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The People's Republic of China has recently become remarkably active in the development of interoperability standards across many areas of Information and Communications Technology (ICT). Such standards are crucial for the creation of new industries and markets for novel ICT products and services. This engagement in standardisation is linked to the Chinese government's strategy to develop indigenous technologies and, in some cases through involvement in international standardization bodies, to put China at the heart of the next generation of global technological infrastructures. In this way China seeks to go beyond its globally competitive productive capabilities to acquire technology innovation capabilities. This strategy throws up important issues for China's technology promotion policy in terms of how to contribute to standardisation processes and of how to exploit public sector research and development. China's involvement in the shaping of these globally significant technologies will have far reaching consequences for developed economies and global ICT markets, posing challenges for industrial strategy and innovation policies across the developed and developing world. The USA has tended to see China's search for indigenous technologies as potentially damaging to free trade and competition. In contrast the European Union has responded by seeking to align China's indigenous ICT innovation policies with the European Research Area. However the globalisation of innovation signalled by these developments, based upon complex matrices of Intellectual Property, innovative capability and market knowledge from a wide array of industrial and research players across the world, calls into question simplistic established conceptions of 'indigenous' technologies. These developments thus raise a number of issues – which are explored in relation to various examples of ICT standardisation and innovation.

Introduction

China's economy outstripped Germany in 2009 and Japan in 2010, to become the world's second largest economy (IMF 2010). This extraordinary rate of sustained economic growth over the last 30 years of economic reform has rested primarily upon China's manufacturing rather than innovation capabilities (Shen 1999). At the same time China's accession to the World Trade Organisation (WTO) has brought requirements for Chinese firms to pay licensing fees for foreign-owned intellectual property, fees which were seen as excessive given the slim margins of many Chinese producers (Fomin et al. 2011) in a context in which intellectual property had previously been seen as a public good in China's socialist culture. The concern to avoid paying licensing fees to foreign IP holders seems to have been a major factor

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underpinning recent attempts by Public Sector Research (PSR) institutes in China to develop 'indigenous' technologies around Chinese standards for emerging Information and Communication Technologies (ICTs) and to promulgate these through international Standards Developing Bodies (SDBs).[i]

These developments throw up a number of issues. Foremost perhaps are questions about whether China's new standardisation and innovation strategy will be effective? Although China is making increasing investments in PSR, private research and development has historically been weak and poorly linked to PSR (Shen 1999). China has little experience in exploiting its growing science and engineering strengths by bringing successful innovations to the market.

What are the prospects and likely outcomes of these standardisation initiatives? And how should developed countries (and emerging economies for that matter) respond?

Goals of special edition

This special edition of *Technology Analysis and Strategic Management (TASM)* on *China and Global ICT standardisation and innovation*, has a particular empirical focus upon these developments and their implications for business strategy and public policy in China and in the West.

It also raises various analytical issues, notably regarding what kinds of framework are needed for an effective understanding of standardisation and innovation?

The traditional portrayal of standardisation within formal Standard Development Organisations as a neutral, technical matter has ceded to a view that standardisation is a vehicle for ensuring competitiveness and promoting exploitation of public sector research and innovation.[ii] However, as the cases in this special edition amply demonstrate, the relationship between standardisation and innovation is extremely complex, and varies between cases.

Standards are widely seen as important, but are not adequately understood by mainstream disciplinary accounts – as represented, for example by engineering, technology policy and management literatures. Instead the papers presented here offer a cross-disciplinary approach revolving around the intentionally interdisciplinary traditions of science and technology studies/innovation studies, and also drawing upon diverse traditions including economics, management, policy/governance and law as well as understanding of technologies involved. This work revolves around a small but growing body of scholars undertaking empirically detailed and theoretically informed research into standardisation. However their insights have mainly been presented in specialist fora,[iii] and have made only limited inroads into technology and innovation management and policy circles. We hope that this special edition can contribute to a wider appreciation and more sophisticated analyses of standardisation within discussion of ICT innovation.

The other research challenge facing this special edition concerns how to address the position of China in an increasingly globalised economy. Though China's increasing economic influence, in particular, has attracted much attention, the Chinese economy

and innovation systems are still not well understood, let alone her distinctive wider social and political context.

