while facilitating the provision of a new generation of data services, such as real-time interactive video, that were needed to compensate for the negative effects of saturating mobile-voice services. Learning from the positive experience of GSM it seemed obvious to the main European players that the solution was to largely re-create the GSM Model, but within a third-generation context. In this way, UMTS (Universal Mobile Communications System) was born, based on a new third-generation technical standard[12], and formally adopted in 1999. To make matters even better, UMTS was simultaneously adopted in Japan[13] although the US prevaricated with limited acceptance of this new standard.

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communications. GSM drew heavily on the Scandinavian NMT standard, referred to in the text, giving an advantage to mobile companies from the Nordic countries such as Ericsson and Nokia. Apart from the major European telecoms companies (both operators and equipment suppliers), government-related organisations such as The European Telecommunications Standardization Institute (ETSI), the Conference on European Postal and Telecommunication Administrations (CEPT), as well as European research programmes such as RACE, contributed to the development of GSM. (See Fransman (2002), chapter 2.)

[9] ANSI-136 and ANSI-95 (based on the American National Standards Institute) and CDMAOne (code division multiple access).

[10] The Personal Digital Cellular (PDC) standard.

[11] For data on the diffusion of second-generation mobile systems in Europe, Japan and North America see Fransman (2002), p.76.

[12] The technical standard adopted as the basis for UMTS is WCDMA (wideband code division multiple access). Code division multiple access (CDMA) is a method of spreading spectrum transmission for digital wireless personal communications networks that allows a large number of users simultaneously to access a single radio frequency band without interference. WCDMA is one form of multiple access in the wireless communication field. The basic technology does not differ from CDMA, but WCDMA uses broader frequency bandwidth waves. In the US, CDMA 2000 has become popular as an alternative to WCDMA (although several US mobile operators have adopted WCDMA). CDMA 2000 is also a radio transmission technology and was developed to facilitate the evolution of narrowband CDMAOne (used in the US as one of the second-generation mobile technologies) to third generation broadband allowing the addition of multiple carriers.

[13] The Japanese had hoped that their domestic digital (second-generation) mobile standard, the Personal Digital Cellular (PDC) standard, would become more widely adopted at least in Asia. The fact that this hope was not fulfilled encouraged the view that Japan needed to throw its lot in with other strong partners in order to develop a globally-accepted standard.

The belief was that this process would facilitate progress along a smooth evolutionary trajectory, much the same way that new generations of microprocessor and memory semiconductors successively replaced one another, leading to new profitable opportunities for users while allowing a rapid growth in the industry as a whole over time. Furthermore, this belief was boosted by supporting beliefs, widely held in the exuberant financial markets at the time, that telecoms in general, and mobile communications in particular, offered opportunities for significantly above-average returns.

Belief-Frustrating Events

Alas, however, the plans of mice and men often go astray. Several factors combined to frustrate the aims of the third-generation mobile standard, UMTS/WCDMA – at least within the timeframe anticipated by its creators and backers.

The first of these factors emerged at the level of the underlying technology and the equipment that embodied it.[14] Rather than the new technological knowledge acting as an efficient instrument to expand the choice set with predictable consequences, it turned out that this knowledge was less than complete and was far more complex and fragmented than had hitherto been appreciated. To begin with, the complexity of the new 3G networks presented greater difficulties than had been anticipated. To complicate matters even further, for reasons of cost and coverage 3G networks were required to inter-operate with 2G networks. At the level of handsets, a crucial selling point for users, unexpected software problems emerged as manufacturers grappled with the task of developing handsets that would efficiently receive both 2G and 3G signals. The result was that operator after operator – beginning with the Japanese company DoCoMo that was to have been the first to roll out a UMTS/WCDMA service in 2001 – delayed the introduction of their 3G offerings.

Secondly, the perceived contents of the choice set changed rapidly. While 3G technologies and services (based on UMTS/WCDMA) were intended to decisively leapfrog 2G versions (using GSM and CDMA 2000), rendering them inferior, the knowledge embodied in 2G was not static but on the contrary improved rapidly, partly in competitive reaction to the imminent introduction of 3G. Furthermore, with the collapse of telecoms share prices from mid-2000, the financial environment within which the decisions were being made changed drastically. Whereas previously exuberant financial markets were more than happy to bankroll mobile operators, now the situation was reversed making the more expensive though technically superior UMTS/WCDMA option look relatively less attractive. Accordingly, while initially many (if not all) saw UMTS/WCDMA as the correct option, suddenly the issue of appropriate choice seemed far more ambiguous.

