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RESEARCH ARTICLE

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State-of-the-Art Research on Technology Innovation Management in China

Abstract The two latest Five-Year Plans of China call for an increasing focus of the whole country on technology-based innovation. Moreover, China's ambition to become an innovation-oriented nation has attracted widespread international interest and academic studies in technology and innovation management. However by now, there is still not a rigorous amount of the research in this field as regards to China. This paper reports a comprehensive review of the research published between 2002 and 2011 in twelve top technology and innovation management international journals. Overall, a sample of 241 relevant articles in 780 issues is used as the basis for the study. The result is a map of the main research topics, their influence, and the availability of tested empirical data, which traces a state-of-the-art research on technology innovation management in China. Discussion on the map draws avenues for further research and insights for both researchers and policy makers on why, where and how to advance knowledge in the field, with a particular focus on implications for developing cooperation at the enterprise level.

Keywords technological innovation, technology innovation management, China

1 Introduction

In the National Outlines for Medium- and Long-Term Science and Technology Development (2006–2020), China's policymakers set the objective for the country to become an innovation-oriented nation by 2020, increasing Research & Development (R&D) investments, strengthening (technology-driven) innovative

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domestic capacity and relying on enterprises as the key driving forces of the innovation process (Schwaag Serger and Breidne, 2007). The latest Eleventh and Twelfth Five-Year Plans re-affirm these objectives and highlight the role of technology as the key driver in China's transformation of its growth model from low value-added manufacturing to a new one increasingly based on domestic, business sector-led innovation.

With the rise of China as the factory of the world and this further step towards becoming a world class innovation centre or "knowledge factory" (Schwaag Serger, 2006), the longstanding national debate on the relevance of technological innovation for the country's progress and competitiveness assumed international relevance. As a matter of fact, since the dawn of the reform and opening policy and back to the founding of the PRC in 1949, technological innovation has always played a prominent role in Chinese economic development. However, it is especially since the second half of the 1980s with the reforms of the science & technology system that China's commitment to expanding economically through reliance on technological development was poised to alter the global economy (Jin and Porter, 1988). Though China was not able to become a significant international competitor in technology-based products by the year 2000, its progress has nevertheless been steady and remarkable, especially in mobilizing resources for Science and Technology (S&T) at an unprecedented scale and speed, leveraging on foreign direct investment to increase its technology and knowledge pool and creating a first wave of innovative global Chinese firms (OECD, 2008). As a matter of fact, China is already ahead of the other efficiency-driven economies according to the World Economic Forum Global Competitiveness Report 2012–2013 data (as plotted in the Fig. 1 below). However, according to this report, there are still a number of gaps among the ones already identified by OECD (2008) and Jin and Porter twenty years earlier that need to be filled, especially with respect to becoming an innovation-driven economy. More specifically, starting from the top of Fig. 1 in a clockwise order, they are the need to address the shortage of specialized human resources needed at various stages of the innovation process, to fill a widening east/west-city/countryside gaps, to increase the financing of R&D, to improve technology-based entrepreneurship, Intellectual Property Rights (IPR) enforcement and corporate governance, to enhance the innovation capabilities and performance of the

Chinese business sector, to reinforce the linkages within the National Innovation Systems (NIS), and to encourage more basic research and increase spending on "soft factors" and non-S&T skills.

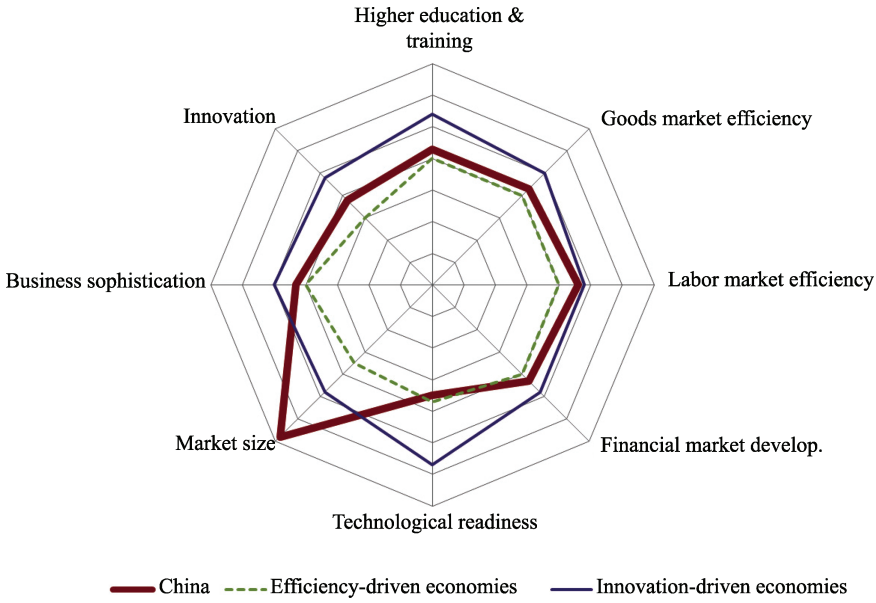

Fig. 1 China towards an Innovation-Driven Economy—Current Situation
Source: Author's elaboration of World Economic Forum 2012–2013 data.

Business sophistication and innovation in particular are the factors that characterize an economy in the innovation-driven stage, and the ones to which a country with the ambitions of China should pay attention to. In a nutshell, this means, according to the World Economic Forum, to compete on higher efficiency in the production of goods and services as well as on branding, marketing and the production of unique and sophisticated products through technological innovation. By technological innovation, referring to OECD/EUROSTAT (1997) and OECD (2005), it is meant implemented (that is, either already introduced in the market or used within a production process) technologically product and process innovation.

Following these considerations, the capability to manage technology and innovation has become a key issue in making China an innovation-oriented economy. The topics related to the management of technology and innovation

converge in an interdisciplinary field that, according to the 1987 workshop report of the US National Research Council, links engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization. Usually referred to as management of technology (MOT), management of technology and innovation (MOTI) or technology innovation management (TIM), it is a field that studies issues such as innovation management, research and development, innovation diffusion, the development, implementation and use of technologies and especially information technologies within organizations, technology foresight, product development strategies, innovation and technology policies, among others.[1]

The relevance of technology innovation management for China was already clearly stated in literature fifteen years ago, when Xu et al. (1998), in an analysis of the evolutionary process of technological innovation and technology management in Chinese enterprises, stressed the importance of innovation strategy and firm innovation system as the pillars to build indigenous technological innovation capabilities and suggested a number of topics for the development of such a kind research in China.