China presents particular challenges for Western researchers wishing to undertake detailed empirical analysis. As well as the sheer size of China and the obvious language and cultural barriers for foreigners, there are particular issues (which arise in the papers published here) in gaining access to political decision making processes in the Chinese setting. Views of China from the outside often differ sharply from the perceptions of Chinese participants. Most of the papers here benefit from collaborative study involving Chinese and non-Chinese partners, allowing better empirical access to developments within China to be combined with international comparative insights and access to the global 'state of the art' of innovation and standards research.[iv]

The international trade impact of China's standardisation and innovation policies

In this context it is perhaps unsurprising that these developments have prompted critical international scrutiny. Fears that (mandated) Chinese standards would constitute a barrier to for foreign suppliers wanting to enter the Chinese market prompted complaints, notably from the USA, of Chinese 'Techno-nationalism' (Suttmeier and Yao 2004). In contrast the European Union has sought to support the development of Chinese standardisation processes and align them with European and international processes.

In his paper on *The Role of Technical Standards for Trade between China and the European Union*, Axel Mangelsdorf presents an economic analysis of the role of technical standards in bilateral trade relationship between the European Union (EU) and China. In general, standards are seen by economists as a catalyst for trade, for example by reducing 'information asymmetries' and thus transaction costs for economic actors. Mangelsdorf's detailed examination of correlations between imports and exports and the stock of Chinese and European standards reveals a complex and uneven picture. He concludes that purely national Chinese standards may serve as barriers to trade (and here Suttmeier and Yao [2004] have noted that linguistic and other barriers may impede the access of Western firms to local Chinese standards and to the standards development process). Chinese international standards in contrast have positive effects on European exports. Similarly European standards and European standards aligned with international standards have a positive impact on both exports and imports.

Mangelsdorf's economic treatment focuses on the contribution of standards to improving transparency of markets, opening up access, and thus enhancing their efficiency with imputed benefits for competition and growth. However standards not only affect market efficiency - they help to constitute markets (and much analysis has focussed on processes of lock-in that may surround the emergence of *de facto*, or market standards – for example Microsoft's dominance over operating systems for personal computers) can be used to regulate markets. The standards we are exploring here are *interoperability standards* – which describe how different components of ICT systems work together (e.g. hardware and software). Crucially they are also *anticipatory standards* which describe the operation (and interoperation of parts of)

future ICT systems that are not yet in operation (Cargill 1995). Such anticipatory standards are seen by scholars from technology and innovation studies as one of the key mechanisms for coordinating the highly dynamic innovation processes underpinning today's complex ICT products, systems and infrastructures which involve increasingly large numbers of players dispersed across multiple organisations, sectors and regions.

Intellectual Property Rights

Fomin, Su and Gao (2011) explore how these standards may favour particular technological pathways which may be subject to Intellectual Property Rights (IPRs), allowing IPR holders to regulate the price and distribution of profits (e.g. through licensing fees) of technologies that implement the standard and associated IPR. Developing countries are confronted by the substantial IPR holdings and established standards of developed economies. Their paper - *Indigenous standard development in the presence of dominant international standards: the case of the AVS standard in China* - explores the challenges for China in developing and ensuring uptake of the Audio Video coding Standard (AVS) – an alternative means of encoding multimedia content to the entrenched suite of technologies based upon the MPEG4 codec. The AVS initiative was geared towards a low (1 Yuan) license fee for set-top boxes. AVS standard setting included developing patent pools and licensing rules from the outset. Fomin, Su and Gao (2011) argue that standard setting can be a market regulation tool. It can affect the IPR ecology. Though the adoption of AVS has been limited to date (particularly outside China), they suggest that the existence of AVS seems to have had effects on international competitors – including the decision by MPEG not to charge royalties on internet video using its H.264 codec.

Fomin, Su and Gao (2011) focus on the role of government and Public Sector Research (PSR) in attempts by a developing economy like China to enter a market and standardisation arena dominated by established Western IPR holders. This and other papers in this edition (notably Kwak, Lee and Fomin 2011, Stewart et al. 2011) show that concern to reduce license fees paid to foreign IPR holders was a common initial goal amongst players from developing economies – Korean as well as Chinese - which did not have an IPR portfolio based around established technologies and standards. However other factors were also important – including security and status issues (Stewart et al. 2011). And as time goes on, these dynamics may change as "latecomers" begin to accumulate IPR, for example, allowing them to negotiate license fees on a more equitable basis.

Governance: the formation and evolution of China's standardisation and innovation policies

Fomin, Su and Gao (2011) show that government intervention played a crucial role in standardisation and innovation initiatives through PSR investment and coordination of diverse public and private stakeholders. Their study of AVS, and its limited achievements to date, reminds us that the economic and innovation effects of standardisation are complex and uneven; shaped by particular alignments and misalignments of myriad players, their outcomes remain difficult to predict. This suggests the need to expand the focus of analysis from aggregate outcomes to more

detailed investigation of the relationship between standardisation and innovation and how these may vary between particular technologies and socio-economic settings.

