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THE INTELLECTUAL PROPERTY BUSINESS MODEL (IP-BM)

LESSONS FROM ARM Plc.

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ABSTRACT

Under what conditions can technology ventures design and implement a sustainable Intellectual Property Business Model? Many new firms in technology-intensive domains seek to adopt such models. This enables them to focus limited resources on core areas of competence, but raises significant challenges. These include the reluctance of customers to license the technology until it is generating value in applications and the experimentation needed to identify appropriate applications and markets, especially for generic technologies. Complementary assets must be fostered to transfer the technology across the value chain. Protecting the IP during scale up is problematic. In this paper we offer a detailed study of a firm that succeeded in overcoming these challenges, ARM plc. We attempt to identify what aspects of their experience (of IP generated growth) are generalizable to other firms. We define a business model as the way the firm is organized to create and capture value. We explore the kind of business ecosystem that must be nurtured for a firm to sustain growth through value creation and capture based on an intellectual property business model and find that reciprocity of benefits across the business ecosystem is needed.

The Intellectual Property Business Model:

Lessons from ARM Plc.

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INTRODUCTION

An intellectual property-based business model (henceforth IPBM) operates in the market for technological knowledge rather than in markets for goods and services (Arora, Fosfuri & Gambardella, 2001). The key competence of the firm is its ability to create, own, market, and sell intellectual property (IP). Many new firms in technology-intensive domains (e.g., semiconductors, biotech, nanotechnology) go to market adopting IPBMs. It appears to be a model that may be especially well-suited to start-ups that have deep technological know-how, together with a lack of resources and experience, as it allows them to focus on what they do best while outsourcing the manufacturing and distributed marketing efforts to third parties. But although benefits include reduced capital requirements and focused use of limited resources on core areas of competence, there are significant challenges in adopting an IPBM. First, it calls for a specialized division of labor between organizations. Yet transferring technology across different organizations differently positioned along the value chain is chronically challenging. Second, patented inventions require the support of complementary assets to ensure that the customer is offered a value proposition (Teece, 1986). Unless the customers can see the intellectual property (IP) applied in use, they may not be prepared to pay for it. Third, the new venture must protect this value to guarantee a durable competitive advantage (Gans, Shu and Stern, 2008), while simultaneously creating the conditions for scaling up the venture. Fourth, for technologies with broad applicability, identifying the most suitable market segment may require extensive experimentation (Maine and Garnsey 2006). As a result, and especially so in science-based startups that operate under conditions of great uncertainty, business models are likely to evolve in unanticipated ways, requiring emergent design choices as new market targets are identified. Fifth, new technology ventures are especially exposed to the potential of contractual hazards (e.g. Pisano, 1990) that is, the risk that the buyer might appropriate part of the value of its proprietary knowledge without paying for it (Katila et al., 2008), a problem first described by Arrow (1962). These challenges are considerable. Not surprisingly, there are several instances of new companies that adopted an IPBM in the early stage that did not succeed in sustaining such model over time. Firms such as Cambridge Display Technology in electronic displays, Qualcomm in semiconductors or Plastic Logic in plastic electronics, which started with a pure play intellectual property business model, have progressively abandoned it (Davis, 2008). The point is that investing in the development of IP before the broader array of factors involved in creating and capturing value are in evidence is unlikely to pay off. Although increasing attention has been placed on better understanding the nature of the challenges faced by technology start-ups attempting to commercialize IP, the equally important issue of how to overcome these challenges and craft sustainable business models has received less attention. Building on these premises, in this paper we pose a fundamental question: Under what conditions can technology ventures design and implement sustainable IPBM? Or, to put it differently, under what conditions can an IPBM be source of sustainable growth?

To start addressing these questions both empirically and theoretically, we focus on ARM Holdings plc, a UK company that pioneered the concept of openly-licensable IP for the development of 32-bit RISC processor-based system-on-chip (SoC) in the early 1990s. ARM, in just a few years from its founding became the number one semiconductor IP supplier in the world and one of the few European technological start-ups to gain a share of the world market. Our aim in using a single in-depth case is to employ evidence to inform theory in an empirical exemplar that helps delineate concepts and connecting ideas.[1] The insights we derive from this revelatory case study are based on rich qualitative evidence collected over almost two decades through an extensive interview program as well as internal documents, newspaper articles and other secondary sources. As documented elsewhere (Garnsey et al., 2008; Ferriani et al., 2012), in the course of repeated company visits we carried out a number of unstructured interviews with senior managers, engineers, and managers who had extensive knowledge of the origin and subsequent development of ARM's strategic approach to licensing and IP management. We use this rich evidence to unpack ARM's capabilities and shed light on the distinctive features on ARM's IP-BM. This allows us to distil some preliminary insights concerning the viability and potential of an IP BM to be source of sustained growth. In particular, we elaborate on two types of challenges, which in our view are especially salient for the sustainability of IPBMs over time, namely IP protection and scalability. In both cases we find that the business model co-evolved with the creation of a business ecosystem that ARM was able to dominate.

The paper is organized as follows. We start by tracing the origins of ARM and its evolving trajectory to show how, starting from a narrow technological space and limited strategic landscape, the company managed to sustain rapid growth, making the transition from proof of concept, to prototyping through to commercialization and scaling. The early stages, while not the primary focus of our inquiry, allow us to underscore the evolutionary trajectory of ARM and trace it to early choices, in particular technological design choices and BM design choices (Casadesus-Masanell & Ricart, 2010). Next, we discuss the process that led to the creation of a worldwide

[1] A single case study does not aim to be representative. But in influential studies, a single case has provided a new perspective on wider issues. Among these are Penrose's Hercules Powder case (Penrose, 1960), the inspiration for her Theory of the Growth of the Firm (1959), Burgelman's account of strategic change at Intel (1994) and Edgar Schein's work on Digital Equipment Corporation in his book on organizational culture (Schein, 2003).

standard, focusing in particular on the company's orchestration of multiple partners and the intertwined activities of third parties. In doing that we seek to illustrate how relational capabilities were coupled with micro tactics enabling the orchestration of the network (Dhanaraj & Parkhe, 2006), which came to constitute an evolving ecosystem (Adner et al. 2013). This provided the business environment that enabled ARM to sustain the competitive advantage offered by the IPBM while scaling the firm. Finally, we focus on the appropriability regime enacted by ARM to prevent imitation and manage the litigation space. We show that these aspects, namely network orchestration and relational capabilities, IP protection and scalability, are related in a mutually reinforcing fashion.

