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Abstract

Media convergence presents a few noticeable dimensions, and requests an interdisciplinary research approach. We conduct a long-run analysis of the main initiatives of technological standardization carried out in the realm of "traditional" (cable, satellite and terrestrial) digital TV, focusing on Europe, to assess the technological determinants of its apparent trends to convergence. This analysis inevitably calls into question IPR strategies and policies. In particular, we investigate how private incentives and the public agenda for interoperability have shaped the on-going convergence of the TV sector toward an "IP-based" meta-platform. Despite the widespread usage of open standards and formats, the real potential for interoperability along the digital TV filière has been modest, and mostly limited to the transmission segment. This is mainly due to the strong proprietary features characterizing the TV sector, where viable content production and provision rests on effective control of content IPR. Further, patent portfolio strategies and control of crucial copyrights become increasingly central for competing in the converging TV sector, where former telecom companies, traditional TV operators and new OTT players strive to become gatekeepers of essential layers of the new IP-based delivery platforms. To sum up, while technological opportunities today do enable pervasive media interoperability and affordable convergence at the user-level, private incentives relentlessly push the industry toward standards fragmentation and the construction of walled gardens.

Keywords: standards, IPR strategies, convergence, DVB, digital TV.

1. Introduction

After almost three decades of "digital revolution", worldwide TV remains the most diffused, important and revenue-generating media outlet. By definition, the move towards digital TV (DTV, henceforth) was rooted in powerful convergence dynamics: binary coding of the analogue audio-visual signal into bits of digital information blurred sectoral boundaries and services specificities,

enabling lateral entry and more variety – hence competition - in a new convergent "TV sector". At the same time, so far convergence did not seem to imply standardization and homogeneity at each layer of the value chain. Instead, a peculiar mix of expanding diversity of devices, "boxes", contents and services coupled with increasing standardization of core technological components seem to characterized today's DTV. Similarly, while technological drivers brought television closer to information technology/Internet (henceforth identified as ICT – information and communication technologies) and telecoms, other economic forces and firms' choices led existing TV platforms to evolve along diverging and differentiated trajectories, introducing different contents, services and business models and enabling new original styles of TV consumption (pay-TV, mobile TV, catch-up/web TV, etc.).

All in all, worldwide forces of convergence and divergence seem to coexist in the DTV ecosystem. The sector itself – whose blurred boundaries now span from the former audiovisual value chain to new telecoms and IT-Internet domains - appears characterized by fast dynamics: rapid technological change, increasingly global initiatives of standardization, high market turbulence and business shakeouts, and accompanying socio-institutional change. The resulting regimes of standardization and market competition, so far, seem to contain both Schumpeterian as well as cooperative-collusive features.

The present work addresses these industry dynamics focusing on the key role played by IPR (such as patents, copyrights, trademarks and industrial secrets), as embedded in technological standards. These IPR do constitute a main ingredient of firms' competitive strategies, being capable of supporting technical and user-level interoperability among different vendors' solutions; alternatively, once appropriately managed, they can also enforce strong proprietary strategies and disrupt product and service compatibility, enabling the market pre-emption of rivals.

The chapter is structured as follows. In section 2, an interdisciplinary literature review surveys the most relevant economic models and legal conceptualizations. First, the basic economic functions of technical standards are illustrated, and the conflicting incentives that different operators may have towards interoperability are explained. Second, we present a compact summary of the most recent IPR phenomena, standardization trends and legal issues, highlighting the polyhedral and ambiguous contribution of standards and patent pools to technology and market convergence. The following empirical analysis (section 3) studies the main standardization initiatives for digital TV[1]: the specifications for signal transmission, those for content and security management, for the applications interfaces and, last, the emerging trends of the convergence between TV and Internet.

[1] Due to space limitations, this empirical analysis mostly concentrates on the DVB and EU experience, although keeping an eye on global trends.

Together, the main convergence/divergence trade-offs are discussed, and the outcomes so far achieved are evaluated. Section 4 summarizes the main results, mentions a few important points left for the future research agenda, and concludes.

2. Literature review

2.1. Technical standards and strategies in network industries[2]

A large literature (among the reviews, David and Greenstein 1990; Matutes and Regibeau 1996) explains how technical standards cater for scale and network economies, potentially improving total welfare. Technical standards are consensual, official and descriptive technical norms; this type is known as *de jure* standard and it is usually produced by an official/formal standards developing organization (henceforth, SDO), having a national status – like DIN in Germany - or a supranational one - such as ISO, ITU or ETSI. Alternatively, consensus might often emerge as a spontaneous market outcome, rather than being the product of a specific official procedure; in this case, we have a *de facto* standard[3], which differs in many respects from *de jure*, being a privately owned and managed piece of intellectual property[4].

In this work, we restrict our attention to standards designed for achieving compatibility and technical interoperability. The current "Knowledge economy" era has greatly emphasised the role of interoperability standards and their large scale diffusion, introducing a more flexible type of interoperability, that is increasingly achieved at the software layer of the concerned goods and services, in parallel with the growing dematerialization of manufacturing output. In particular, we say that a particular digital communication system is interoperable with others if it can exchange digital bits of information and process them according to stated purposes[5]. To this end, beside standards, other less frequent instruments are also available: "ad-hoc" converters[6] (or adapters) -

[2] This section builds on a wide selection of papers and books; for sake of synthesis, we only mention the references most directly connected to our main argument, while skipping other background materials. For a proper presentation of the standardization literature, among others, Blind (2004); Swann (2010).

[3] Here, a single company manages to have its own specification acquiring a leading market share and becoming a *de facto* standard.

[4] Also most of *de jure* standards are privately possessed, but the ownership is usually shared by a multiplicity of subjects/licensors. A main example is provided by patent pool members (see *infra*).

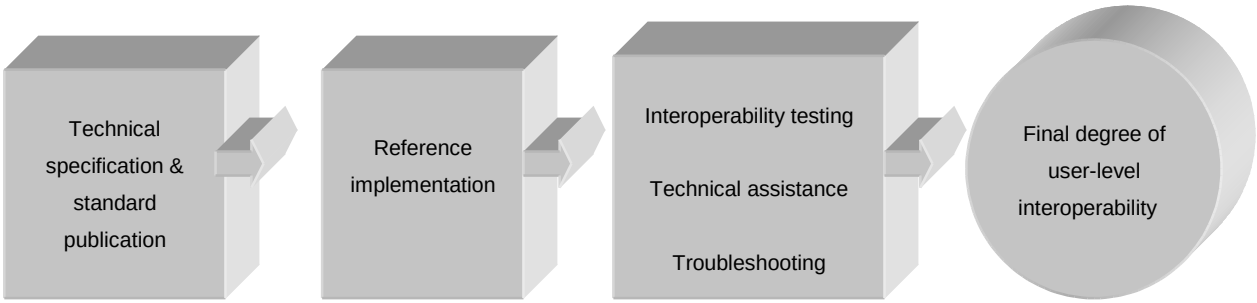
[5] These compatibility standards in the literature have been also called "interface standards" (David and Greenstein 1990).

[6] Generally, a converter is an adapter used to match the physical or functional characteristics of different objects/technologies.

either voluntary or mandatory – provide an alternative path to interoperability (for an economic analysis, Farrell and Saloner 1992; Choi 1996, 1997)[7].

At the same time, standardization might not be sufficient to ensure effective user-end interoperability (see figure 1): in fact, complementary measures are needed, such as producing a good (working) reference implementation[8], performing interoperability testing and organizing services for technical assistance and users troubleshooting.

Figure 1. Factors affecting the final degree of user-end interoperability of a standard



Source: our elaboration

A main feature of the ICT and digital media worlds is that standardization and interoperability create network structures among the concerned products/services – either physical of simply virtual; networks, in turn, possess powerful functional properties and valuable economic characteristics. *In primis*, the value of a network is a convex function of the number of devices/people connected to it, according to the notorious R. Metcalfe's Law (Shapiro and Varian 1999); or of the amount of associated services, applications or content compatible with it. In fact, in communication networks is useful to distinguish between two main types of network effects – the direct and the indirect ones (see the surveys of Katz and Shapiro 1994; Economides 1996; Gandal 2002). While the first type of network effect is related to the number of users connected, like in the typical case of the utility deriving from the fax transmission, in the second example, peculiar to media products, the utility is mostly stemming from the number of attractive contents and complementary services jointly available with the specific communication network.