However, notwithstanding the earlier relevance attached to technology and innovation (Jin and Porter, 1988) and its management (Xu et al., 1998) for China's development, the recent international interest aroused in policy-making institutions and the proliferation of academic studies on the topic, a comprehensive review of technology and innovation management research in China is yet to be undertaken. Therefore, though there is some basic sense about what are the main issues that this research deals with, there is still not a clear and rigorous account on what are the topics that have been and are being investigated, what is their relevance and, more prominently, what are the general implications of the research done, as well as on what research needs to be done and how.

A very preliminary attempt to answer this question was presented in the course of a meeting organized in 2010 at the EU Delegation to China and Mongolia to explore the topic of innovation in China. This study relies on the initial results of this first exploration to undertake a comprehensive and rigorous literature review

[1] A more detailed list can be found at the website of the Academy of Management TIM Division (http://www.aomtim.org).

able to provide researchers and policy makers with reflections on why, where and how to direct research efforts, especially with the final purpose to strengthen scientific and industrial cooperation.

In this endeavor, the work relies on a review of 241 relevant articles published between 2002 and 2011 on twelve top journals in the technology innovation management field to trace a state-of-the-art research that identifies the main research topics. It provides a sample of related studies for guidance and discussion on potential avenues for further research, as well as implications for researchers and policy makers. The methodology followed is detailed next in Section 2. Then, Section 3 will provide a map of the main research topics, their influence, and the availability of tested empirical data. Lastly, Section 4 will discuss main findings and will draw possible avenues for further research as well as insights for researchers and policy makers.

2 Methodology

The papers in our sample were published between 2002 and 2011 in twelve top technology innovation management journals, listed in Table 1 below. The journal selection was based on their inclusion in the Science and/or Social Science Citation Index (see Linton, 2011). Of course these journals are not the only venue for relevant research.

Table 1 List of ISI Citation Indexed Technology Innovation Management Specialty Journals (in descending order of impact factor in 2011)

Journals	Impact Factor 2011
Technovation	5.608
Research Policy	3.783
R&D Management	3.287
Journal of Product Innovation Management	3.062
Technological Forecasting & Social Change	2.520
Journal of Technology Transfer	2.507
Journal of Engineering and Technology Management	2.109
IEEE Transactions on Engineering Management	1.709
Research Technology Management	1.176
Industry and Innovation	1.032
Technological Analysis and Strategic Management	0.958
International Journal of Technology Management	0.885

Relevant research on the topics of technology and innovation in China has also been published in general management journals and a number of journals with an Asia-Pacific and China focus. Moreover, there are also a number of technology innovation management journals, also with a specific China focus, which are not listed in the SCI/SSCI Index. Not to mention relevant conferences proceedings and books, which may offer a more fresh or articulated view of research. As a matter of fact, a further check on academic databases that will be discussed later on, revealed 281 other relevant papers over the same time frame. However, besides the obvious resource constraints to undertake such a huge review and the objective to lead a review in the specific field of technology and innovation management, in which the sources used are legitimately recognized as the most authoritative sources, there were objective reasons to limit the review to the twelve top journals in the field. The first one is methodological. An impact or similar factor was needed to temper the limitations of a simple frequency counts as regards to the effective relevance of the topic in the field. An example will be given later on in this section. This makes for the exclusion of non-indexed works, being technology and innovation management journals, conference proceedings or books. The second one is practical. As a matter of fact, the preliminary explorations mentioned in the introduction were based upon the sources used for this study as well as top general management journals, indexed and non-indexed China/Asia-based general management and TIM-specific journals. In addition, top general management and specific recent international conferences were browsed. The results obtained for that preliminary attempt were not significantly different from the topics studied within TIM reference journals only or other venues. The only difference was in the method followed, which was rather qualitative. This makes for the exclusion of general management and Asia/China-specific indexed journals.

The choice of the interval was dictated upstream, by the symbolic relevance of the year 2002, which marks the first year after the entry of China in the WTO. According to some authors (Xie and White, 2006) this event has brought a fundamental change of China's technology and innovation policies approach, towards what they called the "creative stage," on the basis of a focus on creating global competitors and on the internal development of new, proprietary technologies and innovation capabilities. Downstream, the choice was constrained by the

latest release of impact factors available at the time of the study, undertaken between June and October 2012. In addition, in 2011 the Twelfth Five-Year Plan came in force, making this coincidence a good time to create a balance of research being undertaken on the topic. As a result, among the 273 relevant papers identified, the 32 papers published in 2012 up to the time the papers collection finished (October 2012) were excluded from the analysis, making the final sample amount to 241 papers, though some of them have been later included in the integrative framework realized to draw implications.

Because of the marked differences in technology and innovation systems and practices among Chinese Mainland, Hong Kong and Taiwan firms (see in this last regard Kroll and Schiller, 2012), the sample considers papers concerning exclusively Chinese mainland and Chinese firms. Therefore all papers concerning technology and innovation in Hong Kong and Taiwan, as well as Hong Kong and Taiwan enterprises operating in mainland, were not considered. Obviously, no paper about foreign-invested enterprises has been included in the sample.

Papers were collected by searching all issues of each journal listed in Table 1 during the 2002–2011 period. Overall 780 issues have been browsed. The identification of relevant papers was made first by selecting those papers where the words "Innovation" and/or "China" appeared the title, or one in the title and one in the abstract, or one in the abstract and one in the keywords. Moreover, those papers with Chinese or seemingly Chinese authors' names were selected to ensure that no relevant study would be excluded from the analysis. Then the reading of abstracts made for the final decision about the relevance of the paper for the objectives of the study and the import of its citation and abstract in a purposefully developed ENDNOTE® database. Finally, a further check was performed to ensure a full coverage of relevant works for the analysis to be made. The full ABI-INFORM database was interrogated using the words "Innovation" and "China" in the title, "Innovation" in the title and "China" in the abstract, "Innovation" in the title and "China" in the keywords and "Innovation" in the abstract and "China" in the keywords. This check led to the retrieval of 339 more relevant papers over the same time frame, after having eliminated duplications and non-relevant papers. Of these 339 papers, 212 were published in journals related to the business, economics, innovation and entrepreneurship domain, 69 published in journals pertaining to the technology

innovation and management domain but not in the Science and Social Science Citation Index, and 58 published in the journals considered for this study. Within these latter 8 articles that were overlooked in the full issue browsing were identified and added to the study database. The sample distribution by journal and year is reported in Table 2 below. As can be observed in Table 2, there are "peak years" in some reviews, most of which corresponding to the publication of special issues on China.