Overall, our findings extend the literature examining the effective management of technological innovations in new ventures. In particular, our approach to analyzing intellectual property goes beyond patent analysis to examine directly the nuances and subtleties implied in the development of a global IP capability. These observations have implications for managers in a variety of IP-oriented industries.

ARM: THE ORIGINS

To understand ARM's business model it is important to trace back its origins to Acorn Computer. ARM (Advanced Risc Machines) was born out of the research labs of Acorn Computer in November 1990. Acorn was keen to develop a range of computers with a greater capacity but at a low cost in order to meet the needs of its cash-strapped customers. Initially Acorn had purchased its microprocessors from Ferranti, but in 1982 and 1983 this resulted in serious quality problems leading the Board to decide to encourage in-house development of a microprocessor. Accordingly Acorn developed a dedicated unit devoted to microprocessor development and selected a RISC design approach. A Reduced Instruction Set Computer (RISC) chip is a microprocessor designed to perform only the most common types of computer instructions, so it can work at a higher speed. On April 13 1984, the first RISC microprocessor came out of an Acorn dedicated lab, manufactured by Plessey to power Acorn's Archimedes computer. It was the beginning of a microprocessor revolution, delivering a solution which did the same amount of work compared to other 16-bit microprocessor but used one tenth of the transistors, with a huge reduction in energy consumption. The reduced size of the ARM chip, one16th of the size of the INTEL 486, meant less silicon was required for production, thus making it cheap. More significantly, the reduced power consumption meant that it could be run off a much smaller battery, strengthening its position as a leading microprocessor for embedded applications (see Box 1 for more details on the characteristics of ARM enabling technology).

Box 1 ARM's RISC Enabling Technology

ARM licenses its enabling technology or *architecture* to partners who use it to design and then manufacture the final chip. The term 'architecture' is used within the field of electronic engineering to refer to high-level microchip design. In essence, an architecture identifies the design logic behind a chip, and defines how a processor must operate. An architecture may include the programmers model, the instruction set, system configuration, exception handling, and the memory model. There are two broad categories of chip architecture, built around different design parameters: Complex Instruction Set Computing (CISC) and Reduced Instruction Set Computing (RISC). CISC has around 300 instructions in its instruction set, including complex instruction. It can be programmed upstream using a reduced set of instructions, relying on the comprehensive set of instructions already available in the chip architecture. CISC is the *de facto* standard in the desktop PC applications, in which high speed is critical and power consumption is of little concern. On the contrary, the portable devices market, where low power consumption and cost represent significant design factors, is nowadays dominated by RISC technologies, which rely on a simpler and more agile design that allow design of power efficient and low cost chips. ARM defines architecture specifications that specify how ARM products must operate. Additionally, some partners license the right to implement their own ARM processors conforming to the architecture specifications. This leads to a hierarchical split into three levels of specifications which together describe the behavior and programmer model of the entire SoC:

- Architecture: an architecture defines behavior that is common to many processor designs.
- Processor: a processor is the implementation of an architecture, and can be integrated into several different designs.
- Device: a device contains a processor and additional components

Source: Davis (2008); ARM internal documentation (Architectures, Processors, and Devices Development Article Copyright © 2009 ARM Limited).

The bulk of the advanced R&D section of Acorn that succeeded in developing the ARM microprocessors family of products was composed of 12 engineers, and formed the basis of ARM Ltd when that company was founded. This occurred as a result of the growing interest in the RISC technology from Apple Computers in California. At the end of the 1980s, Apple was working on a new architecture for handheld devices and believed that there would be a market for a personal digital assistant (PDA) for business executives. To this end a joint venture was proposed between Apple Computers, the newly founded ARM and VLSI to develop a microprocessor for what they named the Newton notepad. This enabled ARM to gain leverage from the extensive technological expertise it had inherited from Acorn Computers. As one of the founders of the new company explained to us in 1990 (at the time of founding):

> *It is a bit of a wretch to separate what was an integral part of Acorn, but we have decided that ARM and Acorn are best served by the creation of a separate company. The deal opens up many possibilities in terms of product development which we (at Acorn) probably would not have been able to afford.*

ARM started with £ 1.75 million of seed capital (£ 1.5 million from Apple + £. 250,000 from VLSI) while Acorn's original expertise and development was valued at £ 1.5 million. In those days, microchip factories cost around half a billion dollars. Manufacturing was clearly not an option, but other ways of entering the microchip market could be envisioned. An alternative could have been to subcontract manufacturing but this would have meant paying the subcontractor and commercializing the manufacturing and bearing the costs of sales and marketing activities. After evaluation of the various alternatives (see Table 1), the choice was made to license to multiple partners and to aim to ensure the technology became the global standard, maintained through systematic innovation.

ARM's original business plan had been to license their RISC technology to computer companies like Acorn and Apple, with production being licensed to VLSI. Robin Saxby took over as CEO in 1991, a few months after the launch of ARM. The Apple Newton Notebook was not a success[2] in the market, greatly reducing the demand initially anticipated in their business plan. A rethink to the business model was required. Other companies had already taken the IP route by becoming 'fab-less' IP companies, contracting out the manufacture of their chips. ARM took one step further and decided that they would be a 'chipless, chip company'. As a purely intellectual property firm, ARM would license its chip design to semiconductor companies. The new strategic goal was to make ARM's RISC chip design a global standard:

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[2] In the late 90s with Steve Jobs in exile and the company teetering on ruin, Apple came to sell its stake in ARM for a staggering $800 million and that saved the company from near bankruptcy.
As recently stated by Sir Hermann Hauser, founder of Acorn, "at the time, they (Apple) were in real trouble, real financial trouble, and in fact they were about to go bust," "The reason they didn't go bust was because they sold their ARM stake that they had originally purchased for $1.5 million for $800 million." (http://www.cultofmac.com/97055/this-is-how-arm-saved-apple-from-going-bust-1990s/)

"To be the world standard, we had to get partners everywhere in parallel. And to get partners everywhere in parallel, we had to license the technology many times. That's the order of thinking".