The influence of the Chinese state is also a feature of many of the other standardisation initiatives presented here. Contemporary China seems to represent a distinctive pattern – differing from the traditions in Europe or the USA. Accelerating economic reform is driving a rapid shift towards a market system – albeit one that is closely managed by a state which is directly involved in economic life through State-Owned Enterprises and PSR investments as well as retaining exceptional authority over the behaviour of private firms.

Håkon Ursin Steen (2011) highlights important similarities, as well as differences, between the European Union and China in addressing the key standardisation governance challenge: how to reconcile the benefits of aligning around particular standards (e.g. reducing uncertainty for players, concertation of development effort, economising costs of implementing infrastructures) versus the advantage of allowing private players flexibility in choice of standards offering more competition and retaining openness to newer and better standards and technologies? In his paper: *Limits to the regulatory state in the rule-making of digital convergence: a case study of mobile TV standards governance in the European Union and China,* Steen observes a shift in standardisation policy (and technology policy interventions more generally) away from direct governmental control, towards the *regulatory state* – an "arm's length" approach where public agencies (e.g. the European Telecommunications Standards Institute [ETSI] or the Standards Administration of China [SAC]) set the rules for governance processes whose outcomes arise from interactions between multiple public and private actors.

Effective governance of innovation in the field of mobile broadcasting presents particular challenges as 'digital convergence' has attracted competing initiatives from the formerly separate areas of telecommunications and broadcasting, shaped by their different histories and industrial alignments around differing technical approaches. Steen (*idem*) poses the question of whether the regulatory state will have the authority and ability to align standards where (competing) blocks of actors control technologies underpinning (competing) standards. In Europe, four competing standards were proposed and three were initially deployed. The emergence of these multiple centres of innovation reflected diverging priorities – e.g. telecommunication companies generally favoured approaches with integrated digital rights management capabilities, unlike broadcasters - and histories. Digital Audio Broadcasting offered broadcasters an alternative pathway to Mobile TV. In China Steen shows how three candidate national standards that were being considered by SAC were blocked by the State Administration for Radio, Film and Television (SARFT – a small but powerful Ministry which reports to the Propaganda Department of the Chinese Communist Party and exercises control over the content available on Chinese media), which had the right to test and approve candidate national standards. SARFT instead proposed, and eventually deployed, its own standard – CMMB.

This case provides clear evidence that the Chinese state is not monolithic – as demonstrated by the competition between SARFT, responsible for controlling content, and the Ministry of Industry and Information Technology (MIIT) responsible

for telecoms and internet services and concerned with their impact on economic growth.

James Stewart, Xiaobai Shen, Chengwei Wang and Ian Graham (2011) explore these issues in the long-term development and implementation of an even larger ICT infrastructure – Third Generation (3G) telephony and its extension into Fourth Generation mobile broadband and beyond. Their paper - *From 3G to 4G : standards and the development of mobile broadband in China* - examines the evolving standardisation policies of the Chinese government since 1998 through a study of the development and implementation of the "Chinese" TD-SCDMA standard as a competitor to the already established "US" (CDMA2000) and "European" (GSM) standards. TD-SCDMA (Time Division Synchronous Code Division Multiple Access or TD) uses slightly different radio access techniques than established Frequency Division technologies. When TD was not taken up in the West, its proponents, notably Siemens, were happy to collaborate with Chinese players, notably Datang. Initially met with scepticism, TD only gradually secured support from government bodies and Chinese firms. It was eventually taken up as an exemplar of Chinese efforts to create indigenous innovation capacity around standards in which China owns IPR.[v] Stewart et al. (*idem.*) emphasise the series of gradual alignments involved in this history, "the outcome of which… was by no means predetermined".

Implementation of the TD standard was, in contrast, decisively shaped by the intervention of the Chinese government, which forced the dominant mobile operator *China Mobile* to bring TD to the market – despite its public reluctance – as part of a major restructuring of mobile services involving unprecedented implementation of the 'Chinese standard' and its two entrenched Western competitors. This very visible commitment to 'technology neutrality' between 3G telecommunications standards provided a pragmatic resolution to trade pressures from the USA and also set up a competitive mobile market in China.