Table 2 Paper Distribution by Journal and Year

Journals	02	03	04	05	06	07	08	09	10	11
Technovation	2	3	2	3	3	–	3	1	6	4
Research Policy	–	3	1	2	2	5	5	4	2	6
R&D Management	1	–	8	–	1	1	1	1	1	2
J. of Product Innovation Management	–	1	1	–	1	–	3	1	2	1
Technological Forecasting & Social Change	–	–	2	1	3	6	1	8	3	7
J. of Technology Transfer	–	–	1	–	–	8	1	–	1	–
J. of Engineering and Technology Management	1	–	1	–	–	–	1	–	–	2
IEEE Transactions on Engineering Management	–	–	1	1	–	–	5	–	5	3
Research Technology Management	1	1	1	2	–	2	3	2	3	1
Industry and Innovation	–	–	1	–	–	–	–	7	–	1
Technological Analysis and Strategic Management	–	–	–	8	–	–	2	3	1	12
International J. of Technology Management	4	–	2	4	7	2	6	3	12	5

Figures 1 and 2 below synthesize, respectively, the overall evolution in terms of number of papers in the period considered and compare the journals surveyed on total number of relevant papers published.

As can be observed from these figures, there has been a steady evolution of the number of papers published on the topic of Technology Innovation Management in Chinese Mainland. This steady evolution was led by some journals, in particular the International Journal of Technology Management and Technology Forecasting and Social Change, which alone account for a third of all the papers published in 2009–2012, followed by Research Policy and Technovation, which together with the previous two, account for more than a half of all the paper published over the whole period considered.

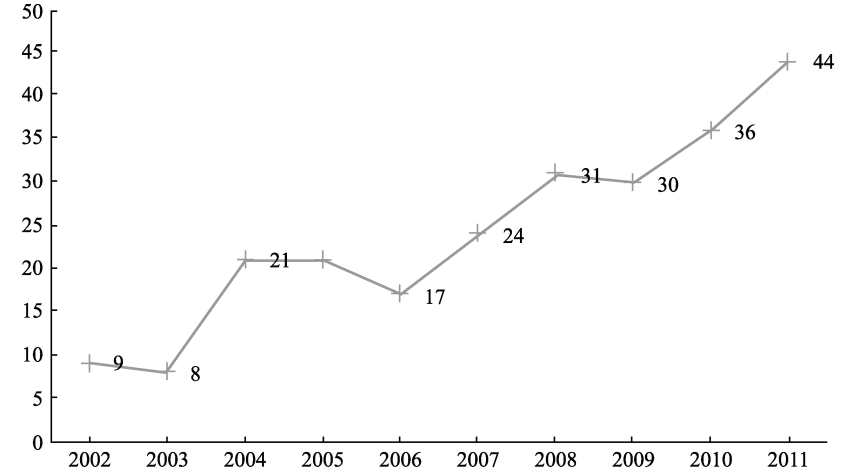

Fig. 2 Paper Evolution by Year

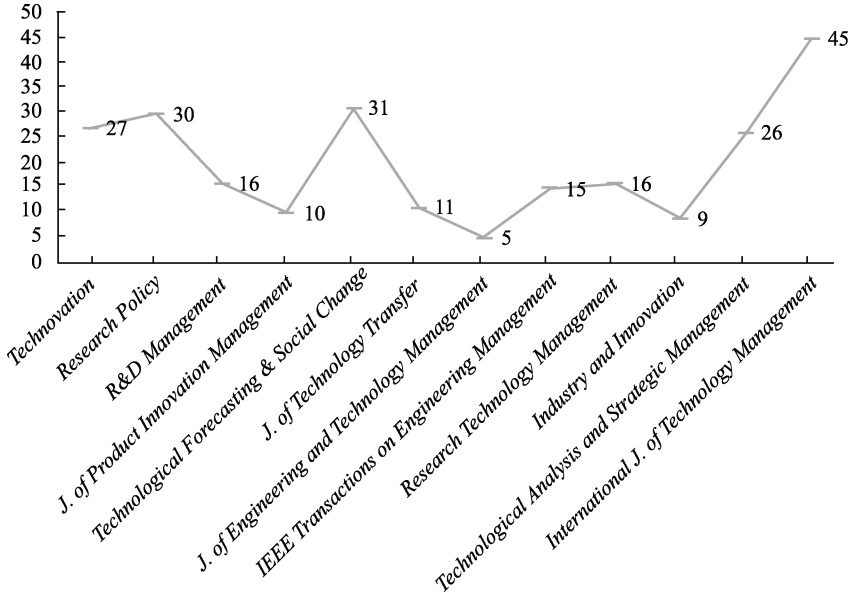

Fig. 3 Journal Comparison

Then to create such a rich body of knowledge that is easily accessible and to balance the need to provide a comprehensive picture with the possibility to draw possible research directions for researchers and meaningful insights for policy makers, the analysis was geared towards the creation of a graphical representation of the domain. This graphical representation took the form of a word cloud that

maps at once 1) the topics studied, 2) their influence, and 3) the availability of empirical data. This was ensured by collecting information about the frequency of occurrence of topics in the keywords field, the ten years impact factors and the theoretical versus the empirical nature of papers selected for each journal. The decision to count the frequency of keywords and how it was made is explained as follows. As for the impact factors, not all journals considered have been indexed in SCI and/or SSCI for ten years. In such cases, i.e., for *Industry and Innovation*, *Journal of Technology Transfer*, *Technology Analysis and Strategic Management*, *Journal of Engineering and Technology Management*, and *Technovation* missing information was integrated with impact factors retrieved from Scopus SNIP index. Impact factors, ten-year average impact factor and number of theoretical and empirical works are reported in Table 3. SNIP indexes are underlined.