Two events dramatically highlighted the extent to which the knowledge, connections and imaginings of the key players had to change in order to keep up with the evolutionary process. The first was the large number of mobile operators around the world who refused to adopt third-generation UMTS/WCDMA, opting instead, at least in the interim, for rapidly-

[14] Elsewhere [Fransman (1995)] I have suggested that for some purposes technology may be fruitfully thought of as belief, more specifically as a set of beliefs regarding how to do things in order to achieve particular outcomes. Since there are almost always alternative ways of achieving the same or similar outcomes, and since over time better ways usually emerge, these beliefs are always held with uncertainty and are constantly unfolding.

improving and cheaper enhanced 2G technologies[15] Some mobile operators in key countries such as the US, China (by far the largest mobile market in the world), and Korea went down this route. The second event was the development in Japan of an innovative and highly successful 'picture phone' service, together with appropriate camera-carrying handsets, using enhanced 2G technology. This service was developed by one of the competitors to the dominant incumbent, NTT DoCoMo, and in 2001/2 outperformed in terms of revenue growth and subscriber numbers the more sophisticated but significantly more expensive real-time 3G video service of the latter.

The third factor threatening to frustrate to some extent the aims of UMTS/WCDMA and making the choice set even more fuzzy was the appearance of a new technology from a neighbouring industry. Wireless local area networks (WLANs, or Wi Fi – from Wireless Fidelity - as the first generation standard is commonly called) provide a radio connection, currently over a distance of about 100 meters, between a user's personal computer (usually laptop or personal digital assistant) and an application point (or base station) connected to the fixed network. Within the footprint of the application point users are able to connect to the network and the Internet by inserting a card into their PC (many PCs now have these inbuilt) avoiding the need for connecting cables.

WLANs were not originally designed in order to facilitate mobility. Their origin goes back to 1985 when the Federal Communications Commission in the US opened up a part of the radio spectrum[16] for unlicensed experimentation. Researchers at several computer companies, including Apple and NCR, began developing wireless networks in order to connect computers and other equipment such as cash registers and motor car assembly lines. However, the systems were incompatible and this inhibited development and diffusion. In 1990 an NCR researcher, Vic Hayes, began his efforts to develop a WLAN standard. In 1997 this effort bore fruit with the release of an IEEE standard known as 802.11b (also called Wi Fi). From 1999 computer companies such as Apple began inbuilding Wi Fi cards into their laptops for as little as $99[17] and soon thereafter 'wireless hot spots' began to be developed in publicly-accessible places such as Starbucks coffee shops.

WLANs compete with mobile cellular networks particularly in the area of mobile data which can be sent and received over either type of network. However, WLANs have a considerable advantage in terms of speed that can translate into shorter download and upload times and enhanced video quality. But mobile phones are quicker and easier to use and WLAN users are limited by the range of the application point. The latter constraint is rapidly diminishing as companies stretch the coverage provided by the application point's antennae.[18] In the area of mobile voice, however, the relative advantages of WLANs are less obvious. The biggest

[15] These included CDMA 2000 – 1X, the improved version of CDMAOne developed in the US, and GPRS and EDGE developed in Europe building on GSM. (GPRS, general package radio service, is an extension for adding faster data transmission speed to GSM networks. It is a package-based technology. EDGE, enhanced data for global evolution, is a faster derivative of GSM. It enables multimedia and broadband functions to be performed on mobile phones.)

[16] This spectrum was at 2.4 Ghz.

[17] *Business Week*, April 28, 2003, p.50. The original WLAN standard was 802.11b operating at the 2.4 Ghz band. Later a second-generation of competing standards was added operating at around 5 Ghz, 802.11a, also developed in the US, and a competing European standard developed by The European Telecommunications Standardization Institute (ETSI), HiperLAN2. Concurrent research has also continued to improve the performance of 802.11b resulting in later generations also operating at 2.4 Ghz, such as 802.11g.

