Review the changing role of intellectual property in the microelectronics sector

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Abstract. *The microelectronics industry has been a driving force behind significant economic and structural changes in the world markets over the last 30 years. The pace of technological change within the sector and its broad impact on most, if not all, other industries make it an extremely rich area to study. This paper will examine how intellectual property rights (IPR) have played a role in the development of the microelectronics industry as a whole and also how IPR has influenced the activities of firms and has, in many respects, forced them to take a 'core competencies' approach prior to the mainstream popularity of the notion. We will argue that IPR, and patents in particular, have played an increasingly important role in the industry, particularly with regards to their financial impact on firm strategies.*

Keywords. Changing role, IPR, Microelectronics industry, Patents.

1. Introduction

This paper assumes of the reader a basic working knowledge of IPR concepts. IPR regimes are diverse and complex, and this complexity increases dramatically as global interactions are taken into account. For the purposes of this paper we will be focusing primarily on patents and to a lesser extent trade secrets as these are the methods by which most microelectronics inventions can be protected.

2. The Microelectronics industry

2.1 Overview

Microelectronics (ME) is the design, manufacture and use of microchips and integrated circuits. Much of the production occurs at the micron scale creating massively complex sub-systems and systems which can easily contain many millions of transistors in a few square centimeters of dope semiconductor on silicon substrate.

Kick-started by the discovery of the transistor at AT&T's Bell Labs in 1947 (Lucent 2002), today the industry is filled with a wide variety of firms ranging from 'captive manufacturers' such as International Business Machines Corporation (IBM) who produce most of their chips for themselves, to 'diversified merchant producers' including Motorola who straddle many fields and produce for their own consumption as well as for clients. Also present are 'specialized single technology or niche' firms, such as Transmeta, who may well outsource their production to larger third parties or focus on producing a very specific chip which larger fabricators find un-economical to make (Podolny and Stuart 1995).

2.2 The Market

There are several key factors are important to the analysis of the ME industry in relation to IPR. Firstly the market has been experiencing technological forces commonly known as 'convergence'; this refers to the fusion of a wide variety of technologies and markets such as telecommunications, film and fashion into integrated technological products[1]. Convergence has forced firms, either through their own growth, licensing or a wide variety of partnering activities to become competent, or at least current, in an ever growing number of technical fields. In many respects ME itself has been the force behind this trend, indeed academic consensus seems to agree that ME is a pervasive technology (van Tunzelmann 1995; Freeman and Soete 1997) which has broader implications such as the technology's likely utility in many fields. The argument is that not only does the pervasive technology get embedded in a broad range of products but that also products, as a trend, contain greater numbers of technologies (Figure 1). This has had significant implications for individual firms' abilities to develop and market new product offerings, and many firms, such as Philips struggled to keep up with the breadth of change (von Tunzelmann 1995).

Apart from the technological forces, the ME market also has undergone some dramatic structural changes in its competitive nature. Citing Dosi, Freeman and Soete argue that while the ME industry was a mature international oligopoly in the 1970s the resurgence of several US firms and South Korea and Taiwan's explosive growth has re-invigorated the market (Freeman and Soete 1997). Most observers would agree with this argument; however in specific sectors of ME market suppliers still hold extremely powerful positions. The best example is, of course, Intel's hold over the X86 CPU product categories. Such is their hold, partially through 'creative' licensing policies[2], that the US Federal Trade Commission has instituted anti-trust actions several times against Intel (Savage 1999). This clearly has a distorting impact on the market making it harder for new entrants in some segments; however the continuing pace of technological development allows new niches to emerge where existing players are not suitably aligned to take best advantage of the opportunities presented (von Tunzelmann 1995).

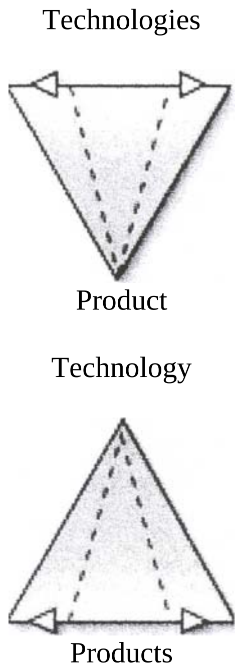

Figure 1. Products have more technologies embedded in them due to pervasive technologies. At the same time, due to its nature, a pervasive technology appears in a large range of products. pp279 (von Tunzelmann 1995)

1 Take for example a modern laptop which may well integrate a DVD player, wireless Internet connectivity and a fashionable slim metallic exterior with a powerful computer.