ARM's Strategic Options		
	CONTENT	CUSTOMER RELATIONS
CONSULTING	Tailor made (on request) content (provide solutions/insights on specific issues)	One shot (project dependent) / Renewable
LICENSING	Licensing + royalties	Several potential customers (typically few license renewals)
I.P. BUSINESS MODEL	License + royalties + services Systematic product upgrade Global standard	Multiple repeated partnerships (customer lock-in)

Table 1: ARM's strategic options.

This strategic approach enabled ARM to rapidly infiltrate multiple markets becoming indispensable to its customers and customers' customers who had extensive market reach. At the same time ARM signaled its credibility though consequent prestigious endorsements.. By associating itself with established powerful incumbents, ARM could convey a stronger identity in the industry. These early connections and contracts with big clients were critical in addressing a major issue facing any new company namely, lack of legitimacy and limited availability of resources.

BOUNDARY EVOLUTION

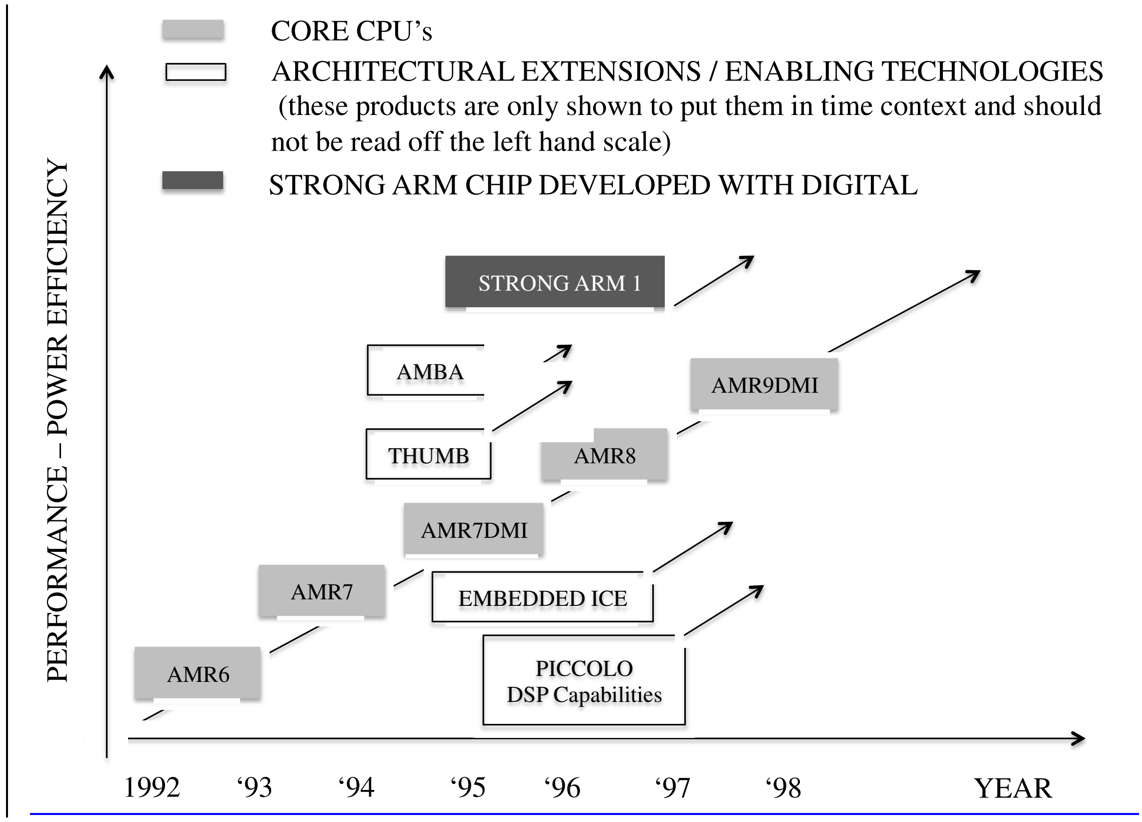
Because ARM's designs were for multi-purpose products and their customers operated in a variety of markets, ARM's boundaries evolved as their customer base grew. Young companies relying on IP business models face an acute need to construct a supportive ecosystem for leveraging the IP (Adner et al. 2013). In an ecosystem, participants generate value collectively but the ecosystem also enables individual units to create and capture the value required for their own survival (Li and Garnsey 2013). It can also be seen that the firm infiltrates the market through its ecosystem linkages whereby it develops an identity as a core constituent of the ecosystem that its activities help to create. At the outset, ARM had very narrow boundaries operating in a restricted niche within the fragmented semiconductor industry, but the business model triggered the development of multiple partnerships across a variety of market spaces working on modularity at the component level of industry organization.

SETTING A GLOBAL STANDARD

The computer industry had already shifted from vertical integration to horizontal specialization with the entry of new specialized component players like Intel and Microsoft. Horizontally specialized firms became the innovators in their domain and had a deep influence on product/technology evolution, requiring the compatibility of modules and standards (Florida and Kenney 1990). Acorn Computers had failed to gain the market penetration required to establish an industry standard. In contrast Robin Saxby encouraged people at ARM to think in terms of standards:

> *"To some extent none of us knew what it (a global standard) meant but you got a bunch of creative people thinking ' Yeah, this is where we are going. We must do things that help it become a standard. We must not do things that don't. We must ignore the things that don't"*

ARM was a driver and a participant contributing to the creation of the new horizontal organization of the industry and the new technological and organizational detachability. Through progressive experimentation, learning by doing, they developed the basis for backward integration building on the principles of modularity (Baldwin & Clark, 2000), reusability and adaptability. Developing highly flexible architectures for microprocessors and allowing a mix of architectural components to be configured around the core was the basis for modularity, reusability and adaptability at ARM. As a result of architectural extensions, (e.g. the Thumb, the Piccolo, AMBA and Embedded CE), it became possible to open up new performance space for ARM's microprocessors, allowing entrance into new markets for embedded applications (see Figure 1). Originally developed for ARM7TDMI and ARM9TDMI, they were compatible with subsequent ARM core microprocessors.