[18] It has been reported that new antennae "with a range in miles" are currently being developed compared to the 300 feet presently available. *Business Week*, April 28, 2003, p.51.

disadvantage currently is that WLANs lack a hand-over function that would allow users to move from the footprint of one application point to another, thus making roaming difficult although attempts are being made to add this functionality.

For computer companies such as Microsoft, Intel, and Apple – until now largely excluded from the European-led area of mobile communications – WLANs present a new opportunity to muscle into the mobile field on the back of a powerful competing technology. So great is the threat that some informed observers believe that WLANs will soon totally replace 3G mobile cellular communications. However, many more are of the view that although there is a degree of substitutability between WLANs and 3G mobile services there is also an important degree of complementarity. For example, 3G networks could be used to provide the roaming function that WLANs currently lack. Attempting to play on this compatibility, many mobile operators are also developing large WLAN networks.

As these three factors make clear, both the choice set in the area of mobile and wireless communications and the knowledge that it embodies are open, often ambiguous, and continuously being transformed. An appropriate theoretical conceptualisation of 'knowledge' must capture these qualities.

BELIEF 3 (late 1990s):

Auctions provide the most efficient way of allocating scarce spectrum to the most suitable operators while maximising the price of this public resource

The transition from second to third-generation mobile communications required the use of additional radio spectrum. This posed a problem for the authorities regulating the mobile industry: how should this spectrum be allocated to those mobile operators wanting to offer 3G services? Closely related to this question was how to price spectrum, a public resource. Seldom mentioned explicitly, a further issue was how to ensure that the solutions chosen in answering these two questions would not damage, but perhaps even enhance, the health of the mobile industry in the interests of both consumers and providers.

The first point to stress is that there was no consensus in dealing with these matters. Instead, two opposing camps emerged. The first, strongly influenced by a number of theoretical economists, proposed that an appropriate auction mechanism should be designed which would solve all three issues.[19] The UK and Germany were included in this camp.[20] The second camp favoured a 'beauty contest' whereby the regulatory authorities would make the final decision. The latter camp included Japan and Sweden.

It is not the intention here to delve into the many complex issues surrounding the adequacy of the auction solution. Rather, in line with the central concern of this paper, discussion will be confined to some comments on the role of knowledge in the auctions.

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19 See http://www.telecomvisions.com/articles/ for three articles by Paul Klemperer, Professor of Economics at Oxford University, who was an important adviser to the Radiocommunications Agency in charge of the 3G auctions held in the UK.

20 Ultimately, the mobile operators in the UK and German 3G auctions committed themselves to the payment of a total of $79 billion (Euros 90 billion) in return for their 3G licences.

Abstracting from the technical issues of auction design[21], attention will be focused here on two areas of knowledge that bidders in the auction process are presumed to possess. The first is the bidder's costs in providing 3G services with the use of the spectrum. The second is the revenue that the bidder will earn by selling these services. An implicit assumption behind the idea of an auction is that the bidder will know its costs and revenue and be able to deduct the costs from the revenue in order to calculate the profits that will be made from providing the services. These profits will determine the maximum amount that the bidder will be willing to bid in the auction for the licence.[22]

If the bidder knows its costs and revenue with certainty (i.e. the choice set is known with certainty and is therefore closed), and if other conditions are met (such as effective competition between the bidders), then there are reasonable grounds for believing that the efficient outcome promised by the auction theorists could be achieved. The problem, however, is that the relevant costs and revenue lie in the future and therefore can only be known with uncertainty (or, in Loasby's more accurate terminology, can only be imagined).

In the event, this posed particular problems for the imagined revenues. (In the case of the costs, the cost of 3G networks were reasonably well-understood having already been the subject of a good deal of work by the equipment suppliers. However, even regarding the costs there was a significant degree of uncertainty as indicated earlier in the discussion of the unanticipated delays that unexpectedly slowed significantly the implementation of 3G networks and services, thus also affecting the revenue projections.)