2 Savage describes one US Federal Trade Commission (FTC) case against Intel that focussed on their refusal to give customers access to key technologies and information unless the clients surrendered certain patents rights to Intel. The case was settled but the terms of the deal confirmed Intel's guilt as it "prohibited [Intel] from withholding or threatening to withhold advanced technical information or products from customers as a means of obtaining intellectual property licenses". An excellent example of patent law being used 'strategically'.

3. ME Research and Development

It is useful to briefly examine how new products are developed within ME firms, in other words the R&D process. Generally US technology firms have a high reliance on public science, 80% of citations on their patents are externally authored, with the overwhelming source being universities (Narin, Hamilton et al. 1997). Analysis of the Yale survey data (Klevorick, Levin et al. 1995) indicates the high importance of physics and computer science to the ME industry and that proximity between the businesses and the fields of science is particularly strong for the ME trade. While this survey data is questionable, particularly due to its reliance on the views of R&D managers themselves, it does align relatively well with evidence from other sources. For example Pavitt addresses this issue by quoting Mowery who argued that existing large science-based companies could develop competencies in ME due to their abilities to establish internal and external R&D projects or linkages as 'insurance' against future trends (Pavitt 1986). In other words, We would argue, the closer a firm is to the relevant fields of science, the better its chances of riding out the tumultuous sea of technical change that characterizes the ME industry.

4. ME Production

Freeman and Soete identify the huge importance of process innovation to the ME industry. A successfully designed product based on strong science and built with leading-edge technologies can fail spectacularly when wafer yields (the proportion of usable silicon wafers produced) can initially be as low as 5-10% and a single production line can cost $200m and entire 'fabs' (chip manufacturing plants) cost as much as $2billion, with the price rising rapidly as the etching scale shrinks (Rapoport 1986; Housego 1988; Freeman and Soete 1997; Becker 2001). Consequently the role of the tacit knowledge (or 'technical expertise' as Taylor and Silberston describe it) is vital and many firms valued it above patentable technical innovations when surveyed in 1968 (Taylor and Silberston 1973), though we will argue the emphasis has shifted somewhat. Nevertheless the huge size of investments in chip fabs and the potentially ruinous yields creates a massive impetus for process innovation and due to the nature of most patent regimes; this is where trade secret protection plays a more significant role (Kehoe 1986). Samsung described their efforts to make their first large scale wafer fab plant commercially viable as "working the skins off" their engineers (Housego 1988). The duality between the R&D and production roles of the ME industry fits well into the distinction, described by von Tunzelmann, citing Hicks as well as Patel and Pavitt (von Tunzelmann 1995), between technology as an artefact and as a body of knowledge. This distinction should not be taken too literally as clearly there are significant technical, artefact based, aspects to the production process; however the main gains for the firm at this stage are procedural and not technical. In many respects technical improvements dramatically raise the risks in production, as highlighted by the enormous cost of creating ever more advanced fabs. Thus in many ways firms regard a successful production process as an art, often the factors contributing to the success are not entirely clear, as typified by Intel who make each fab identical to the others to ensure that whatever aspect it is that works can be carried over to the new lines (Freeman and Soete 1997)[3].

5. THE EVOLVING USE OF IPR IN ME

5.1 The Propensity to Patent

Scherer's 1977 econometric survey of the propensity of several industries to patent identifies the relatively low propensity of the electronics industry when compared to other 'modern' fields of commerce (Scherer 1981).