The topic map was created using WORDLE, a freely available online tool at www.wordle.net, which generates word clouds upon the number of occurrences in the source text pasted directly on the web site. The map was developed following the steps reported below. First, records in the ENDNOTE® database were organized by journal and then by year of publication to be exported in two separated Word files, one comprises all the abstracts and the other all the keywords. Sample word clouds based just on number of occurrences were then generated for two journals (i.e., *Technovation and Research Policy*) and submitted to some colleagues asking which of them was/was felt to be a more informative representation of the topics of a research domain, without eliciting the source (i.e., abstracts or keywords). As expected, the ones made from the keywords file were perceived to be more informative, basically because it reported two-three-word sentences,such as “technology transfer” and “regional innovation system,” and meaningful single words such as “planning” or “marketing,” rather than ensembles of generic words such as “business,” “knowledge” or “technology.” Then the entire keywords file was transformed to suit the requirement of WORDLE syntax, i.e. hooking together two or more keywords with a “~” sign, and intermediate maps for each of the twelve journals to get keywords frequencies counts were generated. This intermediate step was necessary to include information about the influence and the availability of empirical data for each topic in the final representation. This information was obtained by: 1) multiplying the frequencies of the keywords by the 10-years average impact factors, and the ratio of

Table 3 TIM Journals 2002–2010 Impact Factors and Nature of Works

	2011 I.F.	**2010 I.F.**	**2009 I.F.**	**2008 I.F.**	**2007 I.F.**	**2006 I.F.**	**2005 I.F.**	**2004 I.F.**	**2003 I.F.**	**2002 I.F.**	**02–11 I.F. AVG**	Theor. Papers	Emp. Papers
Technovation	3.287	2.993	2.466	1.907	1.004	0.582	0.913	0.371	0.482	0.418	**1.442**	7	20
Research Policy	2.52	2.508	2.261	2.655	2.211	1.328	1.835	1.536	1.404	0.163	**1.842**	7	23
R&D Management	2.507	1.58	0.928	2.043	0.597	0.443	0.506	0.479	0.392	0.536	**1.001**	5	11
Journal of Product Innovation Management	2.109	2.079	1.522	2.65	1.585	1.588	0.917	0.885	1.623	1.25	**1.621**	0	10
Technological Forecasting & Social Change	1.709	2.034	1.776	1.761	0.889	0.798	0.811	0.461	0.512	0.356	**1.111**	20	11
Journal of Technology Transfer	1.176	1.014	0.875	0.983	1.38	0.982	0.915	0.687	0.677	0.55	**0.924**	6	5
Journal of Engineering and Technology Management	1.032	0.737	1.243	0.923	0.98	2.107	0.918	0.899	1.708	0.842	**1.139**	4	1
IEEE Transactions on Engineering Management	0.958	1.344	1.248	1.156	0.962	0.825	0.864	0.573	0.681	0.493	**0.910**	9	6
Research Technology Management	0.885	0.754	0.507	0.676	0.476	0.606	0.385	0.677	0.508	0.494	**0.597**	15	1
Industry and Innovation	0.75	1.831	1.355	1.853	1.458	1.18	0.816	0.809	0.782	0.837	**1.167**	5	4
Technological Analysis & Strategic Management	0.701	1.04	0.929	0.735	0.638	0.123	0.446	0.718	0.842	0.829	**0.700**	10	16
International Journal of technology Management	0.516	0.519	0.419	0.526	0.356	0.233	0.24	0.284	0.266	0.194	**0.355**	20	25

empirical articles on total articles of the journals in which they appeared and, 2) adding the values associated to each keyword with this formula:

$$\sum_{N=i}^{j}\left(\text{Frequency of } K_i \ * \ 10 \text{ years Journal}_j \text{ Average Impact Factor} \ * \ \frac{\text{Empirical Articles}_j}{\text{Total Articles}_j}\right)$$

where "K_i" stands for "i^{th}" keyword found and "j" for the journal in which the "i^{th}" keyword has appeared. Taking "technology commercialization" as an illustrative example, Table 4 below depicts how adjusted weights were calculated.

Table 4 Calculation of the Adjusted Weight for Each Keyword (illustrative example)

Frequency of K_i	10-years-average I.F.	Empirical to total articles ratio	Adjusted Weight K_i	
5	0,91	0,40	1,82	$\sum K_i$ adjusted weights (technology comm. adjusted weight)
7	1,62	1,00	11,34	
1	0,92	0,45	0,41	
1	1,00	0,69	0,69	
3	1,84	0,77	4,25	
5	0,70	0,62	2,17	
1	1,44	0,75	1,08	**21,76**

This was the final step of a progressive synthesis of all the 865 keywords retrieved (this figure includes duplicates).

In brief, for each journal, first the keywords with more than one occurrence were retained. Then for each journal and then again across journals, the same keywords were searched and if found on the same journal, were added to respective categories (for example "Research and Development" to "R&D"), otherwise added to the list of keywords with more than one occurrence in the other journals (continuing the example "R&D" or equivalent concepts, this was queued to the journal's keywords with more than one occurrence in). Once this work finished, remaining keywords were aggregated by similar topics in newly created categories, for example "Institutions, Policies & Government" and "Collaboration and Clustering," which group respectively one-occurrence keywords such as "innovation policies," "state," etc., or "social capital," "networks," etc. In this way it was ensured that, though synthetic, the map did not overlook any of the relevant topics studied (see Table 5 in the next section in which keywords

adjusted weights and frequencies are reported in detail).

Finally, the excel file with the keywords and synthetic values was ordered alphabetically and re-exported in word, adjusted to the required WORDLE synthesis (separating keywords and categories from the value obtained as explained above by a ":" sign) and the map generated (see Fig. 4 in the next section).

3 Technology Innovation Management in China State-of-the-Art Research in a Glance

Fig. 4 below reports the state-of-the-art research over the past ten years in Technology and Innovation Management in China in terms of research topics, their relevance (measured as the aggregated impact factor of the journals in which they were published) and the degree of empiricism (approximated at the ratio of empirical to total papers of the journal in which each topic has appeared), synthesized in a glance with the dimension of each topic within the map.

Fig. 4 Technological Innovation Management Research in China: State-of-the-Art

For example, the dimension of "technology commercialization" has been obtained as the sum of the adjusted weights obtained by multiplying the frequency of occurrence of each keyword/group of keywords by the ten years average impact factor and the ratio of empirical to total papers of the review in which it/they have appeared (that is the value reported in the "adjusted weight"

column of Table 5). Therefore, the bigger a topic, the bigger is its relevance and the likeliness to find empirical evidence in the Chinese context.