While big firms managing incumbent communications networks want to control the access to their installed base of customers (potentially foreclosing the entry of competitors), small and new

[7] Many examples are available in ICT domains, from the simplest (plug adapters and power transformers for electricity) to more elaborated ones, such as analogue-to digital converters for TV receivers (or set top boxes, STB *henceforth*) or, in computer science, file format converters.

[8] This is the implementation of the standard used as its official/definitive interpretation. It checks that the specification is implementable, correcting potential errors and disambiguating its elements. The reference implementation also works as a benchmark for the following (derived) implementations.

entrants have the opposite incentive, being eager to join and interconnect with the larger established base of customers: in fact, interconnection between networks would enable them, at least potentially, to steal customers connected to the incumbent, offering better services or contents. In this respect, Besen and Farrell (1994) define this set of incentives, behaviours and stylised business facts as the property of "time inconsistency of the compatibility choice".

Similarly, firms endowed with a large base of connected customers strive for maintaining them captive, increasing the consumers' "switching costs" to rival alternatives: this strategy, extensively analysed in the literature (for a classic review, Shapiro and Varian 1999), is called "walled garden". As a matter of fact, it is typically enacted by means of strategic standardization and interoperability management based on proprietary and closed technologies; or, in the case of open standards, with manipulative patent pool strategies (see *infra*). For example, in digital pay-TV, most of the times consumers are forced to buy firm-specific reception equipment/STB (such a situation is called "vertical market"), which cannot be used for watching rival channels or unauthorised third party services, or for accessing other TV platforms; in other words, switching to other commercial alternatives is impossible without costly and cumbersome duplications of equipment, and new training. All these inertial factors increase customers' change costs.

In particular, in digital communications, physical networks interconnection has been the most typical instrument for achieving the interoperability of services, and is based on preliminary technological standardization of the underlying infrastructure, including both signal transmission and signal reception equipments. Then, for a smaller competitor willing to enter the market, the lack of interoperability with a larger incumbent would severely diminish the size of the available network effect - thereby reducing the competitive value of its offer and the likelihood of entry.

The market provision of standards typically leads to complex and uncertainty-intensive coordination games. In fact, in analogy with Katz and Shapiro (1994), standards provision, beside being rooted in the hard laws of physics and chemistry, also depends on agents' expectations and economic incentives, as extensively illustrated in mainstream oligopoly models featuring network externalities. The main conclusion of this literature is that decentralised (*id est*, market-based) systems of choice are rarely optimal in terms of social welfare. Stango (2004), for example, observes that spontaneous market acceptance of standards could result either too slow or too fast. Then, in a dynamic setting of standards choice, multiple equilibria are likely to emerge. Moreover, if there are strong network effects reinforcing the first standard arriving on the market, premature standardization might irreversibly displace future superior alternatives (excess inertia equilibrium,

Besen and Farrell 1994)[9]. At the same time, firms' tactics and consumers' expectations might also cause inefficient switches to new (inferior) standards (excess momentum equilibrium), prematurely foreclosing the market for the 'next big thing'. To sum up, in both cases, due to network effects, a suboptimal equilibrium type "the winner takes all" might well occur, due to the 'wrong' winner (Shapiro and Varian 1999).

However, neither the Government or other policy makers are immune from the risk of standardization failure. On one side, a central coordination is mostly valuable when markets feature both increasing returns (arising from network effects) and strong uncertainty (due to high technological turbulence), to induce a Pareto-superior equilibrium. On the other side, as underlined by Cowan (1991), this is also the context where Government's intervention aimed at picking the best standard faces the highest risk of foresight and error.

Finally, other drivers of complexity, like the presence of multiple market stakeholders, augment the error probability of the policy-maker. This is the case of markets qualifying as "two-sided" (or "multi-sided", by logical extension; Rochet and Tirole 2003). A main example is free to air (FTA, henceforth) TV broadcasting, supported by commercial advertising, where the revenues earned from the ads collection side of the market finance the operations (content acquisition, transmission, etc.) in the broadcasting (audience generation) side, yielding cross-cumulative effects. Here, the working of the multi-sided system relies on the usage of a common technical platform (family of standards and other components, like those developed by DVB), which fuels the mechanics of the intra-market effects.

Finally, the previous literature review does not imply that standards wars inevitably end up with one unique technical specification, dictating an inexorable trend of technological and market convergence. In fact, long periods of coexistence of rival standards within the same market are also possible, and this outcome is most likely in those cases where network effects are counterbalanced by platform-specific characters or demand preferences: these uniqueness traits may help the weaker alternative to retain a minimal critical mass of loyal customers. In the PC world, a famous text-book example is the long term struggle played by the two competing systems Apple-Macintosh and IBM-Wintel (Windows-Intel): Apple managed to survive in the PC market segment, although with a tiny market share[10], before rejuvenating with new families of products (tablets, smart-phones, etc.) and becoming a global ICT and media player. We also notice that Apple is expected to become a relevant player even in future hybrid TV, being on the verge of launching innovative Internet-based

[9] In a similar vein, other authors stressed the path dependent nature of standards choice and technology evolution. In fact, initial fortuitous events might result in permanent suboptimal trajectories, due to network effects and lock-in dynamics engendered by consumers' switching costs (hence the dependence - David 1985; Arthur 1989).

[10] A valuable analysis of the Apple-Macintosh and IBM-Wintel saga can be found in Bresnahan and Greenstein (1999).

products and services.

2.2 Recent trends in standardization and IPR management

Since the late-1980's/early 1990's, the previous "command" approach entrusted to European bureaucrats performing top-down detailed standardization activities lost its momentum. Face to the disappointing results of major standardization initiatives led by the EU Commission (for eg., the failure of the European project for high definition TV), a new system based on delegation to formal and independent SDO was believed to cater more effectively for the technological unification of the European internal market, while ensuring fast, consensual and more market-driven standardization processes. Additionally, in several ICT and digital media sectors a progressive hybridization of standardization activities has taken place (Hawkins 1999; Funk and Methe 2001): here, *de jure* standards are initially promoted by private consortia or industrial fora, which eventually submit the developed technical specification for approval to the concerned SDO. A main example, featured in our empirical analysis, is DVB, founded in 1993[11] and aiming at the standardization of digital TV.

Most SDO, implicitly or explicitly, are committed to the development of "open standards" (OS, henceforth). Preliminary, we need to remember that standards embody pieces of knowledge, usually protected by IPR: patents, copyrights, trademarks and industrial secrets. Often, in the most complex cases, a standard may arrive to include hundreds of different IPR, directly or indirectly. Hence, the owner of the IPR embedded in a standard is entrusted by law with powerful legal tools to charge monopoly rents (royalties and fees) for the usage of that standard, to restrain (or even block) the downstream market (product implementation) for third party vendors, or to perpetuate its legal monopoly blocking further related advances (for eg., by preventing improvements over the original standard).

OS emerged as a sort of compromise, believed to mitigate the inner monopolistic potential possessed by successful standards. Paradoxically, there is no "standard" definition of OS in the literature, but several different and partly overlapping ones (Cerri and Fuggetta 2007; West 2003, 2007). For our purposes, we define an OS that whose detailed technical specification is publicly available for interested third parties, thanks to the publication of its descriptive documents[12]. After this basic common denominator, definitions start to diverge.

From a meta-analysis of the literature, three main profiles of OS can be highlighted. First, the openness of the standardization process. In OS, stakeholders act in a consensus-based process

[11] Being DVB a private body, the developed specifications are submitted to official SDO for formal approval. DVB was born as a temporary consortium, and later transformed into a permanent body.
[12] Generally OS have their technical documentations publicly accessible for free or at a nominal fee.

open to a plurality of participants, while proprietary or "closed" standards are dominated by a unique vertical and self-referential managing subject, following autarchic rules. However, openness may be a transitory character[13]: Krechmer (2006) emphasises that ICT standards are increasingly controlled by implementers, and the latter is the crucial layer where to check that an OS does not fall prey of enclosure strategies. In fact, technical change and strategic firms' incentives may transform an initially 'genuine' OS into a series of semi-open or even proprietary implementations, turning it into a de facto closed standard[14]; in this respect, OS may suffer from the same phenomenon of "time-inconsistency" of compatibility as network technologies (see section 2.1).