Jooyoung Kwak, Heejin Lee and Vladislav Fomin (2011) also highlight the key role played by governments in developing economies to use standardisation to bring indigenous technologies to global markets. Their paper - G*overnment coordination of conflicting interests in standardisation: Case studies of indigenous ICT standards in China and South Korea* – addresses the challenging task of analysing 5 cases:
in China: AVS and TD-SCDMA and the earlier WAPI (Wireless LAN Authentication and Privacy Initiative) case;
in South Korea WIPI (Wireless Internet Platform for Interoperability) and WiBro (Wireless Broadband).

Coordination challenges vary between different stages of standardisation: Initiation, Recognition, Commercialisation. Moreover, coordination mechanisms and the ability of the government to cope with globalisation pressures vary between countries.

Kwak, Lee and Fomin (2011) conclude that the factor most likely to thwart international standardisation efforts by latecomer economies is coordination failure in aligning interests of foreign players with those of domestic players. Governments play a crucial role developing good relations with foreign players in initiating standardisation, dealing with players influenced by alternative standards, as well as

dealing with the international power politics that arise where there are strong conflicts between national and international players.

Government success in aligning national players in Korea (and the Chinese WAPI case) was at the expense of dealing with conflicting interests of foreign partners. The Chinese government, in contrast, had learnt from the failure of the WAPI initiative the importance of involving external players. Stewart et al. (2011) also point to (inferred) policy learning by the Chinese government.

Both these papers (and likewise Fomin et al. 2011 and Steen 2011) draw attention to the distinctive features of the Chinese economy, not least the sheer size of its domestic market, which makes it easier to attract foreign players to collaborate in building technical capabilities.

Stewart et al. (2011) and Stern (2011) draw attention to differences between the economic blocks of China and Europe – a collection of nation states – only loosely coordinated by the European Union. The provision of European telecommunications services and infrastructure is fragmented between many countries – allowing less opportunity for the kinds of large-scale infrastructure-building initiative that has proved so successful in China. Moreover the Chinese state seems willing to make major infrastructural investments (and the TD-SCDMA case, far reaching industrial reorganisation) needed to bring new infrastructural technologies to the market.

Globalisation – does it make sense to talk of indigenous technology?

The objective of developing indigenous innovation capability was a shared policy goal underpinning all these cases (Fomin et al. 2011, Kwak, Lee and Fomin 2011, Steen 2011, Stewart et al. 2011), linked to a desire to reduce license fees paid to foreign IPR holders. However the detailed technology histories presented here call into question traditional conceptions of indigenous technology. Thus the mobile broadband study (Stewart et al. 2011) highlighted the important contribution of Siemens and many other global multinationals in the inception and development of the 3G TD-SCDMA technology and standard. In the mobile broadcasting study the Korean T-DMB standard was adapted by the Korean Electronics and Telecommunications Research Institute from the outcomes of a Bosch in-house research project (Steen 2011). Stewart et al. (2011) draw attention to the intricate interplay of Chinese and Western technologies and players in 3G. The 3G market, like the other advanced ICTs discussed here, are large-scale modularised infrastructures. They are complex assemblages of enormous arrays of component technologies/techniques and knowledge drawn from an increasingly wide array of players from different firms and countries (and they note the growing role and global presence of MultiNational Enterprises). Their study highlights the limitations of national strategies in globalised innovation processes. Kwak, Lee and Fomin (2011) likewise note that "While private firms' technology strategies are increasingly internationalised, government technology policies have remained overwhelmingly national."

Critical accounts, portraying Chinese indigenous innovation and standardisation initiatives as traditional *techno-nationalism* focussed upon imputed goals of

protecting national markets and the barriers thereby created for globalisation of technology development and its benefits for the pace of innovation and competitiveness. Yamada (2000) and Suttmeier & Yao (2004) have called into question this dichotomy between nationalism and globalism. Governments must reconcile contradictory pressures towards competition and cooperation – and complex exigencies and trade-offs result in multiple patterns they characterise as *neo-techno-nationalism*. These formulations remain rather loosely defined however. The papers in this collection provide a more detailed account of the complex interplay between technology policy and innovation. Kwak, Lee and Fomin (2011) suggest that we should see standardisation as a form of "outbound globalisation" aimed at establishing a favourable technology regime for domestic industries in global markets.