The usual arguments questioning survey results can certainly be rehearsed on this somewhat dated study, and clearly the industry groupings, based on Federal Trade Commission industry classifications are questionable-specifically how were Electrical and Electronic separated? While it may be a small stretch to use the Electronic industry data for ME it is interesting to note that the reasons Scherer gives for the lower propensity to patent in that field matches those given in

[3] It must be noted that this is not Intel's only reasoning for identical fabs (an approach they call "copy EXACTLY!"), there are also human resources and disaster recovery issues, the uniformity allows staff to move facilities and production relatively painlessly (Intel 1998; Ristelhueber 1999).

other work. Specifically he notes the ease of inventing around electronic inventions (i.e. the low exclusivity of many ME patents) when compared to the fields such as organic chemistry (which regularly has highly exclusive patents). Also noted are the difficulties in patenting systems of the complexity seen in electronics. He argues that the costs per patented invention in the electronics industry, where inventions often may well have ubiquitous implications, are significantly higher than in other industries which results in a lower patenting rate. However the linkage between the scope of the invention and the cost of inventing and patenting the discovery is not firmly identified. These views are supported in the 1968 survey by Taylor and Silberston which Scherer in fact references (Taylor and Silberston 1973).

Taylor and Silberston argue (based on their survey data) that even slight innovations in electronics have a high cost and that the very high support given by governments (as high as 40% of total budgets in 1968) to electronics R&D has been the key factor in maintaining the pace of innovation of that period *(ibid.* pp285-286). They also point out the differential in patenting between the component and system levels with components dominating their results even though such patents have a higher likelihood of being invented around *(ibid.* pp290. 295). If we examine this duality through the two key dimensions of appropriability suggested by Teece, *legal instruments* and *nature of the technology* (Teece 1986) we can see that despite relatively effective legal instruments protecting components (through patenting) competitors can avoid infringements because the nature of the technology allows multiple paths to the same outcome.

The importance of patenting has historically been further reduced by the short product life-cycle that typifies the ME industry[4]. The argument is that with the short life of many technical innovations, and due to their cumulative nature, they will be rendered obsolete before a patent has been granted, particularly if it has been applied for internationally through the PCT system. Several sources identify this as a factor recognized by industry practitioners (Taylor and Silberston 1973; Knight 2001). Furthermore, partly due to this high level of technical change which makes it difficult for patent examiners to remain current, there has been historically a high level of doubt on the validity of many patents. In fact Taylor and Silberston's survey identifies a common level of doubt as being that around 90% of ME patents are probably invalid, which they argue is much higher than for any other science-based industry (Taylor and Silberston 1973). This doubt has continued with many firms pre-emptively challenging patents they regard as invalid while releasing infringing products (Kehoe 1994; Agencies 1996; Dickie 2000). We would argue that these factors are fundamental to a historically low appropriability regime in the ME industry, which partly accounts for the relatively low propensity to patent previously explored.

Not only does the cumulative nature of ME technology raise questions about the benefits of patenting inventions due to its impacts on appropriability, it also creates huge product design problems for those technologies which have been patented. Patents tend to cluster around certain technologies and as products are built up 'royalty stacking' occurs whereby individually reasonable license royalty rates build up to create an aggregate royalty which threatens the financial viability of a product. Due to the fast-moving nature of the technologies it can be hard to keep track of these royalty liabilities during the R&D process, thus to prevent nasty surprises various licensing techniques have been used by firms to preempt such problems, which will be discussed later (Teece and Grindley 1997; Teece 1998).

In their survey Taylor and Silberston's respondents claimed that the size and direction of their R&D activity was not affected in any significant way by patents, nor did patents have any important impact on the competitive landscape of the market, especially for the larger firms (Taylor and Silberston 1973). However we argue that the licensing data to be discussed subsequently indicates that that 1968 response is no longer representative of the ME

[4] The ME life-cycle is certainly short when compared to industries such as the automotive sector, however I am not arguing that product life-cycles are necessarily getting any shorter.

industry, patenting has taken a much larger role.

5.2 The Role of Disclosure

An argument often rehearsed against the use of patents is the forced disclosure of innovations that results from the patent registration process which divulges some technical advantage the firm may have. However Knight argues that skilled patent agents can ensure that no additional tacit knowledge is codified into the application and that only the fundamental technology is described, reducing the perceived disclosure risks to firms (Knight 2001). The 1968 survey has a surprising result which confirms this view: The firms responded, when asked about disclosure, that they were far more concerned by disclosure in technical journals and product documentation (which had to be detailed to keep customers satisfied) than in patent applications where the registration write-up was a closely controlled process (Taylor and Silberston 1973). While we have been unable to find more recent qualitative research on this topic one most note the high rate of patenting by ME firms and the fact that the patenting process continues to be a highly structured activity, due to its legalistic nature may indicate continued relative indifference to the issue of disclosure.