Second, the degree of public (external) availability of an OS may vary; in fact, its actual licensing policy could restrain effective access to the "essential" IPR[15] embedded in the standard for some implementers. For example, West (2003) recalls that some third parties might not qualify for access to IPR (typically, the direct competitors of the standard owner); or the scope of this access could vary (for instance, blocking the right of modification of the standard and its implementations).

Third, the welfare properties of OS (including its purported superiority over proprietary standards) depend on the specific licensing procedure and policy enacted. Generally, the minimal necessary requisite for an OS is to offer FRAND (fair, reasonable and non discriminatory) terms of licensing[16]. However, FRAND terms also conceal areas of ambiguity and indeterminacy:

1. FRAND does not mean necessarily a small fee, for prospective licensees. FRAND advocates point out that, for stimulating innovation, the monopoly rent accruing from IPR should be aligned and proportionate to the "importance" of the concerned OS, somehow determined.
2. Remembering that a single ICT/media standard may arrive to contain hundreds of essential IPR, potentially linked to previous ones, this structural complexity originates many intertwined and recursive linkages between IPR. Similar cases are often defined as "patent thickets", due to the "dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology" (Shapiro 2001; p.120). As a consequence, IPR licensing terms, also in the case of OS, in practice may get very complicate and involve a high level of transaction costs – especially for prospective third party implementers.
3. A further problem is the occurrence of "royalty stacking" (Lemley and Shapiro 2007). This is due to the fact that radically new ICT/media products and services involve per se risky business

[13] Moreover, the concept of "openness" is many-sided and touches upon several dimensions and phases: Krechmer (2006) arrives to categorise ten dimensions of openness, and three main types of stakeholders involved: creators, implementers and users.
[14] The software industry provides a high number of examples for enclosure strategies (Shapiro and Varian 1999).
[15] Those necessary to build a material implementation (a product or a service) of the standard.
[16] In fact, the most credited definition does not assimilate an OS to a free standard (royalty-free, typical of the open source software' world, OSS henceforth).

plans[17]; then, complex standards might add to it, when a cumulative overload of royalties endogenously depresses the ex-ante net value of the project[18], irrespective of its real market potential.

4. More radically, some scholars and practitioners point to the conflicting plurality of criteria implementing FRAND obligations, and to the practical indeterminacy involved in most of them (Treacy and Lawrance 2008)[19].

All in all, these licensing issues may easily become causes of lengthy litigations and costly settlements, and in several cases they do seem to be responsible for hold-up dynamics, market uncertainty and lost business opportunities, dampening the diffusion of the concerned OS.

Is there any effective remedy available for solving these IPR licensing shortcomings, increasingly affecting most ICT and media OS? Patent pools have been representing an appropriate institutional answer, at least in some respects[20]. A patent pool is a private entity (association, consortium, firm) formed by qualified IPR owners of the concerned standard. These owners gather and confer their IPR on the pool, to be available for licensing to interested third parties; then, when the patent pool is effectively set up and run, it should be welfare-increasing, since it acts as a bundling device, lowering transaction costs and reducing "double marginalization" welfare losses (with respect to the individual purchase of IPR).

At the same time, patent pools also display several critical dimensions. First, most of the times the patent pool members exchange reciprocally their IPR licences, instead of paying their full price[21]. So, IPRs cross-licensing automatically confers upon the pool members a superior cost structure, with respect to non-members. This sort of joint market dominance, when pool members are also implementers, is likely to lead to anticompetitive licensing strategies, aimed at "raising rivals' costs" (Salop and Scheffman 1983) and deter potential downstream competitors (Lerner and Tirole 2004); similarly, patent pools can become a natural venue for illegal price fixing. On overall, the risk of having abusing and welfare-reducing patent pools is substantial. Second, royalty stacking may come from patent pools, being itself related to the number of essential patents included in the standard, and to their types. This happens because the essentiality character in practice conceals a strong subjective nature and is plagued by asymmetry of information, being self-stated by patent

[17] In mass network markets the entry phase may require intensive efforts (high sunk costs) to build the installed base and activate network effects.

[18] In other words, in this case the net present value of the project is low mostly because of high licensing costs, rather than negative supply and demand conditions.

[19] A main example is the methodology to be used for calculating the royalty base. When patents are embedded in high value added products – eg: Apple's smart-phones and tablets – and percentage royalties schemes are used, they earn high absolute royalties, irrespective of their intrinsic stand alone technical and innovative contribution to the system.

[20] A compact historical analysis of patent pools and antitrust practice in the US case is provided by Gilbert (2010).

[21] Obviously, the bargaining power of each member of the pool depends on the size and importance of its IPR portfolio.

holders: hence, an incentive to overfill the standard pool with one's own IPR arises, for obvious rent-seeking reasons.

In brief, for these and other reasons, an increasing number of scholars, practitioners and operators have started to campaign for a serious reconsideration of the current system of patent-driven standardization.

3. An empirical analysis of standardization and convergence in digital TV sector

3.1 Methodology and scope

In the following sections we test against the empirical evidence the theories and the models reviewed in section 2, to contribute to a fundamental missing point of the research agenda: the unexplored relation between standardization, IPR and convergence. To this end, we carried out an original and interdisciplinary analysis of major innovative and regulatory activities carried out in the TV sector – mostly in Europe; this exam is based on our scrutiny of standardization and policy documents, technological assessment exercises and market analysis.

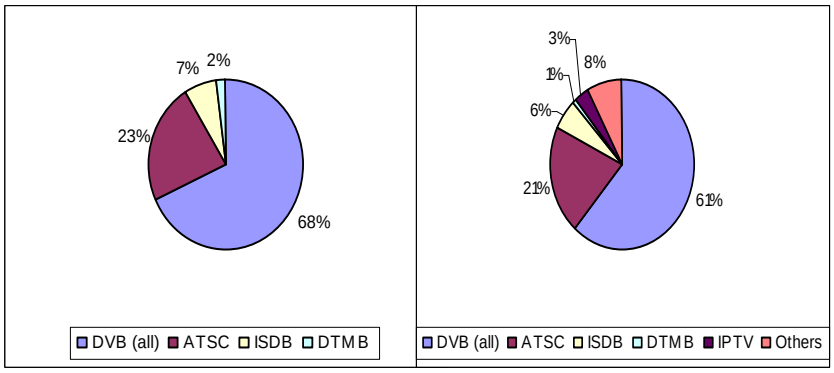
Before presenting the main results, a first important distinction has to be made between technological convergence and industry convergence. For defining the first process we refer to the landmark contribution of Negroponte (1995), who characterised the digital revolution as the transformation of traditional media from atoms (meant in their material supports) into digital bits of information: hence, the dematerialization of media content and delivery platforms possesses strong technological determinants, being dictated by the 'hard laws' of physics and chemistry. The latter spurred the development of micro-electronics as the main technological support for increasingly powerful systems of digital coding and transmission of information, to be used in the telecoms, Internet and television sectors.

With the term of industry convergence, instead, we refer to the industry transformations provoked or stimulated by technological convergence, and to the stakeholders' deliberate strategies or counter responses (either supply or demand side). So to say, we capture with the second concept the economic implications of technological convergence, without assuming an absolute technologically-deterministic stance where, with one-way causation, technology alone would shape markets, social behaviours or institutions. On the contrary, systemic feedbacks are also possible, and technological artefacts themselves are in part modelled and conditioned by economic factors and the socio-institutional sphere.

Having defined the two concepts, we can conclude that, while technological convergence means a trend of progressive similarity (or, at least, interoperability[22]) of the underlying standards and user-level devices, market convergence indicates that, on the supply side, operators along a particular value chain (vertically) and across markets (horizontally) tend to become similar or even coincident (the last case happens with horizontal/vertical mergers and acquisitions). On the demand side, instead, media markets converge when consumers increasingly buy or use different services or devices as if they were similar/identical, and their cross-prices elasticity augments. Obviously, these technological and market-mediated processes of media convergence interact with closely related phenomena of social and cultural media convergence, as comprehensively explored in communications studies, sociology and political science (for example, Jenkins 2006; other chapters in this book).