Figure, 1. ARM product innovation (1992-1999). Source: company reports.

The modularity of the architecture allowed the setup of different client-packages with basic modules being turned into specific contracts and deliverables. As one of our company informants told us:

> *"In the agreement, the needs of the licensee may vary considerably. The Koreans for example, who are not so familiar with certain microcontrollers and microprocessors, as they have never had their own in-house design, will say 'tell us what you've got, and help us to decide what we need, and then hold our hands through the process'. On the other hand, we may have a very experienced manufacturer, who has designed their own processors and controllers in the past, and they will define precisely what they need and this contract can be signed at arm's length. We have to be receptive, adaptable and flexible to the different requirements and specifications. Over the years contracts have been done*

many times and so we know with reasonable certainty what the semiconductor companies want in advance"

The flexibility and modularity of this approach has had a key role in shaping the company boundaries, allowing the technology to cover a broad market space. Indeed, ARM defined a multi-market space for its offerings, with services reaching its customers' customers. Eventually ARM broadened its portfolio of microprocessors so as to encompass three families of microprocessor which are virtually able to cover the entire market for embedded applications (see Table 2 below). Combined with the strategic orientation towards setting a global standard, this approach conferred on ARM the ability to exert a strong control over market dynamics. A standard confers competitive advantage for the owner firm by definition. Flexibility and modularity allow it to be present in several interconnected markets at the same time and gain understanding of the evolutionary dynamics within those markets. This can be achieved if the innovator forges relationships with key players in the diverse markets as the basis for an emerging ecosystem of connected participants; strong alliance capabilities are required for such a strategy.

THE THIRD PARTY SUPPLIERS

The ARM business model relies on third parties upstream and multiple parties downstream to access markets. To better understand the structure of such alliance network a short excursus into the structure of the semiconductor industry is necessary. The increasing trend towards relying on "System on Chip" (SoC) and "System on Package" in developing integrated circuits (ICs) has been accompanied by new IC design approaches that rely on modular, reusable components that are then integrated into a single SoC. This trend has been paralleled by a vertical disintegration of the value chain and a proliferation of companies each focusing on developing core competencies and capabilities around a limited number of components. The functions of IC specification, design, fabrication, packaging, and testing, which were originally performed by single vertically integrated design manufacturers (IDM) have separated into functions carried out by several firms (see Figure 2).

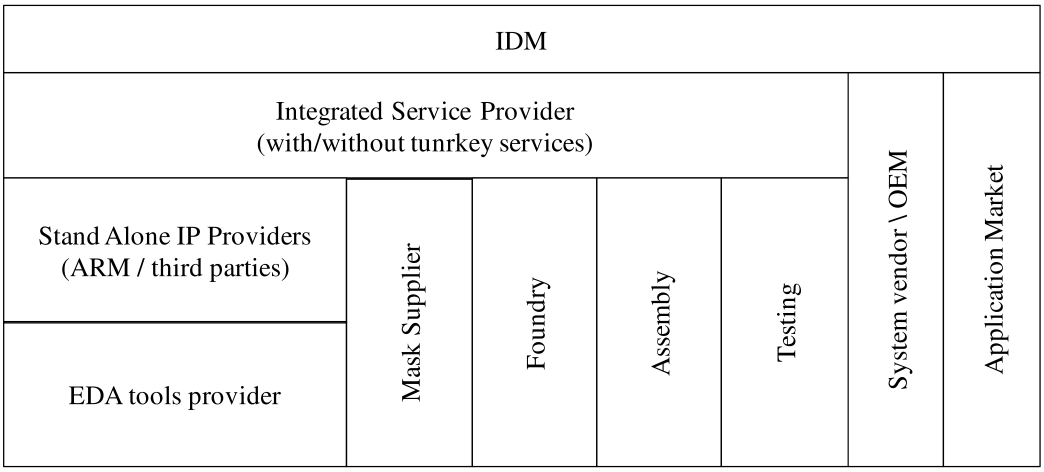


Figure 2: vertical disintegration of the value chain in the semiconductor industry (adapted from Su, Hung & Cheng, 2005)

To provide a complete design solution to customers, several IP providers (including ARM) must collaborate with one another and also with third parties providing necessary complementary capabilities and technologies. Third parties include providers of software for integrated circuit design, i.e., Electronic Design Automation (EDA), as well as design service providers. While the former provide platforms for IP configuration, the latter could be considered to be mediating firms that provide various design services and even turnkey solutions that may include a coordination of downstream activities required for manufacturing. As the figure shows, ARM operates at the center of this complex ecosystem. While the realization of an IC design relies on the competences and technologies supplied by firms that operate upstream in the value chain, including ARM (Williamson, 2012), the physical realization of the system on a chip (SoC) occurs downstream and involves other tasks (such as manufacturing, assembly and testing) and cooperation with other parties, including mask suppliers, foundries and original equipment manufacturers (OEMs).

Because of the highly fragmented architecture of the industry, ARM has to orchestrate a complex network of exchange partners that, as of 2012, comprises more than 900 players (Garnsey et al., 2008). This orchestration effort entails managing two different types of challenges with partners. Upstream (and horizontal) interaction occurs at the design stage, and involves integration of the services and capabilities provided by third parties, tools for electronic design automation and design service firms. From the point of view of ARM (but also from that of other upstream players) this implies developing technologies and solutions characterized by a high degree of compatibility with technologies provided by other parties. However, because of this technological interdependency and the modular nature of final design solutions (which integrate competencies and IPs provided by various specialized players), challenges emerge in terms of the potential for IP infringement. This phenomenon has been widely documented in the literature (Grindley & Teece 1997). The industry has progressively solved the problem by increasingly relying on cross licensing agreements. Issues occurring downstream tend to revolve around problems associated with IP protection and the technological roadmap.