6. Patent Portfolios & Licensing

6.1 How Portfolios focus strategy

As the ME industry has developed and matured many larger firms have built large portfolios of patents which, in aggregate, have significant value. This creates a situation whereby there is competitive advantage in not duplicating the R&D activities of competitors but focusing on core competencies and thus creating a valuable portfolio which other companies need access to (as they to have focused on differing technologies). This creates a situation whereby there are strong inducements to license from each other so that product development is not blocked and those technologies which the company does not have the resources to develop can still be accessed (Teece and Grindley 1997). This could be seen as a market solution to the problem previously mentioned that products in the ME industry require knowledge in an ever widening range of technologies. Thus in many respects the size and nature of ME patent portfolios has inherently encouraged a *core competencies* approach to creating sustainable competitive advantage as described by Hamel and Prahalad, cited in Tidd, Bessant et al. (Tidd, Bessant et al. 2001).

6.2 The Changing Nature of Licensing in ME

While one could attempt to argue our position on the basis of the increasing numbers of patents filed each year by ME firms, we regard this as a trite approach as most if not all of the growth could be accounted for by the expansion of the ME market itself. Thus we have chosen to base the core of our argument that patents have become increasingly important to ME firms on the historical evidence relating to the changing licensing strategies the ME industry has seen and what their evolutions tells us.

For the ME industry the story begins with patent pools, which emerged out of several major firms who had created fundamental inventions that would play a vital role in the formation of the ME industry. The pools, which collected the vital patents for a specific field into an easily licensed collection allowed the field to develop without the cumulative nature of the technology (and the resultant patent problems) blocking progress. This approach emerged, Taylor and Silberston argue, due to the lessons learned from the classic patent blocking problems that delayed the radio and other innovations from becoming mainstream industries (Taylor and Silberston 1973; Teece and Grindley 1997).

However by the late 1960s the patent pool was all but defunct due to a variety of reasons including the expiry of the key patents which justified the pools, the reduced number of large firms in the market (thus making other types of licensing more viable) and the lack of simple clusters of patents (from sources such as Marconi or a productive government department) which could be easily defined and pooled (Taylor and Silberston 1973). We would argue there was one additional factor working on patent pools-the political and legal pressures of anti-trust activity by governments who had, by this time, already forced the hand of IBM and AT&T with regards to patent licensing.

The consent decree induced licensing by IBM and AT&T created an industry attitude to IPR which Taylor and Silberston characterize as 'liberal', certainly many of the key firms were keen to avoid the mistakes, which blocked the industry and prompted the creation of RCA (Taylor and Silberston 1973). At this point Teece describes patents as being seen as a 'weak' market tool, firms were relying on time to market and the production experience curve to maintain competitive advantage (Teece and Grindley 1997) as licenses were usually cheap and easy to obtain.

The licensing regime evolved quite rapidly from this point, but with a common factor remaining throughout, exclusivity was generally avoided-partly to avoid blocking and anti-trust issue but also due to the nature of licensing strategies adopted. From pools bi-lateral agreements became common as did 'armed neutrality' which can be best described as mutual acknowledged infringement. Most bi-lateral agreements were purely to avoid infringement however some included a broader knowledge transfer including process and manufacturing expertise, this choice has remained in ME licensing, though the majority of licensing does not include knowledge transfer (Taylor and Silberston 1973).

As the number of patents companies held in their portfolios increased it became ever more impractical to license patents individually or even in small clusters. In the 1960s Texas Instruments and IBM used the power of their portfolios to muscle their way into Japan, refusing to license local production. Having seen the power of portfolios other firms began to be more strategic with their own portfolios. Furthermore as the decade came to an end the policy used by many US government departments forcing 'second sourcing' came to an end, which increased the value of patents held on ME inventions. Thus by the 1970s entire portfolios or portfolio sections were being licensed bi-laterally. Occasionally a 'sniper shot' license would be given for a single patent, but the transaction costs prevented this being done on more than the key, high exclusivity, patents. New entrants, from the Asian Tigers[5] in particular, created a significantly more competitive ME market- they had paid nominal licensing fees to gain access to technologies but had offered no balancing portfolios to the licensors. Led by Texas Instruments the established firms began to re-evaluate how they licensed, specifically in these unbalanced situations and created processes for accurately putting financial values on specific patents and portfolios. As ME technologies became more complex the risks of launching new products increased (as typified by the cost of Intel's fabs) so intellectual property became more actively used to protect these investments, often by using patents to force joint ventures[6] Or cooperative R&D ventures with infringers. (Kehoe 1986; Rapoport 1986; Housego 1988; Butler and Thomson 1991; Thomson 1991; Anon 1996; Teece and Grindley 1997).