Hence, our point of departure is the informed belief that 'spontaneous' forces of technological convergence and standardization activities are inextricably linked to IPR strategies and to the overall political and institutional spheres governing contemporaneous societies; these spheres see intellectual property and its governing rights as crucial assets to control investments, production, and national competitiveness, beside empowering new effective strategies of trade policy. As a main consequence, we believe that also the very phenomenology of convergence (or divergence) in digital TV cannot be properly understood without a deep appraisal of firms' IPR strategies, economic incentives and related phenomena such as patent portfolio strategies (including patent pooling), IPR proliferation and litigation, which stand as clear stylised facts of contemporary ICT and media sectors (for a recent assessment of mounting IPR litigation, PWC 2012).

Figure 2. DVB share of the worldwide installed base of household digital STB (right) and household digital broadcast (not IPTV) STB (left) - 2011



Source: DVB and HIS-Screen Digest

[22] In the first case, standards do not proliferate and unique designs prevail. In the second case, standards may proliferate, but services and devices are interoperable, supporting multiple standards.

In the following empirical analysis, the DVB consortium will feature as the main protagonist of the story (for a broad presentation of its experience and operative functioning, see Grimme 2002; Eltzroth 2008, 2009). We are aware that important standardization activities for digital TV were also carried out by other competing SDO and institutions, based in different geographic areas (primarily, US and Asia), as nicely described by previous works (Farrell and Shapiro 1992; Gerbarg 1999; Shapiro and Varian 1999; Hart 2004). Despite this, our focus on DVB is principally motivated by its leading role acquired within the global system of ICT and media standardization – particularly for digital TV. The noticeable impact DVB managed to exert on worldwide DTV deployments is indirectly showed by its substantial share of the global installed base of digital set-top-box (henceforth, STB) – this base being estimated at 1.4 billion pieces by 2012. In particular, the left part of figure 2 demonstrates that, considering only broadcast transmissions, in 2011 DVB controls 68% of the world installed base of DTV, while the closest rival (ATSC, the US alternative) commands only 25%. Then, if we consider the DVB share on the total world installed base of digital STB - including narrowcasting modes (such as IPTV) - its share slightly falls to 61% (right part).

3.2. Standards for digital transmission

The first generation of DVB standards for signal transmission began to be worked out a few months after DVB formal foundation (1993): first, in 1994 was issued that for satellite (DVB-S), shortly after came that for cable (DVB-C) and finally that for terrestrial TV (DVB-T), in 1997[23]. DVB-S, DVB-C and DVB-T are based on a common signal compression specification (MPEG-2, previously standardized at ISO), a then powerful algorithm able to compress the large video output of TV studios[24] to a datarate of a few Mb/s (so called "source coding"); the transmitted signal is later decompressed once received by the STB. Before transmission, the source signal needs to be adapted to the transmission medium ("channel coding"): this involves the usage of specific algorithms to perform errors correction, modulation, format conversion and filtering of the signal. At that time channel coding operations were designed and developed as platform-specific. For example, DVB-S, DVB-C and DVB–T incorporate different modulation systems, implemented with tailored hardware: hence, they result to be different and not interoperable standards, so that a TV viewer

[23] Other ancillary supporting standards were also developed, such as DVB-SI (for service information), DVB-SUB (for subtitling), and MHP, the open middleware specification analyzed *infra*. The transmission-independent part of MHP has led to the GEM specification, used also in off-line media (Blu-ray Disc).
[24] At that time, typically, a signal of 166 Mb/s or more.

willing to subscribe to all the three platforms' services, transmitted with the first generation, should buy and pile up at least three different STB.

Was this divergent outcome inevitable? On one side is technically dubious if a unique transmission standard for the three platforms would have been feasible with the technology of mid-Nineties, given the pioneer stage of digital signalling technologies and the country specificities permeating terrestrial services (and the delays likely to affect their switchover processes). Lacking any counterfactual, we tend to think that its retail cost would have been prohibitive and its niche business model unsustainable. On the other side, a higher degree of interoperability might have been feasible between cable and satellite transmission standards, since the modulation requisites of the two platforms were more similar[25]. More explicitly, the absolute and symmetric incompatibility choice[26] between satellite and cable equipment made while designing the first generation seems to have been dictated firstly by the diverging commercial interests of the incumbents, oriented to stifle the first signs of strong competition between the two platforms. Consequently, the economies of scale actually enjoyed by the CE industries were significantly lower with respect to those originally anticipated during the standardization process, and this, due to the higher unit cost of the STB, might have somehow dampened the DTV diffusion under the first generation.

Residually, one can investigate if the degree of STB interoperability was sensibly higher at least within each transmission platform. Also in this respect, DVB transmission standards did not enable any relevant degree of intra-platform interoperability between devices and services, across Europe and even within single EU members. The case of DVB-T is probably the most paradigmatic, since its STB market across EU remained strictly national. Basically, during and after its standardization, it was clear that national raisons linked to spectrum management and policy, technical idiosyncrasies emerging from the operators' legacy equipment and the different stages of the national switchover processes would have lead to diverging geographical implementations of the same transmission standard[27]. However, in this specific case, it is fair to affirm that most interoperability limitations were rooted in technical and institutional constraints, rather than firms' strategies and IPR incentives. The Italian DTT experience is a case in point, with the R&D centre of RAI (the public broadcaster) having played a qualified role in developing specific adds-on to the

[25] Historically, satellite and cable have been used complementarily for primary transmission of TV signals. The wide footprint enjoyed by satellite helped to connect separate distant cable networks (Parsons and Frieden 1998).

[26] Concerning modulation, two different techniques were chosen. For satellite, QPSK (quadrature phase shift keying), for cable QAM (quadrature amplitude modulation). These techniques, through different implementations, are also the modulation core of other platforms such as DSL modems, CDMA, 3G, Wi-Fi and WiMAX.

[27] For example, two different modulation schemes were developed, differentiating geographical areas starting DVB-T services early (based on 2k OFDM+QAM) and those starting later, and building on single frequency networks (SFN, henceforth). The second required adopting 8k OFDM+QAM modulation, which is backward compatible with 2k/QAM broadcasts. Later on, several EU countries adopted improved algorithms, adds-on and devices to the basic DVB-T standard, in order to cater for their specific transmission and spectrum needs.

basic DVB-T specification; in particular, these adds-on enabled the correction of the high rate of interferences damaging terrestrial transmission, due to the chaotic allocation and usage of the Italian UHF and VHF bands of the TV spectrum (see, for example, the CD3-OFDM equalizer). Later on, a similar beneficial role was also played by the DGTVi association (constituted by the main terrestrial broadcasters), which acted as the main technical body for coordinating and fixing transmission and reception shortcomings affecting the Italian DTT roll-out (for an exam of DGTVi, Matteucci 2009).

Instead, looking for interoperability limitations directly attributable to IPR incentives, the story of satellite DTV standardization is more illustrative. Since the mid-Nineties, digital TV diffusion in Europe was first driven by the expanding pay-TV offers, initially broadcasted via satellite. Basically, the fact that the satellite transmission standard (DVB-S) was the first to be completed responds to favourable technological opportunities. Satellite transmission systems – especially those performing "direct to home" transmission, DTH henceforth - pose inferior technical challenges in terms of interoperability of devices and operations, being the platform/system management fully centralised[28]. Similarly, the switchover process of the satellite platform encountered less coordination problems and switching costs with respect to cable and terrestrial, whose switchovers are technically and normatively more complex and cumbersome. Finally, satellites enjoy huge scope economies, being their fleets regularly updated and incremented to satisfy a large variety of communication purposes (telecom services, military purposes, space-related and broader scientific activities, among others): hence, most R&D and deployment costs were shared. However, despite these favourable pre-conditions to interoperability, most satellite services have showed a market divergence across Europe, requiring specific equipment and STB; this was mostly due to the 'converging' incentives to incompatibility held by leading pay-TV operators, willing to keep their subscriber bases as walled gardens. Finally, the platform temporal leadership is also a main explanation of why, still in 2011, the DVB worldwide market position remains particularly strong in satellite: in fact, DVB is holding a 68% market share in the world market of satellite STB, while the corresponding one drops to 57% for cable STB and to 55% for terrestrial STB (table 1)[29].