Table 5 Technological Innovation Management Research in China: Topics & Ranking

Topics*	Adjusted Weight	Frequencies
Technology commercialisation	**21.76**	23
Industries	**17.89**	38
R&D	**17.23**	44
Collaboration & Clustering	**15.74**	34
Technologies	**15.51**	45
Intellectual Property Rights & Protection	**14.64**	21
Technology transfer/spill-overs	**14.31**	25
Comparative Studies	**13.62**	43
Technology Planning	**12.48**	34
Foreign Direct Investment (FDI)	**11.87**	26
Institutions, Policies & Government	**11.14**	32
Capabilities & Competitiveness	**10.13**	23
Innovation performance	**9.57**	10
New Product Development/Product Innovation	**9.39**	16
Performance	**9.37**	17
Productivity/efficiency	**8.97**	16
Organizational Incentives	**8.51**	6
Players	**8.45**	18
Entrepreneurship	**7.52**	8
Innovation Systems (National/Regional)	**7.41**	14
Catch-up/leapfrog	**7.12**	14
Knowledge transfer/spill-overs	**7.09**	14
Corporate Governance	**6.27**	8
Developing/Transitional Countries	**5.4**	13
Organizational behaviour	**4.68**	9
Globalization	**4.48**	11
NPD performance	**4.44**	6
Standards	**4.29**	10
Technological learning	**4.29**	6
Knowledge Management	**2.11**	10
Technological dynamism	**0.87**	3

* Keywords & Keywords group (indicated in *italic*).

As it can be seen in Table 5, this information is richer than a mere frequency count. Continuing with the example of "technology commercialization" and related topics, though it is not appearing as in many studies as respectively Technologies, R&D, Comparative Studies Industries, Collaboration & Clustering, Institutions, Policies and Government, F.D.I. and Technology Transfer and

Spillovers it has received more thorough attention and produced more empirical data than the others, of course as far as the impact factor and the availability of empirical data are believed to be measures of the overall relevance of a topic over the others. In this sense it is worth to notice that its adjusted weight is more than the double of the one of "capabilities & competitiveness" at parity of frequency. This is natural as the second topic is more central in strategic management studies than in technology innovation management ones.

However, it is also clear as with a mere frequency count the importance, continuing with the same example, that "capabilities & competitiveness" and related social network (i.e., "collaboration & clustering") and institution-based (i.e., "institutions, policies & governments") perspectives would have resulted overestimated within TIM in China. The next section will be dedicated to detailed discussion of most relevant topics and representative studies.

4 Main findings and Implications for Research and Practice

The highly differentiated nature of topics being explored is a characteristic of the Technology Innovation Management field, which by definition, relies on a multitude of theoretical perspectives: innovation management and management of technology first, but also strategic management, with the related social capital/networks and institution-based perspectives, entrepreneurship and organizational behavior. The keywords and the keywords groups in Table 5 highlight as research has been made on a number of internal and external factors, ranging from capabilities, processes and incentives to inter-organizational collaborations networks and the institutional environment, through industries, regional/national innovation systems and country levels.

Observed in further detail, it is evident as the most relevant and investigated topics focused on technology commercialization (which includes spin-offs, science & technology parks, science-industry linkages as well as processes related to the introduction of new products into the market) in a variety of industries (from high-tech ones such as Telecommunications, Computers and Software, to low-medium tech ones such as Automotive, Machinery and Agriculture) with a strong concentration on R&D, collaboration & clustering (which include research collaborations, interactive innovation and industrial

clusters) and technologies (covering all the nano-info-bio range and a variety of applications such as RFID, electric vehicles, renewable energies and pollution control). These topics are closely followed by Intellectual Property Rights and protection issues, technology transfer and spill-overs (which include technology diffusion). Most of the topics above relate to performance issues concerning innovation and new product development performance, overall performance and productivity/efficiency. Other relevant topics are the ones related to the tools, techniques and issues of technology planning and the impact of foreign direct investments and the institutional environment.

On the other hand, among numerous topics, hardly any of which have been published, it can be seen as topics such as knowledge management, organizational behavior, standards and technological learning have been given some attention but are still somewhat less important, whereas organizational incentives and entrepreneurship turned out to be promising topics, with few but significant contributions especially as related to organizational incentives. Considering the breadth of the topics treated, the almost complete lack of individual-level studies is worthy of attention.

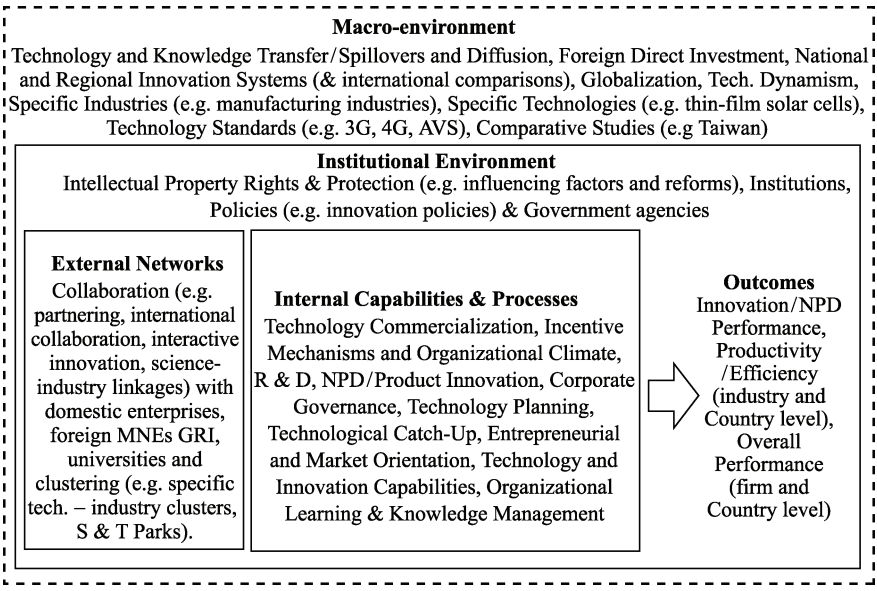

Fig. 5 Technological Innovation Management Research in China: An Integrative Framework

Table 6 TIM Research in China: Representative Studies, Topics, Constructs & Implications