Revenues were particularly problematical for the simple reason that many of the intended 3G services were entirely new with the result that it was uncertain whether consumers would want them, and if they did, what they would be willing to pay. To make matters worse, the timing of the auctions coincided with the late stages of the Telecoms Boom. The expectations of mobile operators and their exuberant financial market backers became mutually reinforcing. Optimistic imaginings that consumers would be willing to pay profitable prices for services such as real-time video phone conversations and conferencing and seeing the latest football goals being scored nanoseconds after they had actually been scored went virtually uncommented upon. Clearly, these imaginings had a significant impact on the expected revenue and therefore on the maximum auction price that the bidders were prepared to pay.[23]

The outcome with the passage of time and with hindsight is now known. The introduction of 3G services were delayed considerably beyond what bidding operators had assumed in making their bids and expected consumer demand was significantly downgraded. What ex ante had seemed like reasonable bids turned, ex post, into costly mistakes. The extremely

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[21] For a discussion of some of these issues see the articles by Klemperer referred to in the footnote above.

[22] In an ascending auction where the bids are made known at each stage to all the competing bidders there is the opportunity for a bidder to learn something about the cost and revenue assumptions of its rivals. This may allow a bidder to revise its own estimates.

[23] Overly optimistic revenue expectations, influenced by contextual factors such as the Telecoms Boom and its set of underlying expectations, were far more significant than the pressure that some leading mobile operators have claimed they were under to secure a licence if they wanted to remain in the mobile market. The fallacy in the argument of these operators is that, although they may have been under pressure, they would clearly not have been willing to pay any price. As auction theory states, the maximum price that any operator would be prepared to pay would be determined by expected long run costs and revenue. To go beyond this price would imply bankruptcy or unsustainable indebtedness. Accordingly, this anti-auction argument put forward by some operators does not hold water.

high levels of indebtedness that afflicted all the 3G mobile operators, particularly those that had committed themselves to paying high auction prices, was the price to be paid. Uncertainty was the devil that had damaged the detail, in precisely the same way that it destroyed the risk-eliminating calculations of Nobel prize-winning economists and their colleagues who created Long Term Capital Management.[24]

As this auction story makes clear, knowledge issues were at the heart of the auction debacle. One implication is that a clearer conception of what these knowledge issues are, and how they should be conceptualised, would improve our understanding of events such as these.

BELIEF 4 (late 1990s):

In order to create new mobile internet services it is necessary and sufficient to create a de facto standard protocol (that became WAP[25])[26]

In the latter-1990s the two fastest-growing areas in the entire information and communications industry were the Internet and mobile communications, high-growth beginning coincidentally at about the same time in both these fields. However, until about 1999 they grew in parallel, with little contact between them. Unsurprisingly, in the late-1990s many began turning their attention to the creation of the 'mobile Internet', to ways of accessing Internet web sites from mobile phones. Two major initiatives emerged, in Europe and Japan respectively, the two leading regions in mobile communications. Early in the new millennium it soon became apparent that while the European-led initiative had become a major failure the Japanese initiative was a resounding success, giving birth to the mobile Internet. Since on the face of it both initiatives had the same general objective – to reformat web pages so that they could be accessed by mobile phone – the different outcome in the two regions begged an explanation.

In Europe both Ericsson and Nokia began in-house research in the latter 1990s to develop the mobile Internet. A major incentive was the sale of related equipment to their major customers, namely the mobile operators. However, they soon established partnerships with several other companies, including from the US Motorola and a small start-up that had been working in this area for some time, Unwired Planet. Eventually the WAP Forum was established as an institutional way of facilitating standardisation and collaboration. Significantly, the mobile operators played little role in these proceedings.

Once the protocol was up and running the mobile operators began offering WAP phones and services. Some of them advertised the possibility of accessing the Internet by mobile phone. However, contrary to expectations, consumers showed little interest. Of the drawbacks of the service the most important was the relative absence of content and applications suitable for mobile phones. A further problem was the high price and the charging mechanism. Provided on a circuit-switched mobile network, users of WAP services paid by the amount of time they used. Given the speed of the second-generation network it took a relatively long time for material to be downloaded. Many users felt as if they were stuck in a traffic jam with the

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[24] In the latter case it was the unimagined Russian default that upset the apple cart requiring a controversial bailout by the Federal Reserve Bank.