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ORCHESTRATING MULTIPLE PARTNERS

The upstream, stand-alone position of a standard design supplier can only be reached with the orchestration of a complex system of partners involved in manufacturing and serving the final user (Dhanaraj & Parkhe, 2006; Lipparini et al., 2013). The number of partnerships signed by ARM scaled very rapidly. In 1991, ARM signed the first contracts outside the circle of the original equity partners, with GEC-Plessey. One of the members involved in the negotiation inside Plessey paraphrased the essence of the selling approach as follows:

> *"We have got this core. It must be useful to people for something. We don't really know how you might want to use it but we are prepared to work with you to understand it".*

In 1993, ARM signed a second partnership with Sharp and, in 1995, a contract with Texas Instruments: both contracts represented a turning point in ARM's development because of the size and the reputation of the players. T.I. was trying to complement its DSP system with ARM CPU in order to package a solution to Nokia mobile phones. Nokia fed back with a list of unsolved requirements based on a reduction of power consumption and code size and they started to work together in order to make further steps forward. Ultimately, the collaboration resulted in the creation of an innovative architectural extension (Thumb) which was developed to fill the technological gap between ARM's existing technology and Nokia Technical requirements. These interactions turned out to be foundational for delineating the core triadic structure that characterizes ARM's collaborative model. The triad involves three partners, a software firm, a hardware manufacturer and an industrial user who ultimately commercialize the final product (Figure 3).

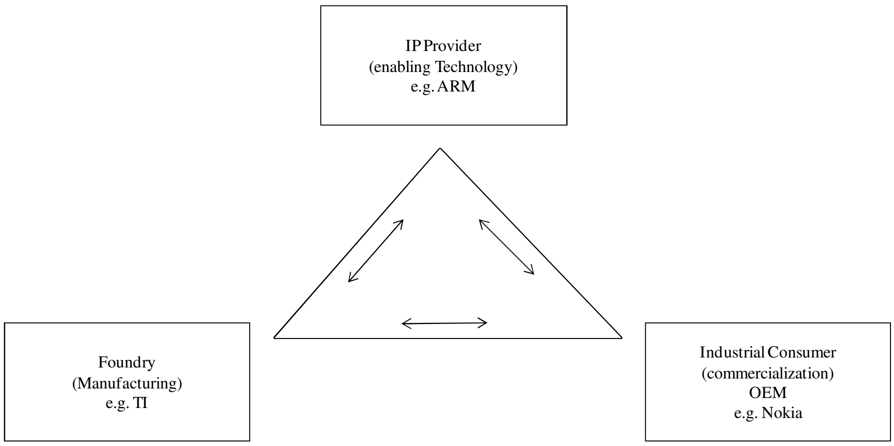

Figure 3: The partnership triad

Within the triad ARM is the recipient of manufacturing information from TI and, at the same time, is the recipient of market information from Nokia. This combined match of different information sources, multiplied by the many triads in which ARM is nowadays involved, contributes to the definition of ARM's technological roadmap. As Peter Magowan, Executive Vice President of Business Development, explained to us:

> *"By 'speaking' to OEMs we achieved a number of objectives: firstly, we exposed them to the full range of possibilities available from the ARM products and ARM development environment; secondly, we found out what they most wanted as features from their processors and secured design wins; thirdly, we gained their trust, as we delivered on promises; fourthly, we brought them into the fold of ARM architecture and standard*".

The most important effect of this triadic engagement is the contribution that it makes to the discovery of new opportunities and the identification of different types of user problems and customers' emerging needs.

This strong partnership orientation became part of ARM's broad culture early on, which included technicians and engineers who were deliberately involved in customer meetings to elicit bonding at a deep technical level. The very term *customer* was replaced by *partner* to strengthen the relevance and significance of relational elements. The distinction is an important one, as illustrated by ARM co-founder James Urquart, referring to semiconductor companies working with ARM:

> *The semi-conductor companies were our partners, not our customers. They paid us money. They were where the money came from, but ultimately it was thanks to them that our technology could make it into a product that final users would buy. So, we had to work with them and understand where their customers were using the technology, why their customer used the technology, what where the advantages, what where the problems.*

Robin Saxby, CEO of ARM, adds that:

> *We really treat our customers as partners involving them in agreeing specifications and taking joint-risk and benefiting on projects. […] We are in daily communication with 78 semiconductor manufacturing companies globally, […] we visit their factories and work with them on site. It's just that we do not own the manufacturing plant.*

The connections with third party suppliers and the leveraging of information and expertise from technology partners create a powerful intelligence network which feeds ARM's continuous innovation and development of product families. Continuous innovation is important to maintain the standard and make it flourish. Indeed, as patents expire and technology gets outdated, a continuous flow of innovation is necessary to nourish the standard. Figure 4 below illustrates an uninterrupted path of innovation in power efficiency outcomes relying on core microprocessors (and architectural extension not shown here). Table 2 shows the domains of application for ARM's products.

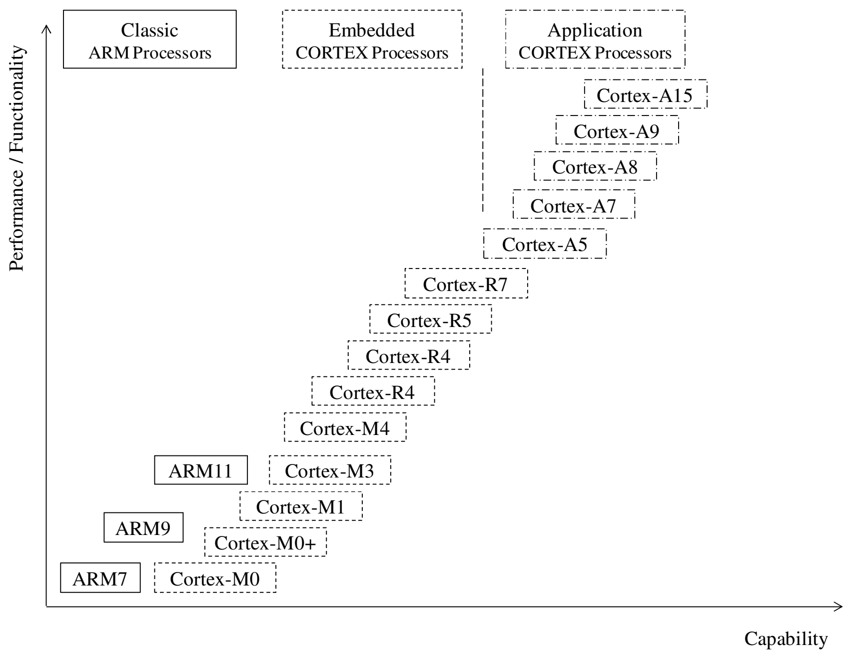

Figure 4: ARM portfolio of Processors Source: company records

Through the gradual development of its expertise and global reach, ARM ensured that it became the preferred supplier of microprocessor design for Apple's iPhone and iPad, enabling ARM's designs to reach millions of customers of new generations of smart phones (Morrissey, 2010)