[28] In fact, with satellite, a single up-link transmission site (from the earth base station to the satellite transponder) concentrates all system control and signal management functions (Drury 1999; Reimers 2006). Here the main problem is transmitting a compatible signal receivable by household devices produced by different vendors, and patronized by different satellite TV operators, while satellite services have transnational coverage and reception.

[29] All figures include the DVB second generation of transmission standards. The latter at 2011 is relevant for satellite, still marginal for terrestrial and zero for cable.

Table 1. Worldwide shares (%) of total TV receivers diffusion, by platform – 2011

	DVB		Other standards	
	2009	*2011*	*2009*	*2011*
Satellite	72	68	28	32
Terrestrial	43	55	57	45
Cable	49	57	51	43

Row/Year sum to 100. All platforms count the first and second DVB generation.
Source: DVB and HIS-Screen Digest.

Has the interoperability and convergence potential progressed in the second generation of DVB transmission standards? On overall, we can respond positively, although the extent of the progresses varies according to the different TV platforms considered - traditional (cable, satellite and terrestrial) and newer or emerging ones (IPTV, mobile TV and hybrid TV).

In detail, on the one side intra-platform compatibility issues were specifically considered while designing the second generation. For example, the DVB-S2 specification (developed in 2003 and ratified by ETSI in March 2005) provides options to make it-self compatible with the installed base of DVB-S STB (thereby supporting backward compatibility[30]), while offering new services to TV viewers agreeing to substitute their STB. Then, DVB-S2 includes new functions connected to the convergence between Internet and TV, such as a generic transport mechanism for IP packet data; additionally, the second generation can accept different input data formats, especially in professional applications.

DVB-S2 market deployment has been fast, and the new standard has basically replaced most of the existing DVB-S services in Europe and US. According to DVB sources, two main drivers pushing this fast process of diffusion and substitution have been the clearly-stated early ITU support and the IPR strategy adopted by the patent pool members. In fact, in 2006 ITU formulated a recommendation of DVB-S2 as the best satellite option for conjugating both audio-video and data transmission needs; at the same time, DVB-S2 IPR holders fixed rapidly and with certainty the licensing terms, which appear to have been considered at least acceptable by the concerned market players.

More generally, a higher interoperability potential seems to mark the second generation of DVB standards, compared with the first. This is certainly rooted in stronger technological opportunities (for an economic analysis of this concept, Klevorick et al 1995), due to accelerated

[30] Obviously, backward compatibility is a technological possibility offered by the DVB-S2 design, but its actual materialization will always depend on what happens during the commercial implementation, *id est*, on the commercial choices and incentives held, country-by-country, by broadcasters and satellite operators, which interact with CE manufacturers' incentives and market expectations.

technical advances pushing the semiconductors industry. In particular, the development of superior CPU and systems on chips (SoC, henceforth) has yielded tremendous gains in computing and memory power (according to the famous Moore 1965's law) - unthinkable ten years before, at the time of the first generation. Further, the second generation embeds the outcome of important research advances, which pushed the signal transmission performance very close to its theoretical maximum (Siebert 2011). Finally the second generation, although in varying degrees across its main platforms, was the first to be specifically conceived to enable an efficient transport of IP packets, thereby making the first sizable step in the long journey towards the convergence between the two separated worlds of broadcasting and Internet.

3.3. Standards for conditional access and content management

The early deployment of the satellite DTV platform was also supported by the strategic choices of pay-TV operators; these, starting from the analogue era, had begun opting for firmly-controlled "vertical" business models[31], featuring proprietary and *de facto* standards governing the core elements of the transmission and reception devices: primarily, the CAS, API and EPI modules. In the digital era, such a proprietary business model has become the rule, for several reasons. First, operators must control crucial components essential for the viability of the pay business model (for example, the piracy-proof security of the CAS), and have to ensure interoperability with reception equipment produced by different vendors - absent a *de jure* or *de facto* standard. Second, during the analogue-digital switch-over, they need to subsidise prospective viewers, in order to win their reluctance to adopt the new technology, because the retail price of STB and the complementary receiving equipment (antenna, etc.) may represent a significant upfront cost, for the median income household. Last, but not least, a proprietary STB better caters for walled garden strategies against potential entrants, especially when this technical incompatibility strategy is conjugated with exclusivity strategies based on premium content acquisition. However, while at the beginning these proprietary strategies fuelled the take-off of the first digital platforms, later their industry-wide net effect turned negative, because of the dominant positions they created. Matteucci (2004; p. 59), for example, describes the lengthy battles fought by the Italian satellite pay-TV duopolists with the goal of dampening the reciprocal interoperability of their STB bases: they stubbornly resisted the

[31] Nolan (1997) remembers that a strong obstacle for analogue satellite TV diffusion in EU had been the fragmented structure and incompatibilities affecting the reception devices, with the satellite receiver being typically universal and separated from the decoder (signal descrambler), proprietary. Hence, those offering a proprietary unique piece of receiving equipment (STB) enjoyed a strong market boost.

normative provisions and the market pro-compatibility sentiment, even at the cost of being fined by the national regulator.

Indeed, these incompatibility strategies are believed to have caused subscribers' hold up behaviours and prolonged market uncertainty, which might have stalled satellite subscriptions in a favourable period, when DTT offers were still unavailable and satellite was the main multichannel novelty in most EU countries, beside analogue cable. All in all, the satellite platform presents a rather counter-intuitive market outcome of technical standardization, whose precompetitive and pro-convergence trend was reversed by the pro-divergence incentives permeating a small but influential part of the DVB membership. At the end, despite the global reach and convergent potential of the platform, satellite TV services have remained fragmented and relatively underdeveloped across EU, and its market share is now progressively eroded by the other platforms, both traditional (DTT and cable) and new ones (such as IPTV and new hybrid forms of online TV consumption).

Another story featuring lack of user-level interoperability is that of CAS, equally regarding the three traditional TV platforms. Surprisingly, CAS standardization was one of the main remits of the DVB group, and a domain where also the EU Commission put many efforts, revamping a clear interventionist and pro-industry approach, culminating with Directive 98/84/EC on the legal protection of services of conditional access. This story has been widely studied (Van Schooneveld 1996; Cave 1997; Cawley 1997; Helberger 2005), and will only be tacked here in relation to IPR and its divergence outcomes. Basically, DVB members worked hard to find consensus on a standardised descrambler and CAS, but at the end two alternative systems were submitted to the DVB's Steering Board, Simulcrypt and Multycript, and both were later approved. In fact, while Simulcrypt was patronised by incumbent pay-TV operators willing to retain full market power over their installed base of decoders, on the contrary FTA broadcasters, new pay-TV entrants and CE equipment manufacturers were in favour of the Multycript option (or Common Interface, CI henceforth), enabling direct and fuller CAS interoperability. In fact, CI is a CAS detachable module (hence, CAM) and incorporates both the smart card chip and the descrambler chip, so that it fits a variety of STB from different vendors, rather than requiring lengthy negotiations between entrants and incumbents for obtaining the rights of access to the reciprocal SBT installed bases (as in the Simulcrypt case): hence, CI/CAM qualifies as a proper interface standard, enjoying a higher potential for interoperability. As a result of DVB internal fights and decision impasse, both CAS options were transposed into national laws, following Directive 98/84/EC - that obliging member countries to mandate at least one of the two systems. At that point, market equilibria, unsurprisingly, tipped in favour of Simulcrypt and, despite formal FRAND provisions, new

operators willing to enter the pay-TV markets were effectively deterred, so that many consumers across EU were stranded after their initial STB choices, either with Simulcrypt (failing negotiations) or Multycript (unavailability of CAM for certain services). This was also due to the fact that, while the scrambling mechanism was standardised and subject to FRAND, other STB components did not enjoy the same guarantee, as in the case of EPI and API, which however are components equally necessary to reach broad audiences of TV viewers (for an early appraisal, Cave 1997). In this case, given the proprietary nature of most EPI and API used in pay-TV STB (for the latter, we mention MediaHighway, OpenTV, Liberate, Microsoft TV, NDS, PowerTV), many new operators could not enjoy the same degree of pro-competitive protection and interoperability, with respect to the incumbent' base of STB.