[25] Wireless Application Protocol (WAP), a protocol for the re-formatting of web sites so that they could be accessed by mobile phones.

[26] This section is based on Fransman (2002), Chapter 9.

meter running and the content, when it eventually came, was a further source of disappointment.[27]

WAP became one of the biggest disappointments in the mobile industry in Europe at the turn of the century. Ironically, while WAP was intended to be the first major mobile data service, taking over from voice as the main growth generator, it was a completely unintended and unanticipated service that took its place. This was SMS, short message service, or texting as it has become known (the equivalent of e-mail). Although SMS was a facility provided on GSM networks, no-one conceived the possibility of consumers being willing to go through the laborious process of inputting the letters making up a short message. But in the early years of the new millennium SMS became one of the most important sources of revenue-growth for European mobile operators. Once again the choice set had changed in an unanticipated way.[28]

In Japan, however, a very different trajectory was followed. Rather than beginning with a *standard*, the Japanese incumbent that led the mobile Internet, NTT DoCoMo, started with a *service*. Taking the initiative, DoCoMo was a dominant mobile operator in contrast to the European mobile Internet leaders who were equipment suppliers. Aware that the mobile voice market in Japan and other industrialised countries would soon be saturating, DoCoMo's leader instructed that work begin to develop a new mobile data service. A team was established to carry out this task (and, unusual for established Japanese telecoms companies, two Japanese outsiders were appointed to this team).

Although a business service was initially intended, the team soon changed its focus to the young mass-consumer market on the grounds that young consumers would be more tolerant of the unavoidable technological shortcomings at the time of mobile data services. This meant that while DoCoMo *started* with a specific consumer segment in mind, the creators of WAP began with a standard and neither they nor their mobile operator customers gave much thought to the ultimate users of their service.

The evolutionary path of DoCoMo's mobile internet service – that came to be called i-mode – followed from the initial choice of customer. Most importantly, thought was immediately given to the question of the content and applications that this consumer segment would want, to the pricing of these services, and to the technologies that would be required to deliver them. DoCoMo soon came to the conclusion that it was a network service provider rather than a content provider. Accordingly, it made the choice to work with partners who would provide the content and applications. Significantly, a further key decision was made to give strong incentives to content and applications creators thereby creating a "win-win situation" for both parties. At the same time, the decision to use DoCoMo's billing system to collect payments for the content and applications, passed on to the creators minus a 9 percent commission, provided a solution to the micro-payments problem.[29]

In choosing technology DoCoMo settled on old technology rather than new. In order to avoid the 'taxi meter' problem referred to earlier, the company provided a package data

[27] At the time of writing, aided by enhanced second-generation data-switched mobile networks, mobile operators have begun offering picture-phone services, hoping to emulate Japanese success with this service.
[28] Similarly, e-mail, the main driver of Internet services, was also initially an unplanned and unanticipated mass service.
[29] The micro-payments problem, which also bedevils Internet services, arises because of the absence of suitable mechanisms for making very small payments.

service (although partly over a circuit-switched network) enabling users to pay for the service according to the amount of data rather than the amount of time. At the same time, a variant of the widely-known Internet software language was used for the creation of i-mode web sites, the software application tools being made freely available over DoCoMo's web site to would-be i-mode content and application developers.[30]

However, in the area of handsets, a key fashion consumer good for many young users, DoCoMo worked closely with a number of Japanese electronics companies. As the largest mobile operator in Japan, with its own substantial R&D capabilities, and drawing on parent NTT's long history of close cooperation with its suppliers, DoCoMo was able to ensure the co-development of attractive handsets that would further stimulate the adoption of i-mode services.

DoCoMo's i-mode service was launched on February 22nd 1999.[31] By March 2001 DoCoMo had signed up its 20 millionth customer. Almost 1,500 i-mode content and application sites were directly accessible from DoCoMo's i-mode button on its mobile handsets while a further 40,000 were also accessible from the phone. Currently there are more than 40 million users of i-mode in Japan. Corresponding figures for WAP are not available although it is widely acknowledged that the take-up has been extremely disappointing.