As we seek to draw some preliminary lessons from a description of how complex early network effects influenced the IP business model and came to provide for ARM a supportive business ecosystem, we must also emphasize the barriers to imitation resulting from the combined coupling of technological architecture and organizational architecture. The combination of knowledge and practices underlying the technical and organizational network creates "causal ambiguity" for any imitators attempting to replicate the unknown success factors behind a technology, making imitation unlikely (Lorenzoni and Lipparini, 1999). Moreover, the fast evolution of the product families over the years through the tight involvement of third parties and partners creates a lock-in effect, with high switching costs to customers considering alternative sources of technology.

ARM's portfolio of processors

	Classic ARM Processors	Embedded CORTEX Processors	Application CORTEX processors
Description	Classic processors, based on ARM classic architecture, offering market-proven technologies for cost sensitive solutions	Processors delivering high deterministic real-time behavior in power sensitive application. These processors typically execute a Real-Time Operating System (RTOS) alongside user-developed application code.	Processors able to execute complex Operating Systems (e.g. Linux, Android, Windows or Symbian) and to enable complex graphic user interface. Equipped with a Memory Management Unit (MMU)
Applications	General: wide range	• Automotive Control	• Smart-phones

of performance capabilities for cost sensitive solution	Systems • Motor control Systems • White Goods controllers • Wireless and Wired Sensor Networks • Mass Storage Controllers • Printers • Network Devices	• Feature Phones • Netbooks/e-readers • Advanced personal media player • Digital Television • Set-top boxes & satellite receivers • Personal navigation devices

Table 2: ARM CPUs families and applications

THE APPROPRIABILITY REGIME

David Teece's influential contribution sets the stage for a better understanding of the conditions for gaining rents from technological innovation (Teece, 1986). In particular, Teece (1986) focuses on the role of the appropriability regime - weak or strong - in protecting innovation from potential attackers. In a weak appropriability regime barriers to imitation can be built, leveraging on complementary specialized assets in addition to technical and legal assets. In a strong regime, technical and legal assets are available to master and defend the appropriation of rents. Companies select their rent-capture strategy depending on specific regimes (Pisano, 2006). Strong appropriability regimes are characterized by the presence of strong legal and patent mechanisms. Interestingly enough, while ARM has registered a relevant number of patents over the years, the size and litigation potential of the legal unit is relatively small. This apparent contradiction, suggests that other mechanisms may be at the foundation of ARM's ability to shape the appropriability regime.

In the early days ARM founders were well aware that if they had a problem with IP appropriation, they did not have the resources to engage in litigation on a solo basis. However, they also knew that pressure on potential imitators could be brought to bear by Apple Computers. More crucially, as the company was growing and gaining new customers, ARM started entering into cross patent licensing deals, thus reducing the litigation space. Partnerships with large OEMs operate as signals that also generate barriers to imitation. As pointed out by one of our informants:

> *"If a company like Samsung or TI is licensing from us, this means it may be difficult to develop our technology."*

Multiple licenses create a psychological barrier to entry. In addition, the IP that is licensed needs to be complemented by ARM's customer services and considerable expertise which is not fully codified (nor codifiable) in the transacted IP. This aspect works as a protection mechanism. For example, licensors need expertise from ARM at various stages, including testing, debugging, and production. This illustrates how ARM license position preempts litigation by removing incentives for it.

In the light of the above observations we can distil four important insights:

a) ARM is a "chip-less chip company" providing architectural design and not relying on either manufacturing rents nor preferences of final consumers;
b) The positioning of ARM is far upstream from the final market but this potentially vulnerable position is coupled with IP in RISC design that is the acknowledged technology standard with massive market share.
c) The global standard of its designs, achieved through multiple long term market partnerships, supports the thesis that a strong appropriability regime is based on

idiosyncratic knowledge and social mechanisms (i.e., IP protection arises from relationships and BM design).

d) At the same time, strategic and organizational barriers have been built up to lock in the market. High barriers to entering or copying are generated by tailor-made solutions for customers' customers who rely on the modularity, reusability and high adaptability of the ARM offer. Associated product flexibility creates technology and market options for the partners and facilitates integration and continuity of the ties.

Table 3 below offers a summary of the key micro-dynamics underlying ARM's IPBM. At the core of ARM's IPBM sustainability is the co-evolution of technological innovation (modular architecture) and BM (scaled evolution). An IPBM comes with the advantage of offering quick access to market by means of a capital-light model which allows the firm to concentrate on its core technological capabilities without having to sustain the investments necessary to move into manufacturing. This also allows retaining the ability to exploit opportunities in several end-markets, thus setting the conditions for an increased portfolio of contracts on the same class of licenses. However, these advantages come with several challenges, notably the need for downstream market intelligence, the need to protect IP against imitation and efforts to reduce information asymmetry between the licensor and licensee, which create the potential for moral hazards. To understand how ARM BM made it possible to overcome these challenges, turning them from potential threats into sources of competitive advantage, we need to understand the second central feature of ARM BM, that is the reinforcement between product architecture (in particular its modularity), relational capabilities and the BM. Technology modularity delivers innovation into specific modules, thus creating a flow of continuous (incremental) innovation that is competence enhancing for both ARM and its network of exchange partners. This is also an enabling condition for favoring the creation of long term relationships, which are trust based and involve co-creation and joint development efforts from ARM and its exchange partners. This provides us with insight into how a supportive business ecosystem can be created. The ecosystem supports the innovator's IP because of the reciprocal absorptive capacity developed between the licensor and licensee. This form of co-creation results in high switching costs for partners, which are locked into the relationship. As technology evolves continuously, the scaling of the BM is fueled by further licensing agreements and the licensor. So the licensee's capabilities coevolve, reinforcing their relationship over time and making it extremely difficult and costly for outsiders to imitate. The BM itself becomes a source of IP protection.