Long Term Evolution

Static analyses – as exemplified by the conceptions of techno-nationalism as a 'zero-sum game' - may be unhelpful. The developments described here are part of the long-term evolution of increasingly interconnected national and globalised innovation systems. Short-term analyses may fail to grasp their long-term significance. Thus Stewart et al. (2011) remind us that China's efforts to develop innovation and standardisation capabilities represent a multi-level game. The most important outcome of the TD-SCDMA case may not be the 'indigenous technology' but the institutional learning that has accompanied it. China has been 'learning by doing' through practical involvement in developing its own standardisation systems (and IPR regimes such as the AVS patent pool). Today we find an increasing number of Chinese players on international SDBs – and with growing experience and confidence, their involvement in more influential positions. China's increasing understanding of and engagement in international standardisation processes, coupled with the growth of globally competitive Chinese MNEs like Huawei and ZTE, has enabled Chinese institutions and firms to become global players in mobile telecommunications technologies. Through its involvement in the extension of 3G technologies and standards through the 3GPP consortium Long-Term Evolution project, China has become part of the global community developing standards and technologies for the next, fourth, generation of mobile broadband infrastructures and services.

These are unfolding processes – and as Kwak, Lee and Fomin (2011) point out, we are still at an early stage of many of these initiatives. The long-term prospects for AVS in particular have not been resolved (Fomin et al. 2011).

Moreover the global innovation and standardisation system is changing, partly in response to the involvement of Chinese players. These developments are changing the ecology of standardisation and, with innovations such as patent pooling and low fee IPR environments (Fomin et al. 2011), its attendant knowledge economy. The fourth generation of mobile broadband technologies currently being developed through the 3GPP consortium draw on novel air interfaces and will not be fragmented between incompatible regional standards (Stewart et al. 2011). This opens up a new form of competition – in place of the past history of battles between competing standards to dominate the global mobile market we now see firms competing to maximise their share of the global IP pool.

The diverse cases presented here are all form part of the emerging generations of converged information infrastructure. They reveal a complex pattern with diverse technical and economic outcomes. The contribution of standardisation to innovation is extremely variable - shaped by particularities of the technology in question and its markets; global industrial divisions of labour and of knowledge; governance arrangements and other contingencies. These factors bear directly upon the number and diversity of players involved, and thus difficulties of alignment, and the cost of harmonisation (which may be very different where standards are implemented in software than when they are embedded in the design of physical components) and of implementing a standard. Thus, as the papers in this special edition reveal, there are marked differences in the challenges and outcomes of standardisation initiatives between a generic infrastructure (such as mobile broadband), a dedicated service like mobile broadcast and a software component technology like AVS.

We hope that this special edition will throw light on the contribution of ICT interoperability standards to innovation and developing countries and beyond. We must also consider limitations surrounding the research reported here. As several of our authors have commented, we are still at the early stages of many of these development, and would benefit from longer-term study. There are obvious advantages in extending the geographical scope of investigation, for example to include other developing economies – and perhaps more importantly to include transnational and transregional enquiry. The "Chinese" (and "Korean") developments reported here emerged from a nexus of public and private actors including not only US and European actors but also networks of other East Asian players (and our case-study based papers - following the development and uptake trajectories of particular artefacts - provided an effective way of tracking these various institutional and geographic moves).

Finally we must also consider the marked bias in the cases reported here towards ICT infrastructural innovation. This primarily reflects the Chinese (and Korean) government's choice of flagship development initiatives (also mirrored in the concerns of Western governments and academics). We have noted the key role of the state in coordinating and aligning national and international players – culminating in large-scale infrastructure building. Here the Chinese state showed its willingness to develop a long term perspective, to review and learn from experiences and to make major investments. However, as the value chain tilts from the ICT infrastructure towards the information and cultural products that run upon it, attention needs to shift towards innovation in on-line products and services. Standardisation and interoperability challenges are very different here and have not revolved around international SDBs (Hanseth & Nielsen 2007). This raises questions about whether the standardisation and arrangements that have helped China become a global player in ICT infrastructures will be adequate for the emerging on-line service economy (da Silva 2010).

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[i] The WTO Agreement on Technical Barriers to Trade requires members to avoid local standards that might constitute unnecessary obstacles to trade and use international standards wherever possible (Mangelsdorf 2011).

[ii] For example a recent Communication from the European Commission, COM(2009) 116, *A strategy for ICT R&D and Innovation in Europe: Raising the Game,* (SEC{2009}289) Brussels 13.3.2009, states that "Ensuring **interoperability** and the emergence of **standards** is essential to foster innovation uptake on a large scale within the EU" (2009:9 emphases in original).

[iii] For example associated with the *European Academy for Standardization* (EURAS), *the Journal of IT Standards Research*, *International Conference on Standardization and Innovation in Information Technology.*

[iv] Many of these papers emerged from the *China EU Standards Research Partnership*, part funded under the European Union under Grant agreement no. 217457. See http://www.china-eu-standards.org

^v Despite the fact, as Yan (2007) observes, that Chinese players are estimated to hold only around 7% of the core patented technology for TD.