Once again it is clear that the knowledge that was needed to launch mobile Internet services was, from an ex ante point of view, both complex and uncertain. In Loasby's terminology, while the players involved made their connections and imagined the mobile Internet future, things did not always turn out as they expected. Even for DoCoMo's i-mode team each step of the way was marked by uncertainty and ambiguity with success never being guaranteed until the point when it was actually achieved.[32] (Tales of success when told backwards seldom capture the complexities of the ex ante process unfolding uncertainly in real-time.)

BELIEF 5 (mid-to-late 1990s):

Financial markets believed that above-average rates of return would be earned by mobile companies – both operators and equipment suppliers. Hundreds of billions of dollars were channelled to these companies to fund their expansion.

As noted above in the discussion under Belief 1, in the early-1980s when analogue mobile networks began commercially operating there was a fair degree of scepticism regarding how popular this service would become. It was only some years after the 1992 adoption of the GSM standard that mobile communications began to take-off in Europe as a truly mass-market service and the same process took place in Japan on the basis of the PDC standard.

[30] A version of HTML was chosen for this purpose, called cHTML (compact HTML). HTML (hypertext markup language) is the language used by programmers to design a home page for computers on the Internet as part of the World Wide Web. Although WAP was not significantly more difficult for programmers to learn compared to cHTML, DoCoMo claimed that the latter benefited by being more familiar to programmers, thus lowering technological entry barriers for i-mode content and applications creators.

[31] Several months later some of DoCoMo's Japanese competitors also launched their own competing mobile Internet services, highlighting the fact that although it was the first-mover, DoCoMo was not the only Japanese company to be moving in the area of the mobile Internet. However, as the dominant Japanese mobile operator, with more than 50 percent of the Japanese market, DoCoMo also dominated the mobile Internet market.

[32] This emerged clearly in the author's interviews with key members of the i-mode team.

Several years later the same process was repeated in the US and began in many middle-income countries.

During the Telecoms Boom from around 1996 to 2000 mobile communications were one of the brightest spots in the entire telecoms industry. Although a good deal of the exuberant attention of financial markets was focussed on the fixed new entrant operators – such as WorldCom, Qwest, Level 3 and Global Crossing in the US and Colt, Energis, Mannesmann and Mobilcom in Europe – and the equipment-makers that supplied them (such as Lucent, Nortel, Cisco, Alcatel and NEC), mobile communications also attracted a good deal of attention.[33] The reason was the extremely rapid growth in subscriber numbers as market penetration rates in Europe and Japan rapidly moved towards the 70 percent level. Indeed, it became apparent by 2000 that although the fixed Internet and data communications more generally were growing rapidly, profitability in this area lagged significantly behind that in mobile communications.[34]

It was not surprising, therefore, that the exuberance of financial markets during the Telecoms Boom was also focussed on mobile communications. And the leading mobile telecoms companies, rising to the occasion, did not disappoint. The star performer, without doubt, was Vodafone.

Vodafone began life in 1982 when Gerald Whent, Chairman of the British company, Racal Radio Group involved in military-related equipment, persuaded the board to bid for a UK cellular license. In 1985 Racal's mobile subsidiary (that was de-merged from Racal in 1991, becoming Vodafone) launched its analogue mobile network. In its formative years up to 1993 the company benefited from being one of only two competitors allowed into the mobile market by the British regulatory authorities, the other being Cellnet, established by the British incumbent, BT, and a minority-holding partner. However, the company's big breakthrough came in 1988 when Whent made the decision to develop mobile telephony internationally by entering national consortia formed to bid for local licenses. At this time no other mobile operator saw global opportunities for mobile communications.[35]

During the late-1990s financial markets became increasingly interested in the mobile sector as mobile subscribers, revenues and profits grew rapidly. Furthermore, even after the fixed new entrant operators began to lose some of their shine as intense competition and excess capacity began emerging in long-distance and international markets, mobile operators continued (at least for a while) to look attractive. Vodafone was one of the main beneficiaries.