	Main topics/Constructs	Implications
Macro-environment Guo (2008) Liu & Buck (2007) Filatotchev et al. (2011) Tsai& Li (2009) Li (2009) Cai (2011) Das (2012) Hu & Phillips (2011) Guoet al. (2010) Stewart et al. (2011) Chang & Shih (2005)	– Impact of technology acquisition channels and international technology spill-over on Chinese industries productivity and innovation performance – Knowledge spill-over from returnee entrepreneurs effects on high-tech firms innovation – Patterns of (Taiwan) Foreign Direct Investment (FDI) in China. – Innovation performance disparity between Chinese regions. – Role of exogenous technology shock in China's development and its role as a knowledge diffusor for other countries – Technological dynamism in telecommunication sector – Technological interdependence in China's biofuel industry – Nanotech-enhanced thin-film solar cells, cross-country comparison of research activity, impact and diversity	– Inter-industry spill over improves manufacturing industry labour and total factor productivity (TFP), and together with in-house R&D, industry TFP and innovation performance. In-house R&D & Foreign technology transfer influence labour productivity. Relevance of government regulations in this relationship. In the high-tech sectors learning-by-exporting (and importing) promotes innovation. Foreign R&D activities by MNEs significantly affect the innovation performance of domestic firms only when absorptive ability (internal/indigenous R&D efforts) is taken into account. – Returnee entrepreneurs are an important source of external knowledge spill-over; moreover, returnee presence facilitates knowledge spill-over to non-returnee SMEs, provided they have a sufficient level of internal R&D skills (i.e. absorptive capacity). – Taiwanese FDI in the IC design industry influences the FDI decisions and subsequent clustering of the Taiwanese IC manufacturing and packaging/testing industries in China. – Government support, the constitution of the R&D performers, and the regional industry-specific innovation environment are significant determinants of innovation efficiency. When regional innovation modes are firm rather than universities/public research institutes (PRI) dominant, innovation efficiency gaps are more marked. – Four key factors affecting telco service operators' dynamic capabilities have been explored. Through considerable resources and effort devoted to the development of static capabilities, with technological dynamic capabilities impeded by inadequate regulatory system, insufficient competition, unsophisticated home demand and an ineffective corporate governance system.

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	Main topics/Constructs	Implications
	– Chinese firms engagement in TLC/ICT international standardisation processes & with TD-SCDMA &next-generation ICT standards – Cross-country comparison between China and Taiwan technology innovation systems	– Exogenous technology shocks aided by human capital based absorptive capacity, better governance and institutions, diffuse to the South and Chinese dynamism propagates innovation to peripheral South Countries. China is seen at the centre of South–South rather than North–South cooperation in technology catch-up. – "Forward Engineering" as technology development mode, university-led, application-oriented and highly intertwined with the pharmaceutical industry. – Identification of key technological attributes, leading countries, organizations and research networks. India leads, though China showed a strong increase in both research activity and impact, but a weak international cooperation. – Standards (TD-SCDMA & Next Generation IT) involve a wide range of domestic, foreign and Chinese state actors in complex interactions. The idea of indigenous technological development vis-à-vis globalised innovation processes is questioned. – Similar distribution of key sectors and innovation flows, but differences in terms technology innovation system structure, with the Chinese one less dense/connected and centralized; efficiency, with the Chinese one less efficient in diffusing innovation; technological concentration, focused more on heavy rather than high-tech industry.
Institutional environment Hu (2010) Li (2012) Hu et al. (2009) Hu &Mathews(2008) Liu et al. (2011)	– Reasons for the surge of foreign and Chinese firms patenting – Effects of IPR and seed industry reforms on cotton industry's farmers welfare – China's National Innovation System transition from imitation to innovation	– Competitive threat from both domestic Chinese firms' imitation and intensification of competition with foreign firms in the mainland affects foreign patenting in China, whereas implementation of provincial patent subsidy programs played an important role for domestic patenting, not only for firms, universities and PRIs, but also for individuals. – Improvements to the IPR environment and greater commercialization in the seed industry increased the economic & social benefits for farmers, derived from new cotton technology.

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	Main topics/Constructs	Implications
	– Evolution of Chinese innovation policies together with the changing understanding of innovation by policy makers	– Increase in patent activity and quality (mainly in the private and university sector), a strong role of universities against the apparent mixed contribution and probably more indirect effects of PRIs, through private R&D, to national innovation capacity. – China shifted its S&T and industrial policy-centred innovation strategy towards better coordinated and innovation-oriented economic and technology initiatives, with greater attention to financial, tax and fiscal measures.
External Networks Ma et al. (2009) Zenget al. (2010) Zhang & Gao (2011) Guanet al. (2005) Su & Hung (2009) Li (2010) Guo&Guo (2011) Hu (2007)	– Patterns of international collaboration between China and major industrialized countries or region via a patent analysis – SMEs cooperation networks and innovation performance – Diffusion of interactive innovation and network effects in mobile value-added services (M-VAS) – Science-industry linkages effects on industrial innovation and efficiency – Analysis of different modes of emergence and evolution of a (biotech) cluster in comparison with US – Key factors that influences MNEs choice to collaborate with Universities or Firms – Technological learning at the industrial clusters level	– Increasing collaboration in inventive activities between China and other major inventive countries in the past decade, specifically with USA, Taiwan, Japan, Canada and Germany. – All sort of cooperation, except the one with government agencies, has a positive impact on SMEs innovation performance. Inter-firm cooperation is the most relevant and cooperation with customers and suppliers is more relevant than the one with universities and PRIs – Not just demand-side, but especially supply side dynamics (i.e. choice of platform strategies) helped drive the take-off of M-VAS innovations – Collaboration between public research institutions, universities and industry is positively related to technology novelty, though it is less efficient in terms of innovation performance (i.e. sales, profit ratios) and not capable of stimulating innovation from the industry side. – Human and financial capital is important for both clusters, though in China these resources are provided by the Government. The Chinese cluster is less entrepreneurial, short in social capital (except guanxi) and characterized by looser networks. – University Research Institutes (URIs) are preferred to local firms as foreign investors gain R&D experience in China and when the alliance is established for research rather than development purposes.

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	Main topics/Constructs	Implications
	– Policy incentives vs. external economies in the clustering of high-technology firms in technology parks	– The underlying complexity of technology, the inter-connectedness between product and process, path dependency in knowledge searching, and the incremental nature of a cluster's technological development are decisive for cluster-level technological learning. – No evidence that firms benefit from concentrating in technology parks or being close to a large metropolis. Policies incentives and foreign FDI/linkages with Foreign Invested Enterprises in the host City more relevant.
Internal capabilities & processes Li et al. (2008) Perks et al. (2009) Wei & Morgan (2004) Cai & Tylecote(2008) Xie & White (2004) Minagawa et al. (2007) Liu et al. (2011) Yam et al. (2004) Wu et al. (2009) Kim et al. (2009) Gao et al. (2007) Liu et al. (2009) Fisher & Von Zedtwitz (2004) Yang (2011)	– Impact of incentive mechanisms on entrepreneurial orientation and its effect on technology commercialization. – Effects of guanxi on R&D-Marketing integration in new product development – Impact of market orientation and supportiveness of organizational climate on new product performance – Effects of corporate governance characteristics on technological capabilities. – Foresight on the evolution of green technology in the automotive industry Case studies on capabilities development, counterfeiting, imitation and learning process from the perspective of Chinese manufacturers	– Incentive mechanisms (CEO ownership and CEO turnover frequency) have a positive impact on entrepreneurial orientation and this latter positively affects technology commercialization, with technological turbulence positively moderating this relationship – Guanxi can influence integration in mid- to late-phase NPD activities acting as a unifying force in underdeveloped processes, may reinforce acceptance of formalized structures and address the deficiencies of formal external institutional structures. – A positive direct relationship of market orientation on firms' new product performance and an indirect positive effect of supportiveness of organizational climate via its impact on market orientation – Private firms are generally inferior to state-owned enterprises in technological capability (because of poor access to finance and other resources). Among SOEs, the ones with State minority stakes proved to have better technological capabilities than the ones with State majority stakes. In any cases management selection method (shareholder over administrative selection) is more significant than proportion of state ownership and ownership type. – An improved framework based on the idea of sustainability made of scenario techniques, Delphi techniques, a questionnaire and a new statistical model for green technology foresight.