3.4. The first DVB 'patent' failure: the MHP standard[32]

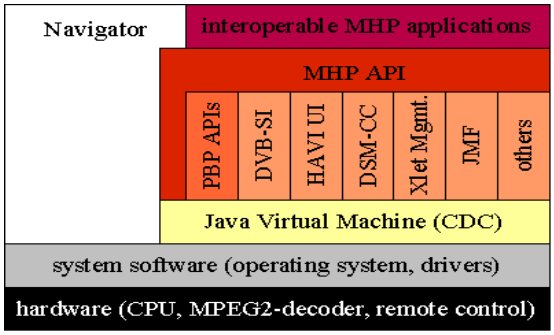
After the noticeable market success obtained by the first generation of transmission standards, DVB activities encountered the first critical steps while moving along the digital TV value chain, at the services/content layer. As a matter of fact, the MHP specification (Multimedia Home Platform) was the first burning failure dampening DVB' reputation. The MHP is an open standard for API, which is a crucial software layer (or middleware) located inside those TV STB which have interactive capabilities (higher quality types; for an example, see figure 3). Basically, the API governs the informative fluxes within, from and to the decoder, and provides external applications and services with a compatible interface and a standardized execution environment. In particular, MHP works independently of the underlying STB' system software and hardware, so that third-party content and applications are portable across types of STB produced by different vendors, without need of re-authoring. Moreover, the IPR licensing of MHP, being it an OS, is bound to FRAND terms, differently from proprietary API. Hence, *ex ante*, the leverage effect of a standardised open API such as the MHP should promote the emergence of an horizontal market for STB, originating larger economies of scale and reducing retail prices.

During the second half of the Nineties, several FTA broadcasters and CE manufacturers started to design new enhanced TV services and STB provided with interactivity functions, envisaging interactive TV (ITV, henceforth) as a sort of counter-move against the increasing momentum of the Internet. Further, the contemporary developments of pay-TV were urging a new generation of more intelligent decoders, capable of performing new transactional functions: an

[32] This section partly builds on Matteucci (2008;sect.3 and 2009). We refer to these papers for a comprehensive techno-economic analysis of the EU market experience and policy for Interactive TV, and for a focus on the Italian case.

adequate API was then needed. DVB embarked in MHP project since 1997; however, at that time, DVB membership did not include major ICT and API producers, so that the original MHP project built around the idea of a simpler low-cost API; later on, the MHP project became more articulated and ambitious, and produced a number of versions and upgrades of increasing complexity.

Figure 3. Software layers and structure of an MHP STB



Source: http://en.wikipedia.org/wiki/Multimedia_Home_Platform

Meanwhile, European market stakeholders had started to lobby for informing the EU regulator about the need for a EU-wide standardised open API, publicly available for potential implementers. However, at this stage interests and views on MHP were already diverging, within DVB. Strong MHP supporters were found among Scandinavian TV operators and German broadcasters, together with the bulk of major CE manufacturers; later on, also EBU (the association of European broadcasters) would have taken a more explicit position aimed at strong and direct public support for MHP. On the other side, pay-TV operators, having their respective installed bases of proprietary API and STB, did not fancy this public support to an OS; they also claimed that MHP was not so costs-benefits effective, and believed that ITV did not have interesting market potential. Geographically, Scandinavian countries, Benelux and Germany were in general MHP supportive due to their analogue TV legacy, while most of the larger countries (UK, France, Italy, Spain) were opposed, or alternatively were just favouring a long-term migration strategy to MHP, while maintaining compatibility with existing proprietary API and remaining open to alternative future specifications; in particular, in UK and France there was a strong preference for a simpler specification, MHEG-5, better catering for the limited interactivity potential of standard FTA terrestrial services. Equally, several European cable TV operators were preferring a standardised but simpler API, given the MHP higher development and roll-out costs and its technical complexity and immaturity (ECCA 2003; p. 3).

Despite lack of consensus, efforts towards MHP and the largely utopian idea of introducing at that time ITV were accepted and included in the EU New Regulatory Framework, issued in 2002.

The final draft of the NRF incorporates an elaborate political compromise agreement between these diverging views. In particular, Art. 18 of the Framework Directive assigns a special status to open API (and, *de facto*, to MHP[33]) and specifically mentions interoperability as a means to achieve horizontal markets, beside other socio-political and cultural goals. Operatively, Art. 18 foresees a system of immediate national market incentives to stimulate spontaneous tipping towards the DVB specification, while does not exclude the "last resort" option for the medium term: old-style direct intervention by the Commission to mandate standardization on MHP.

This complex policy-mix was specified in a series of policy documents. Since the beginning, the Commission had recognised that - due to the diversity of industries, operators and business models called to provide convergent interactive services (deliverable by either digital TV or mobile platforms, such as the UMTS) – achieving effective interoperability of API would have required due time, meant different things and possibly diverging paths. For example, during the mid-2004 public consultation EBU (2004) claimed that, although there were different paths to interoperability (for example, by means of content re-authoring or broadcasting in multiple formats), only the one based on an OS (like MHP but also MHEG-5) would have been rapidly effective at the consumer-level. Further, EBU warned the Commission against a minimalist approach bound to ensure interoperability solely within the DTT platform, because interoperability limitations significantly affected also satellite and cable. On the other side, operators from the pay-TV, telecoms and IT worlds showed a more liberal and market-oriented attitude to interoperability and market convergence of API, claiming that publicly-mandated standardization would have chilled private innovative efforts; moreover, the same subjects observed that interoperability should have been demand-driven, and preferably realised at the content level (for example, with portable content formats, needing re-authoring), rather than at the STB level (with a new API).

Unsurprisingly, face to this plurality of views, in 2004 the Commission (EC 2004) adopted a cautious waiting approach, to finalise its review in 2005 (EC 2006), when it decided not to mandate standardization and to maintain a market-led orientation to the promotion of open API, facilitated by public financial incentives. As an example, the Commission pointed to the MHP developments in Italy, where more than 2 millions of MHP-interactive STB had been sold, after being publicly subsidized[34]. Incidentally, EC (2006) also mentioned the market progress of two other non-DVB

[33] Despite the general formulation requested by law, the provisions of NRF were first and foremost inspired – if not specifically crafted - at the benefit of the MHP, which was the first specification to be formally recognized in the list of EU official standards for ITV.

[34] At that time, EC (2006) argued that this success was jointly due to a virtuous and synergic public-private mix of factors: the public subsidies to MHP decoders, the voluntary agreement of Italian broadcasters to use MHP, and the definition of common specifications for the national implementation of the MHP standard. As a counterfactual, the Commission noticed that the same degree of stakeholders coordination did not materialize in Germany, nor in the Northern EU markets, despite the early market consensus.