To indicate the massively transformed scale of licensing in the ME industry it is useful to note that from 1952 to 1963, as Taylor and Silberston quote Freeman, AT&T's Western Electric subsidiary recorded only a £3 million licensing income for their transistor patents when by 1965 over £20 million has been spent on R&D whereas, in contrast, Texas Instruments (TI) earned $85 million when they settled a single DRAM infringement suit with Samsung in 1988. By 1992 TI had, by one estimate, cumulatively earned $1 billion from infringement lawsuits and Teece quotes cumulative royalty earnings of over $1.8 billion between 1986 and 1993; this income was so significant TI used it to offset a sales slump during an industry downturn.

As previously described the breadth of technologies required in new ME products forced companies to increase their licensing activity, Teece even quotes a manager from IBM as saying "[we have] less time to invent everything we need". All the surveys and reviews we have examined highlight access to technologies (and thus infringement avoidance) as being significantly more

5 The Asian Tigers are : Taiwan, Hong Kong, South Korea and Singapore

[6] Counter examples certainly exist for at least the role of patents in joint ventures e.g. After a flurry of joint venture activity between Hitachi and Texas Instruments, IBM and Siemens as well as NEC and AT&T Microelectronics a Financial Times article noted that the primary motivations has been political and financial, intellectual property issues had been of low importance in this raft of activity. See (Butler and Thomson 1991).

important to ME firms than the potential revenue earned from licensing. In spite of this Teece identifies a trend whereby licensing has moved from a liberal 'capture' model to the more flexible and financially astute (for the licensor at least) 'fixed period' model which gives limited survivorship rights and more opportunity to renegotiate payments (Taylor and Silberston 1973; Housego 1988; Podolny and Stuart 1995; Teece and Grindley 1997).

7. New IPR concepts

Current IPR legislation has not covered significant portions of innovation created by the ME industry and, thanks to the economic importance of ME firms in many economies, the industry has been able to lobby for extensions of IPR concepts in the legal regime to cover their requirements. Examples include the 1989 Chip Protection and 1994 Integrated Circuit Layout Protection Laws in Taiwan (Chang and Tsai 2002) as well as the 1984 Semiconductor Chip Protection Act which gave mask[7] works 10 year copyright protection from first registration or first commercial exploitation (Podolny and Stuart 1995). This leads one to conclude that in spite of increasing use of patent and trade secret protection, ME firms have not seen these tools as sufficient to protect competitive advantage. Industry observers may well offer different interpretations of this increased IPR control!

8. CONCLUSIONS

Due to the resource constraints we have used a literature and news publication review of admittedly limited scope to argue our case citing some historical and more current sources. From these we have attempted to show that as the ME industry has matured into a field with short product-life cycles and increasingly capital intensive production IPR and specifically patents have become increasingly more important to the industry and especially the large firms, in spite of a relatively low appropriability regime.

We have also argued that due to their growing portfolios and the cumulative nature of the pervasive technology on which ME firms are based, their strategic hands have been forced into a core competencies approach for, at least, their R&D activities.

These tentative conclusions raise further research questions: What are the industry's views on this topic today versus Taylor and Silberston's 1968 results? Can we create and measure some useful indexes to track this trend quantitatively over time? The analysis provided also does not give us much guidance for future change, especially considering recent comment that the trend to open standards committees with compulsory licensing terms is threatening the value of patents (Festa 2002). The dynamic nature of the ME industry's use of IPR will continue to provide fertile ground for further research.

[7] A mask is effectively a template for etching a chip and is the key architectural document.

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