ARM IPBM Evolutionary dynamics between IPBM and modularity			
ARM Plc.	*Key Features*	*First order consequences*	*Second order consequences*
IPBM	Flexible capital light model Upstream positioning within the value chain far from final customers Need to protect IP License fees are not substantial Information asymmetry between licensor and licensee (e.g. knowhow not fully codified in the license, lack of understanding of the manufacturing process or the technological roadmap)	Rapid access to market Makes it possible to access multiple downstream markets simultaneously Challenges in defining the technological roadmap Difficulty in scaling the venture solely on the basis of licensing revenues Need to develop "reciprocal absorptive capacity" (i.e., licensor invests in acquiring knowledge of the manufacturing process – licensee invests in acquiring technology knowhow)	Ability to scale (by accessing multiple markets) Partners' high switching costs (on the basis of investments in technological knowhow) IP protection
Modular Technological Architecture underpins participation in ecosystem	Technology embedded in modules evolving incrementally around a "core"	Continuous incremental innovation confined within modules. Innovation is "competence enhancing" for both the licensor (i.e., build on its technological knowhow) and for the licensee (build on its acquired knowhow).	Long term trust based relationship sustained by continuous interactions (coevolution of licensor and licensee capabilities) Access to downstream market intelligence (Licensing-in/licensing-out, reciprocal knowledge transfer) Partners' high switching costs (on the basis of developed mutual trust and reciprocal non-technological absorptive capacity)

Table 3: ARM IPBM and Key Underlying Mechanisms

In summary, the particular configuration of ARM's IPBM – its architectural logic and the nature of the relationships involved – facilitates knowledge mobility, supports continuous innovation, fosters reciprocal absorptive capacity and the generation of mutual trust, leveraging a network of partnerships in which the parties are strongly tied together in a mutually supportive business ecosystem. By orchestrating a 'relational model' ARM creates the conditions for sustaining an interrupted flow of value creation for the customer while keeping customers locked into their technology. The resulting network architecture is costly to replicate, conferring on the firm the means of sustaining its competitive advantage over time. Nevertheless, in the technology wars that occur between leading standards, all members of an ecosystem are affected by the relative success of key technologies, and firms providing platform designs are involved in such rivalries as those between Apple and the companies using Android technologies for smart phones (Müller et al., 2011)

DISCUSSION

The objective of this paper was to offer insights into the IP commercialization strategy of technological start-ups and investigate salient features of purely IP-based business models. A business model "encompasses the firm's economic activity, how it is resourced, the way it creates value and how returns are to be realized" (Garnsey, 2003). The example of ARM provides an exemplar of how a business ecosystem can be formed to support and sustain an innovation that is potentially vulnerable, as revealed by the difficulty experienced by most firms that attempt to scale up an IPBM. ARM's business model is based on an open ecosystem; it is characterized by high transaction intensity with customer-partners and a focus on a set of core architectural activities (Baden Fuller and Hefliger, 2013). We found that ARM's success in creating a worldwide leadership position only a few years after its founding can be traced to the manner in which it managed to craft a business model that exploits IP value through "two-way" licensing agreements supported by long-term partnerships and complementary services. Partners not only boost ARM's sales, they also add to its knowledge base, enhancing ARM's ability to design chips that meet the future application and technological needs of its partners. Thus, the licensing/royalty model ties the destiny of ARM and its partners together, creating a strong business case to pursue joint design-wins and share the knowledge necessary to mutually maximize the probability of success. This business model and the ecosystem which sustained it did not pre-exist ARM. Nor was this business model the result of foresight or strategic vision. It emerged as a response to necessity and had to be operationalized gradually through trial and error and following a discovery-driven approach (McGrath and MacMillan, 2009).

We believe that ARM's approach represents an attractive and increasingly popular commercialization option in the development start-ups that are resource-constrained and lack legitimacy. Despite being premised on the idea that start-ups can extract value from their know-how by patenting and selling it, the IPBM model has distinctive features that differentiate it from traditional licensing models, or any model more generally based on the sale of patents. The key difference is that the sale of IP is part of a complete IP capability that makes it possible to transfer idiosyncratic knowledge over time and to distinctive clients who have specific needs and requirements. This capability is designed on the principle of reciprocity. It means that every time ARM grants a license it tries to build a reciprocal relationship that affords ARM insight into the licensee partner's technological roadmap and access to new knowledge about emerging applications. Furthermore, in order to maximize the range of users for ARM products, the company provides a basket of supplementary tools, software and system IP that facilitate adoption and incorporation. Clients, in their role of customers-partners, are crucial contributors to the company's knowledge base, enhancing the company's ability to develop technology fitting its partners' future application needs. Thus, partnerships become platforms through which the exchange parties jointly determine their strategic and technological trajectory.

While the way in which business ecosystems are needed to sustain innovations is increasingly recognized (Adner et al 2013), there are few detailed studies of the specific manner in which innovative ecosystems can be created. ARM furnishes one such exemplar, from which we can better understand how a key position can be secured by an innovator providing a critical technology adopted by other participants.

Managers often overestimate the role of IP *per se* while underestimating the way in which such IP must be integrated into a fully fledged IP market and technology strategy, as Fisher, William and Oberholzer-Gee (2013) have pointed out. The IP capability developed by ARM embodies much richer know-how than would be possible through the one-off provision of patent licenses alone. Within such a configuration licensing is just one component of a sophisticated approach relying on the maintenance and nurturing of long-term relationships with clients (Pfeffer and Salancik, 1978). In configuring business activities with an IPBM, the design of an ecosystem of exchange partners does not represent a 'nice to have' asset. It is a core constituent of the strategy, and the basis for the sustainability of the model.