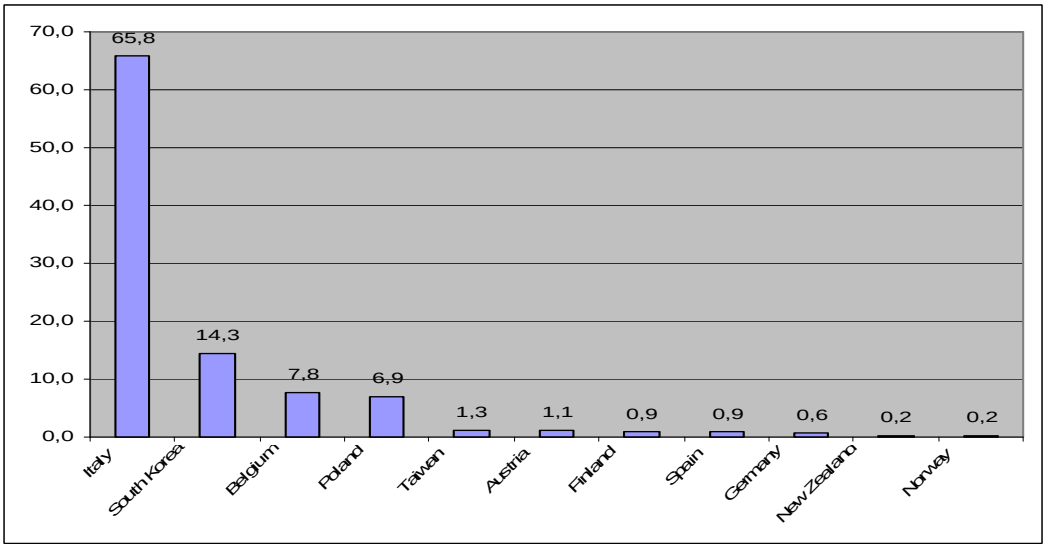
standards – MHEG-5 and WTVML[35]; these newer API specifications, despite being still waiting for acceptance as official OS and not being supported by public subsidies, by 2005 managed to total respectively 5 and 7 million units sold. This fact is very curious and interesting, once compared with the institutional fuss devoted to MHP: their formal accreditation as ETSI standards came after spontaneous market acceptance, contrary to the MHP case. Hence, this comparison shows effectively that not all OS are equally market-driven.

Unfortunately, the early Commission (DG Information Society)'s enthusiasms for the Italian MHP experience were too hasty. In fact, the Italian Government's implementation of the EU policy for OS and MHP was highly contentious (Matteucci 2009, 2010), being centred on public subsidies and advertising support to MHP STB, but limited to terrestrial TV - the incumbent platform. The public measure, opposed by excluded operators, gave rise to a complex and lengthy state aid case: the final decision in 2007 (from DG Competition) was negative, qualifying it as an illegal state aid, being selective and market distortive and tailored to the benefit of one incumbent TV operator, Mediaset (controlled by the family of the then Italian Prime Minister).

Obviously, from a market convergence point of view, the distortionary public aid measure did favoured the widespread diffusion of DTT and MHP in Italy against the satellite competitor and rival API, thanks to the ensuing economies of scale and the falling retail prices of DTT MHP STB. However, from the point of view of the effectiveness of the underlying innovation policy for ITV, the entire pro-MHP public campaign was a waste of tax-payers money. In fact, given the premature stages of the early MHP versions and the small interactivity potential of the subsidized STB (equipped with a narrowband return channel), real two-way interactive services did not take off in Italy. Consequently, Italy has acquired the rather bizarre and embarrassing primacy of having the largest share of the worldwide installed stock of MHP interactive STB (65.8%, figure 4) and one of the lowest rates of actual roll-out and usage of ITV. In fact, the most relevant usage of the MHP-enabled two-way interactivity is that serving the SBT's pay-TV subscriber management system, for which the public subsidization of MHP acted as free manna from heaven; meanwhile, paradoxically, the country is plagued by insufficient and faulty broadband supply and has one of the lowest rates of Internet usage among OECD countries (for a recent assessment, Matteucci 2013).

[35] MHEG-5 is a language for presentation of multimedia information, particularly used for ITV services. To be useful for broadcasting, the language has been codified ("profiled") as ETSI standard. WTVML (Worldwide TV Mark-up Language) is an XML-based content format, standardized through ETSI, allowing web designers to create ITV services with minor adaptation requirements.

Figure 4. Worldwide % shares of the installed stock of MHP STB – End 2011



Legend: % country shares of the total MHP base, equal to 16725000 pieces at November 2011.
Source: our elaborations on www.mhp.org data.

During the last decade, despite (or, perhaps, because of) this intensive institutional support, the IPR and licensing profiles of MHP remained uncertain; the patent pool formation was very late, and the exact terms of licensing were published only in February 2007. This situation also prompted a formal protest of the EU Commission, which wrote a letter to the DVB Chairman to express its disappointment and concerns over the MHP project shortcomings. Moreover, the MHP licensing royalties were considered too high by most broadcasters, whose main association (EBU) announced in March 2008 the discontinuation of its support to MHP. The boycott was later reconsidered, but by that time MHP had already missed most of its opportunities, and did not take-off (apart from Italy).

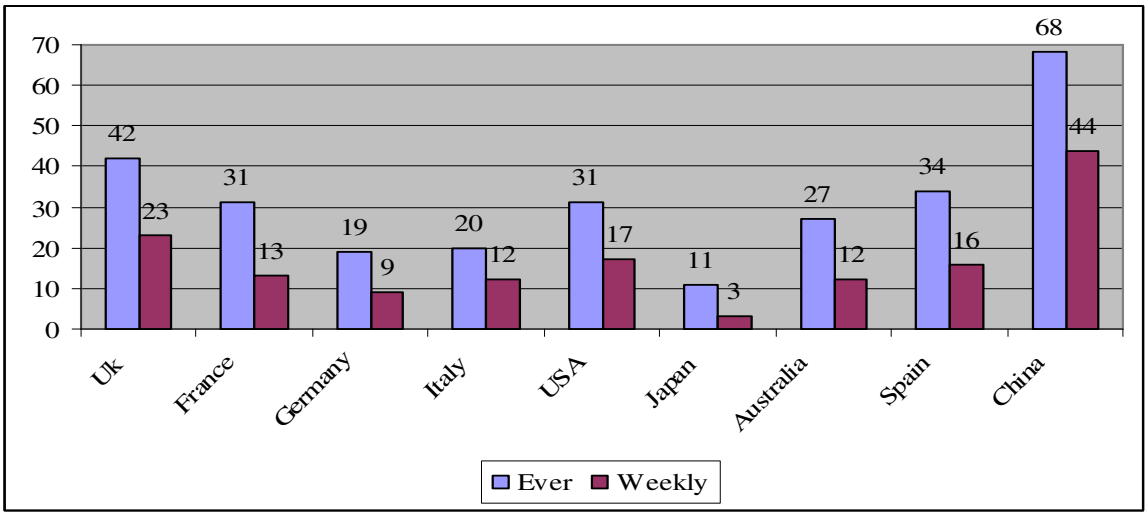
Face to the MHP failure (resembling in part that of the first DVB standard for mobile TV - DVB-H, not analysed here), the EU Commission started acknowledging how interoperability is difficult to be provided not only by Governments, but also by hybrid settings such as the DVB-ETSI tandem; basically, the latter did not manage to harmonize the consortium members' conflicting visions, incentives and agendas concerning ITV standardization. This story also illustrates how short even OS may fall of guaranteeing interoperability and market convergence, absent a suitable technological landscape and aligned market incentives.

3.5. New hybrid forms of TV

So far, we concentrated our analysis on traditional TV platforms; after all, during most of the 2000's, they managed to maintain the bulk of their audience ratings and advertising shares, in aggregate, despite the growing diffusion and usage rates of the Internet. However, starting from the late 2000's, a clear stylised fact of the sector is the mounting audience-stealing effect deriving from the consumption of online TV-related content (videos, TV channels, etc.), as figure 5 indirectly demonstrates. It shows that, by the end of 2012, a significant portion of citizens has gained a first experience with online TV content (first histogram); beside this, another significant part (second histogram) exhibits a frequent behaviour (weekly) of on-line TV consumption. UK is the most representative case in EU, since 42% of the interviewed persons admits to be experienced with online TV, while almost one quarter (23%) of the population watches it weekly. Other notorious technology-minded countries like China appear to be even heavy on-line TV viewers, with 68% and 44% of the interviewed population interested by the same phenomenon.

Indeed, broadband roll-out progresses worldwide, and its increasingly pervasive availability and higher transport capacity are opening revolutionary perspectives for TV convergence, based on the usage of IP networks for content transport and delivery. This trend includes both proprietary networks – like the IPTV - and, increasingly, the open Internet, where OTT operators are active service providers and have been acquiring growing shares of loyal Internet users.

Figure 5. Usage and frequency of access of TV content over the Internet – % values; October 2012



Legend: the graph reports the proportion of respondents that accesses online TV in each surveyed country (respectively, usage/weekly frequency).
Source: OFCOM (2012; Fig.3.12).