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	Main topics/Constructs	Implications
	– Technological innovation capabilities effects on performance – Impact of Information Technology Investment on firm's performance – Technology strategies to compete with foreign MNEs – Longitudinal case studies on organizational learning effects on technology innovation capabilities and innovation models – R&D evolution in Chinese firms – Knowledge management process, innovation capabilities, rewards systems and marketing fit effects on Chinese high-technology firms' corporate growth	– Chinese firms follow evolutionary, path-dependent and stage-wise progress from initial sales, distribution and service activities to manufacturing, product and process design and, finally developmental R&D. Some case studies suggest that in the occurrence of a nonconsensual acquisition of technology finalized to technology capabilities development, firms affected by the infringement should consider whether there are opportunities for collaboration rather than resorting IPR enforcement and compensation. – A positive relationship between TIC and competitive performance (mainly SOEs), with R&D (for LMEs) and resources allocation (for SMEs) the two most important TIC to enhance innovation rate, sales growth and product competitiveness. – Validates the impact of IT investments found in developed countries as related to firm's performance and found a positive impact, not very different as compared with US, confuting previous studies on the subject. – Developing innovation capabilities and core technologies more effective than development of strong manufacturing capabilities if there are opportunities for improvement. – Organizational culture, human resources (especially) and organizational structure, are more relevant than technological and innovation resources in building firm's TICs. Chinese firms pursue a secondary innovation model based on combining the acquired technologies with existing technology systems and further with local user requirements. – Chinese R&D main issues identified as follows: raising technological literacy, reduction of R&D workers turnover and retaining of the best people, improvement of technology research and creativity over product/process improvements, R&D internationalisation, IPR management and performance improvement. – Knowledge management process competence, innovation capabilities and marketing fit affect significantly corporate growth. The relationship between innovation capabilities and corporate growth is curvilinear. Both management strategies- and dynamic capabilities-related factors are important for long-term Chinese high-tech firms' growth.

However, though this is valuable information about what topics have received major attention and evidence, what topics not and what other topics have the potential to attract more interest, the diversity of theoretical perspectives, topics and level of analysis makes it difficult to draw actionable theoretical and practical implications. Therefore, to facilitate accumulation of knowledge and focalize the efforts where these are more needed, an integrative framework has been developed.

The integrative framework is depicted in Fig. 5 below. It organizes the main areas of research in internal capabilities and processes, external networks, institutional environment and macro-environment. It also identifies the performance implications of these constructs that have been studied in the literature surveyed. More in detail, the framework helps in: 1) organizing relevant keywords for each area of research, 2) identifying the outcomes and 3) specifying topics, constructs and implications of representatives studies selected for each of the research areas and the main keywords reported in Table 6 that follows.

For a matter of synthesis, representative studies have been tracked back from the keywords with the highest adjusted weight in each category. From the initial 78 studies, 30 retrieved ones have been chosen to collect hints of the main topics, constructs studied and implication drawn. Therefore, the choice did not assume any evaluation on the quality and relevance of the sample studies reported, but rather their capability to represent the broadest range of concepts according to the framework developed. So any paper that has not been reported is only because the topic, construct or the implication is already being tackled by the papers chosen. The same applies to all the other papers not retrieved, including the 2012 published works not considered in the analysis, which have been reviewed again in search for framework's relevant topics, constructs and implications that might have been omitted. In this manner, 8 more studies have been added to the sample of representative papers. Some stylized facts that can be drawn from the analysis performed on research on technology and innovation management in China areas follows.

(1) Over the period considered, technology and innovation management research in China has added to its domestic relevance (especially for what concern indigenous innovation and technology-based development policies) an

international stance, testified not only by the surge of Chinese studies and sample in TIM journals (see Fig. 2 above) but also from the increased interest of the international community in gaining more knowledge about the functioning of the Chinese technology innovation system, assessing the likely impacts of China's scale-up, and ultimately understand how to relate to China in terms of science, technology and innovation development, that is as partners, as competitors or both.

(2) It crosses different disciplinary boundaries in the same vein of its parent stream, but it is still bound by language and cultural boundaries. As a matter of fact, much of the studies are authored either by Chinese authors (Mainland or expatriates) or foreign authors. Chinese authors are in general able to go deeper into the topics studied exactly because of the language and the better connections with the Chinese reality, whereas foreign authors are able to bring in more generalizability, but with a limited access to the Chinese reality and all that is in the background. More significant cooperation, of the kind that will lead to more co-authoring, could definitely help in breaking existing boundaries and leverage on both strengths to ultimately offer more sound theoretical development and useful implications.

(3) It is too high-technology oriented and more prone to theory application and testing rather than to theory development. Both are actually a result of the peculiar Chinese context. The technology bias of Chinese developmental culture may account for the first. The ways in which Chinese management research has been born and evolved (for example, see Peng et al, 2001; Peng, 2005; Barney and Zhang, 2009), may account for the second. Nevertheless, case studies and other forms of theory development are used more often that it is generally thought. In addition there are already valuable attempts that tried to unveil the specificity of the Chinese context, not only vis-à-vis of the West, but also with regards to the previous industrializations of neighbouring countries and other emerging /transitional economies in general, put forward by some Chinese-based international journals.