Conclusions

We believe our study offers valuable theoretical insights into the interplay between technological architecture, firm's capabilities and the evolution of the IP BM in the context of an innovative ecosystem. First, our study contributes to the literature on modularity (Baldwin & Clark, 2000) and architectural innovation (Henderson & Clark, 1990) in general and on the interdependence between technological architecture and firms capabilities in particular (see more specifically Henderson & Clark, 1990 and later studies). While the received literature has primarily focused on the consequences of modularity in technology design on incumbents' survival and competitive dynamics, our insights underscore the role of modularity in inter-firm collaboration and IP protection, two aspects that have been largely overlooked by prior literature[3]. Technology modularity opens up opportunities to scale an IP BM because it allows the licensor to embed innovations and technological advances within modules that revolve around a 'core' that, in turn, may evolve incrementally - as opposed to radically. Incremental advances are "competences enhancing" (Tushman & Anderson, 1986) for both the licensor and the licensee because they build on their technological core competences (Abernathy & Clark, 1985). The latter, which is incremental innovation being competence enhancing for the licensor, is particularly important because it allows setting a precondition for long term collaboration – as opposed to isolated contractual agreements – and repeated interactions in which the licensor and licensee become partners in the creation of the next wave of technological innovation. It is these recurrent and sustained relationships that provide the basis for a sustained business ecosystem. As we have shown, this has important implications for creating downstream market intelligence for companies operating in

[3] A notable exception is represented by Henkel, Baldwin & Shih (2013). However their focus is on the interplay between product design, modularity and IP protection, and not on IP licensing, inter-firms relationships and IP protection, a conceptually distinct phenomenon.

the market for technologies that are disembodied from physical products (e.g. see Arora & Gambardella, 2010).

Our study also speaks to the received literature on business models (e.g. see Zott, Amit & Massa, 2011). Our analysis of the dynamics behind the functioning of ARM's BM and, more specifically, the interplay between technological architecture, organizational capabilities and inter-organizational knowledge transfer in an IPBM, suggests that shedding light on the dynamics underlying a BMs may be a non-trivial exercise, requiring fine-grained understanding of the organizational model subsuming the working of a given BM (e.g. see Morgan, Gregory & Roach 1997). To date, however, the BM literature has evolved rather separately from the organization design and organization theory literatures. The BM-organizational model duality has also potential implications for the literature that focuses on BMs as models, in particular on how BMs are enacted by organizational members into cognitive and linguistic devices (e.g. see Baden-Fuller & Morgan, 2010; Baden-Fuller & Mangematin, 2013). Within this line of inquiry, our findings point to the the importance of analyzing the extent to which managers form images of organizations when enacting BMs and what are the consequences of the presence/absence of such images for the development of of BM cognitive and linguistic schema.

Finally we find that concept of business ecosystems provides a basis for drawing together and integrating the diverse themes addressed in the analysis of reciprocal IP relationships. This evidence also indicates that to integrate the analysis of business models with business ecosystems, attention must be to be paid to the specific nature of the relationship between participants and the manner in which reciprocal value creation is ensured. In the case of IP, such relationships take on a character that has not received detailed analysis in the emerging ecosystem literature (Adner et al. 2013).

We conclude this essay with some reflections on the role of manufacturing in a pure play IPBM, a theme relevant to understanding the complex nature of innovation ecosystems. Because manufacturing falls outside the range of activities performed within a typical IPBM one would expect expertise in this area not to be crucial. Yet technology licensing works only to the extent that the licensee is capable of identifying a profitable market application and is willing to make the massive investments that are typically required to build a plant and scale up production. But the licensee does not always have all the necessary manufacturing competences, especially in the case of disruptive technologies. If that is the case, two enabling conditions appear especially important for increasing the likelihood of successful licensing: a) the licensor's ability to provide engineering consulting and customer services; b) the availability of a small scale pilot-plant which demonstrates the viability of the manufacturing process, thus serving as proof of concept. The availability of a small-scale pilot plant is particularly important in the negotiation phase as it can help the licensor not only to prove the feasibility of the product but also to address a variety of application and implementation issues that may otherwise deter the buyer from moving forward.

Several of our informants at ARM pointed out the importance of having at least some manufacturing know-how in house to establish necessary expertise and credibility with manufacturers, to include them as key players in the innovator's ecosystem and secure and forge enduring partnerships. This know-how, in ARM's case, was developed early on through its interaction with VLSI, to which they outsourced the manufacturing of the very first chips. Just as important is the "package of deliverables", that is, the additional support, tools, extensions and training accompanying the sale of the technology. From a list of 10 deliverables that accompanied the first ARM product, ARM licenses in 2001 had "about 200 deliverables". Today ARM engineering consulting and related services contribute significantly to its profitability, accounting for approximately 12% (on top of the licensing fees and royalties) of the overall revenues (see Figure 5). Although ARM does not make any manufacturing investment, ARM has developed the capability to work across boundaries to support the manufacturing activities of its partners.

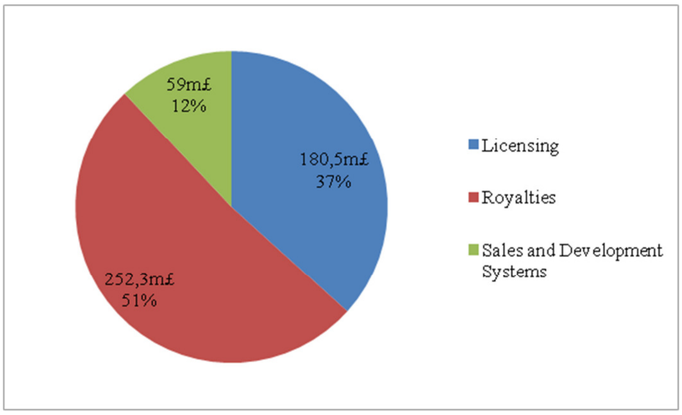

Figure 5: Sources of revenues, ARM (2011). Source: company records

The majority of IP-based technology startups focus on licensing their IP while leaving all downstream activities to the licensors, leaving them isolated within a narrow business ecosystem. A few companies manage to "follow the license" and share with the licensee at least some downstream activities and so create and capture a much greater share of value. Unless they can devise organizational and technological solutions that enable them to create relationships beyond their boundaries, new technology ventures adopting an IPBM are likely to face major obstacles. We have proposed that where strategic goals are difficult or impossible for the venture to achieve on its own, the innovative firm's business model may represent an attempt to construct a potentially supportive ecosystem populated with actors who generate value collectively (Chesbrough and Rosenbloom, 2002; Baden-Fuller and Mangematin, 2013). Though ARM achieved this in a unique manner, their innovative approach which involved building open ecosystems through learning partnerships, are available to other resource-constrained start ups seeking to scale up their operations.

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