Until 1998 Vodafone's strategy was to take minority holdings in the overseas consortia it entered. In 1998 it made its first major acquisition, a New Zealand GSM network. This was followed in 1999 by its second major acquisition, AirTouch of the US, the former subsidiary of the Baby Bell, Pacific Telesis. The third major acquisition was Mannesmann of Germany, made in 2000. Advised by investment bank Goldman Sachs, Chris Gent, Vodafone's chairman, had come to the conclusion that in the mobile industry of the time it was a matter of either "eat or be eaten"[36]. So Vodafone ate, using its rising share price as a currency with

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[33] For a more detailed discussion see Fransman (2002).

[34] One of the reasons for the profit differential was the limited number of mobile licences issued that created oligopolies with around four mobile operators in most countries.

[35] Gerald Whent's decision is examined in more detail in Fransman (2002), p. 117-119.

[36] Author's interview in Goldman Sachs.

which to finance its acquisitions. The virtuous cycle redounded to Vodafone's benefit, its high share price begetting acquisitions, which in turn begat an even higher share price and market capitalisation, which begat the currency for even further acquisitions, etc.

Vodafone also benefited from the fact that it was a 'single play' mobile operator, its performance not dragged down by fixed long-distance and international networks that by 2000 were beginning to affect negatively the share performance of even the strongest fixed new entrant operators such as WorldCom. While in July 1999 WorldCom's market capitalisation was $152 billion, making it the fourteenth most valuable company in the world, by October 2000 its value had fallen to $52 billion. In 1998 Vodafone's market capitalisation was around $10 billion and in July 1999 Vodafone did not even make Business Week's list of the most valuable companies. However, by October 2000, after the acquisitions of AirTouch and Mannesmann, Vodafone was worth $225 billion, making it the most valuable company in Europe and the seventh most valuable in the world. The other major mobile operators also benefited, although not to the same extent as Vodafone, from the mobile mania.

Behind the spectacular rise in financial valuations were the beliefs that drove financial markets. These were the beliefs not only of private, corporate and institutional investors who bought the new and existing shares of the mobile companies (mobile operators and the equipment suppliers – such as Ericsson, Nokia and Motorola – that supplied them). They were also the beliefs of the bankers who loaned money to the mobile companies as well as the bondholders who bought their high-yielding bonds.

But exuberant beliefs were not the only explanation for the financial valuations. Also significant were some of the organisational routines that were part and parcel of the modus operandi of financial institutions. One key example is the practice of benchmarking on a quarterly basis the performance of fund managers and their funds. Designed as a way of regularly monitoring investment performance in the interests of investors this widely-practiced routine also had the unintended and undesirable effect of putting significant pressure on fund managers and their financial companies to include in their portfolios the shares of high-performing companies such as the mobile companies. Failure to include these shares meant running the risk of not meeting benchmarks such as stock exchange indices and, in turn, not delivering the same returns as competing funds that had made the inclusion. (The indices themselves were significantly affected by the main telecoms shares.) Leading institutional investors have reported that in many cases in 1999 and 2000, even when fund managers believed that the share price of telecoms operators were overvalued and would soon fall they were nevertheless forced by these pressures to buy and hold telecoms shares.[37]

As shown earlier under Belief 2, the mobile industry in Europe went into the third-generation era with the enthusiastic backing of financial markets that initially were willing to finance both third-generation infrastructure and auctioned licences. However, for reasons examined there, this enthusiasm did not survive into 2001 and 2002. Along with the other telecoms companies, and the so-called 'tech sector' as a whole, the share valuations of mobile operators and equipment suppliers were substantially down-valued from this time. The beliefs that had fuelled mobile mania had significantly moderated.

[37] This conclusion is based on numerous interviews by the author held with leading institutional investors in 2003.

CONCLUSION

In this paper the evolution of the mobile communications industry has been examined in terms of some of the key events that have shaped this industry and the knowledge related to them. The theoretical purpose of this paper has been to propose a conceptualisation of knowledge in keeping with the unfolding and uncertain evolutionary process itself. This conceptualisation diverges from the utilitarian and instrumental concept of knowledge that, it is suggested, is frequently used in evolutionary economics. Rather than seeing knowledge (including tacit knowledge) solely as an instrument to aid in the production of innovation and output (although at times knowledge certainly does perform this function), knowledge is conceived of in a broader way, as an uncertain process in which the knowledge involved in the process is itself constantly being transformed.

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