Indirectly, in the previous section, we detected a few signals of this trend commenting on the fact that the second generation of DVB transmission standards, while does not offer a significant quantum leap in inter-interoperability within the TV world (for example, it continues to require specific duplication of electronic components to produce high-end STB capable of multiplatform TV reception), has been specifically designed for enabling a higher potential of IP capacity and interoperability (hence convergence) with the Internet world, with respect to the first generation. This is a clear sign that traditional TV operators and their standardization representatives felt the competitive threat of the Internet, as wisely envisaged by Owen (1999), and have started to harness the opportunities connected to it, responding in several ways to the growing momentum of web-related content consumption.

So far, the main threat for traditional TV players does not seem to come from IPTV operators (with the only exception of France, where the latter has achieved a high rate of diffusion, reaching 28 of TV homes in 2011, OFCOM 2012). In fact, the diffusion of IPTV has long been dampened by a few shortcomings affecting its business model: among the most important, we include the shortage of premium content, and the typical usage of strict proprietary and IPR-closed business models, which do not appear conducive to ease the market entry of a new operator (for the considerations spelled out in section 2.2). In the future, however, the latter obstacle might fade away, as soon as IPTV operators continue to develop new hybrid business models and adopt more interoperable types of equipment.

Rather, the main challenge to traditional TV operators seem to come from OTT players. In particular, the main ones (such as Google-YouTube and Apple) since the second half of the 2000's have been introducing a series of initiatives signalling a clear interest to enter the TV sector, either in the form of free (advertising-funded) or pay business models (such as VOD, pay-per-view or subscription based). OTT typically focus on aggregating content and attracting audience, for sale; this, until now, has not included the control of an IP-based transport infrastructure, or a content delivery network (CDN). However, in several cases they have been developing new reception devices, own or in collaboration with major CE manufacturers, to better manage their installed base of viewers/subscribers and provide new converging multimedia services (beside TV content). Main examples are the Internet-connected personal video recorder of TiVo (US), the TV box of Apple or the game-consoles of Sony (Playstation), Microsoft (Xbox) and Nintendo (Wii).

Further, major CE manufacturers have being developing new Internet-connected TV sets, incorporating higher memory and computing power, and featuring original interactive functions and "smart" capabilities (such as voice or eye-based control), teaming up with major content providers or OTT players (like in the case of the software widgets of YouTube, Yahoo and Facebook

embedded into the flat panel display (FPD) TV sets of LG, Philips, Samsung and Sony). This has originated a wide and expanding array of accompanying neologisms like "Connected TV", "Smart TV" and so on[36] (for a recent taxonomical and classification effort, Quayle 2012).

Finally, the latest technological frontier appears to be that of the "Hybrid Broadcast Broadband TV" (or HBB TV), where the two experiences - that of the TV and the Internet, previously offered as separated bundles of services – here are designed and presented to the user as a unique experience and service. Indeed, HBB TV currently represents the most advanced frontier of media convergence between the Internet and the TV. From a technological point of view, the development of multiple competing technical specifications for HBB TV (both in EU and abroad, such as HbbTV, MHP, MHEG, YouView and others) let to prefigure a trend towards accentuated standards fragmentation and industry turmoil, mostly due to the diversity of the existing legacy solutions.

4. Conclusions

This chapter proposed an interdisciplinary perspective on the growing role of technical standards and IPR in the converging TV sector, investigating the main standardization initiatives carried out in the last twenty years, to examine any possible trend toward media convergence or divergence, both within the traditional TV world and in relation to previously separated ICT sectors.

In detail, we first reviewed the economic function of standards to achieve technological and user-level interoperability, to uncover that standards in ICT and media markets open up a series of technical possibilities, as well as strategic incentives, that may enable or foreclose market entry for rival operators, by manoeuvring interoperability and convergence.

Then, recognising that complex standards may arrive to contain hundreds of IPR, we reviewed the main stylised facts and latest trends in IPR management and policy. In detail, the current hype of open standards (OS) was assessed, and the characteristics of licensing coalitions (patent/IPR pools) were highlighted. This survey uncovered several criticalities affecting OS, FRAND terms and patent pools, associated to contractual loopholes and legal idiosyncrasies. All in all, OS and patent pools cannot completely sterilise the likelihood of anti-competitive and rent-seeking behaviours, and pose new original implementation challenges. In several situations, because of strategic manoeuvring of large IPR portfolios by stakeholders during and after standardization, initial openness and interoperability might fade away, at the expense of smaller competitors, of the

[36] Minor variations and logical subsets are also "Web-TV", "Net TV", "OTT TV", "Catch-up TV".

market competition and of the consumer welfare. As a result, most of the current technological potential for converging ICT and media markets might be captured for the benefit of a small group of stakeholders, imposing suboptimal 'captive' convergence and stifling wider economic growth and societal progress.

Then, moving to the empirical part of the chapter, we carried out an original long-run empirical analysis of the main standardization initiatives in the TV sector, based on the DVB and EU experience. As a first stylised fact and driver of media convergence, we provisionally accepted the technological explanation initiated by Negroponte (1995). Indeed, the availability of increasingly powerful systems of digital coding and transmission of multimedia content has market the passage from the analogue to digital TV, initiating an era of pervasive dynamism and convergence along its entire value chain. Moreover, thanks to our empirical analysis, we appreciated that, over time, in parallel with the diffusion of the Internet, there has been a second 'reinforced' type of technological confluence of TV standards, with the latter joining a common converging micro-electronic base and adopting the main standardized protocols of the Internet word, such as the TCP/IP.

The in-depth analysis of the work of the DVB consortium supports this view, and uncovers other interesting regularities. The standardization endeavour initially worked well - especially while dealing with the transmission layer (first generation), but has later showed increasing signs of pain and inadequacy when trying to address the more IPR-intensive layers of the value chain - like the stories of the CAS, EPG and API demonstrated. In particular, our analysis of the MHP case highlighted the conflicting visions on interactive TV and the diverging agendas held by the most important DVB stakeholders; this situation, together with the IPR shortcomings of the late patent pool, defeated the big efforts played by EU public bodies toward the deployment of that open API. At the same time, the status of microelectronics and software technologies and the potential for interoperable interactive services were too unripe to enable, during the first half of the 2000's, the successful introduction of truly converging types of interactive or Internet TV, which represents a landmark achievement in media convergence. At the same time, the exam of the case of transmission standards showed us that, on overall, the technological potential for inter-platform interoperability within the traditional TV world has remained under-developed, due to adverse incentives to interoperability and convergence held by traditional TV stakeholders.

Instead, during the second half of the same decade, additional factors ignited new and more powerful convergence trends between the TV and the Internet. Certainly, increasing worldwide Internet penetration and broadband roll-outs set the stage, and put a mounting psychological pressure on TV incumbents, prefiguring increasing audience-stealing effects. This, jointly with the

higher technological opportunities unfolding in the same period, contributed to increase the effort towards "external" interoperability of the DVB work, as we detected in the case of the second generation of DVB transmission standards. This trend is also an indirect sign of the fact that traditional TV operators acknowledged early the incoming Internet' threat (see Owen, 1999), and have been working hard, in several domains, to prepare them-selves and accommodate convergence while exploiting their TV market incumbency. Big OTT operators, in turn, seem to be in a strong position to exploit their market incumbency in the online content market, and to transfer part of this to the converging TV one, teaming up with other key players, like CE manufactures producing smart TV sets and other Internet-connected TV "boxes".

Finally, the latest technological frontier of the convergence between TV and Internet appears to be the recent standardization efforts for the hybrid broadcast broadband TV, although here the market reality is still too fluid and unripe to inform a reliable analytical effort aimed at detecting robust convergence or divergence trends.

All in all, so far, despite this high technological turbulence, the established media landscape seems to maintain its main classical characters, with traditional TV and telecoms operators striving to keep market shares through walled garden solutions and lobbying for stronger IPR protection, due to the higher piracy potential of the Internet. Nevertheless, we believe that this apparent market continuity is about to end quickly, as soon as the main and new OTT operators will find new lateral in-roods into established TV markets: audience trends signal already the first traces of the next storm, with on-line TV viewing progressing at high rates at the expenses of traditional TV consumption.

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