From the theoretical perspective, the studies surveyed and the framework resulted, reveal as there are a number of research areas that deserve more attention as compared to the current international state-of-the-art in technology and innovation management and contiguous fields. More specifically:

- The linkage with the entrepreneurship perspective and the study of organizational incentives has already been mentioned as being promising but hardly published. However, entrepreneurship has long been recognized as a fundamental driver of the technological innovation process (Burgelman et al., 2001), even referred as the glue required to melt all the elements to convert a technological opportunity into commercial success (Hindle and Yencken, 2004). As per organizational incentives empirical researches have observed that, different human resource management practices may produce different effects on different types of innovation (for example, Subramaniam and Youndt, 2005).Therefore it may be worth to take an integrative view within the TIM field to investigate these relationships.
- In the same vein, considering the positive effects of knowledge management on innovation found in Chinese samples, in both technology innovation management (see Yang, 2005; Rui et al., 2008) and human resources management (see Wei and Xie, 2006), as well as its linkages with entrepreneurship (see Petti and Zhang, 2013), the relationships between organizational incentives, entrepreneurship and knowledge management may be fecund of both theoretical developments and practical implications.
- Another area is the study of medium and low-tech sectors, service sectors and in general other forms of innovation outside the R&D domain, which has not received enough attention in China TIM literature, though some studies have started to be undertaken. I refer in particular to the interactions, of high-tech sectors with medium and low-tech sectors (see Robertson and Von Tunzelmann, 2009) and of technological innovation with other forms of non-technological innovation such as business model innovation put forward by Chesbrough (2007) and pioneered in China by Wu et al. (2010).
- The same is for the role of individuals. For example study on the impact of cultural and behavioural characteristics of technical professionals on creativity and innovation (see for example Goncalo and Staw, 2006) or how entrepreneurial behaviours shapes technological innovation capabilities development and exploitation (see, for example, Dyer et al., 2008) may prove to be valuable research in understanding the underpinnings of technological innovation. In addition such kind of in-depth research may provide insightful managerial implications, not only in China.

– Above considerations leads to two more general considerations about the directions that requires more attention. The first is the need to focus more on overall dynamics and on a comprehensive understanding of micro-macro especially on the firm-level effects of the institutional structure of Chinese innovation system, that as, Table 6 shows, has been rather tackled at the system level. The second is the opportunity to continue to stress-test current theories in search for similarities and solve apparent contradictions, while increasing the reliance on contingency factors and more case studies to unveil uniquely Chinese phenomena that may expand received theories as suggested by Barney and Zhang (2009) with regards to the overall Chinese management research.

With respect to the kind of research, irrespective of the topic, there is the need to make research more multi-disciplinary, mixed and collaborative. Multi-disciplinary means that the effort should come from more than one management discipline and perspective, and also from external disciplines, primarily engineering, sociology and psychology. Mixed means that both qualitative and quantitative research methods should be used, as well as confirmative theory-testing and explorative theory-developing research should be undertaken, both in the search for unique research phenomena, and to discern which of them are really different and which merely appear to be. Collaborative means not only more collaboration, but also better collaboration, in terms of more frequent, longer and deeper contacts between scholars.

In practical terms, this kind of research can prove mutually beneficial for policy makers in China, as it can provide inputs for its development policy and especially abroad, since it can deepen the knowledge on what China their strategies and policies are based and offer a more accurate evaluation of the effects of its technological rise on them, as well as lead to the identification of the areas of complementarity on which to engage in mutually beneficial strategic cooperation and learning.

For the same reasons it can also prove beneficial at the enterprise level, especially when it comes to cooperation. At the organizational level, there are in fact a number of issues that are quite complicated: the effective and, from foreign enterprises perspectives, worrisome weak IPR enforcement and culture; the numerous and widespread examples of customers, suppliers or partners turned into competitors, even in the international market; the reciprocal difficulty to recognize

the differences in perspectives and a number of taken for granted or reciprocal stereotypes on how a business is run. For example the thought-to-be-known cultural elements as *guanxi* from the West side, the widespread belief among Chinese entrepreneurs that "only Chinese can do business in China." Not to mention the prejudices at the bottom line due to a widespread lack of knowledge on how things are really going in Chinese enterprises, with the exception of small and privileged circles. Nonetheless, there are also a number of complementarities on which to leverage, testified by the huge imports of technologies and as much huge exports of final, and definitely cheaper technological products. In this exchange, technologies, design, and advanced components are provided by Western enterprises, on which they enjoy a comparative advantage. Chinese enterprises on the other hand could deploy their huge industrialization and manufacturing advantages, and especially their capabilities to dramatically decrease costs at, by now, quality parity. Provided the above-mentioned difficulties could be tackled, this can prove to be a profitable business for both, but it is something that transcends the work of researchers since it requires a set of reciprocal adjustments at the institutional level, such as the effective strengthening of IPR enforcement, to reassure foreign technology providers from the Chinese side, as well as to resist to the temptation (at present justified by IPR issues) to export second-tier technologies to China from the Western side. This is because both really engage in a mutually beneficial learning process that only the increase of the number and the quality of exchanges of any kind and at any level will make possible, inside as well as outside the academic world, especially between companies. This means to increase the number of partnerships and alliances between Western and Chinese enterprises, which is the best way to learn, in addition to learning from mistakes.

However, this and other prescriptions transcends the objectives researchers work, including the author of this work, who should rather try to study, understand and describe how things work as close as possible to reality, so as to hopefully provide policymakers and entrepreneurs with sufficient clues to form their own conclusions and make informed decisions.

5 Conclusion

In this paper a comprehensive state-of-the-art research of technology innovation

management research in China has been performed. Relying on earlier calls on the relevance of technology innovation and its management in China, as well as on the recent rising of international interest to know and cooperate more on this topic, this paper offers a map and an integrative framework of the main topics being investigated, their relevance, their implications and avenues for further research of both theoretical and practical relevance, especially for enhancing scientific and industrial cooperation.

However, though it has required relevant work, it has never been thought as a definitive step, but rather just a step forward in tracing and understanding the topic. As pointed out, technology and innovation management is an interdisciplinary field of study and already more than two hundred works have been found over the same time frame in journals related to the business, economics, innovation and entrepreneurship domain (see Section 2). Moreover, major conferences are another relevant and timely source of research and very good, actionable research is often reported in books. Moreover, other researchers might want to extend the period of reference and go back to the springs of the research in China. All of these are definitely interesting avenues to deepen and extend this research. On the other side there are a number of analytical techniques and tools by which such an analysis can be made; for example, co-occurrence bibliometric mapping or meta-analysis, which can offer more fine-grained results, especially if targeted to more specific topics within the field.

Therefore, it is the hope of the author that this work should at least serve to interested researchers and practitioners in the same way a first chart brought back by an explorer is useful to give others hints on where to go and what to look for, and especially the necessary motivation to undertake the journey.

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