VUZF University of Finance, Business and Entrepreneurship

Economic Foresight & Scenario Thinking as a Planning Tool for Addressing China's Uncertain Environment

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“Change is the only constant:
No man can step in the same river twice”

Heraclitus
Greek Philosopher

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ABBREVIATIONS

A.I.	Artificial Intelligence
BAT	Baidu, Alibaba, Tencent
CCP	China's Communist Party
CIA	Cross Impact Analysis
CLA	Casual Loop Analysis
EC	European Commission
EOR	Enhanced Oil Recovery
FDI	Foreign Direct Investment
FQ	Focal Question
JRC	Joint Research Centre
MNC	Multi National Companies
NOC	National Oil Companies
OECD	Organisation for Economic Co-operation and Development
PLA	People's Liberation Army
RTD	Research & Technological Development
RTI	Research & Technlogical Innovation
RTO	Research & Technological Organisation
SES	Scenario Exploration System
STEM	Science, Technology, Engineering and Math
SOE	State Owned Enterprise
TIA	Trend Impact Analysis
WTO	World Trade Organization

ACKNOWLEDGMENTS

Having read several books, I understand that this is the place, to explain the motivation behind the work, to thank everybody that contributed, and to express my very personal thoughts.

I am not sure how to start, but I guess as China is the focal point of this research, it makes sense to explain my love and hate relationship with China that started more than 10 years ago. At that time China was different, so was I, we both developed (although I myself, not as fast as China). I love China because its different and charming, and because the gained experience, helped me to advance professionally and academically, while even this Phd thesis wouldn't be possible without China. I hate China, because it is so big, and changes so rapidly that needs one's constant attention to stay tuned. Slowly, I had to leave all my other "International Cooperation" activities in Latin America, Arabia, Africa, and Central Asia, because China needs exclusivity, and leaves no space for anything else. Nevertheless, this is China - big, fast, and mysterious.

During the first years of my professional career, I had practically zero experience on foresight. The spark lighted some years ago in an afternoon meeting with several stakeholders, based in Thessaloniki, to discuss the establishment of a Millennium Project node in Greece, a think tank[1] performing futures studies research. From that moment future studies became my monomania. Training, reading, testing tools, and again reading and training. For the first time, I felt the meaning of the words of Confucius "Choose a job you love, and you will never have to work a day in your life".

The list of the people to thank is rather large. First, I would like to thank my friend Stavros that introduced me to the Futures discipline and supported my initial training in the field, Ulf that was an inspiring mentor in foresight, Laurent who trusted me to become his research partner, and of course Tomas in China whose assistance and collaboration was indispensable for performing this research. I would also like to thank all my colleagues that at some point assisted me in this research, Laura, Elli, Keqin, Rikard, Jessy, Daile, Huanhuan, Daoliang, Odette, Michele, Sophie, Rossitsa, Diego, George, Anthony, and Laurent.

In addition, special reference needs to be made to the DRAGON-STAR project, funded by the European Commission under the Horizon 2020 program, that supported the foresight activities in China and the vast part of this research.

Finally, I would like to thank my family, Stavroula, Harris, and Celia for their patience, especially during the hours I was absent at the basement working, or traveling to China, missing our joint family activities. Nevertheless, my special thanks go to my son, as he was my travel partner in an adventurous trip to Sofia, to make the first discussions for starting this PhD; it was a road trip we will never forget, both of us. Last but definitely not least, my super special thanks go to my awesome supervisor, Daniela, who was ALWAYS online to provide technical feedback or spiritual support and resolve any academic and administrative issue and guided me until the end.

I hope you will enjoy it, as much I did.

[1] A body of experts providing advice and ideas on specific political or economic problems.

INTRODUCTION

1.Why Now?

For the most of part of human history the global economy was remaining rather stable (Figure 0.1), while the last two centuries it has experienced a rapid growth mainly due to the scientific & technological discoveries that initiated the industrial revolution. In addition, today, the economic growth and changes are becoming faster and faster. The British Empire managed to double the income per capita in almost 60 years, while modern China managed the same in less than years (Figure 0.1).

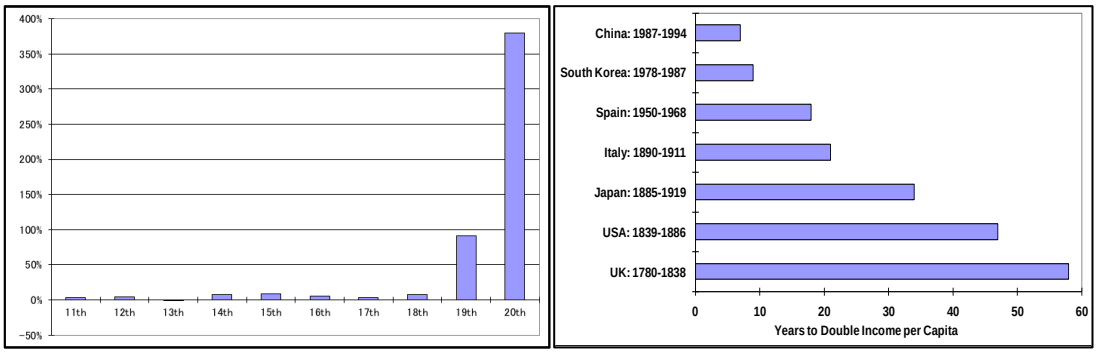


Figure 0.1: The growth of the world economy (Cordeiro, 2014).

According to, MIT-Lemelson prize-winning scientist, Ray Kurtzweil (2005) and the Millennium Project (Glenn et al., 2017), the pace of change accelerates continuously following an **exponential curve** (Figure 0.2). Today, this exponential growth is fueled by a group of new technologies (artificial intelligence, robotics, DNA sequencing, etc) that rapidly transform the economy, the society, and the environment.

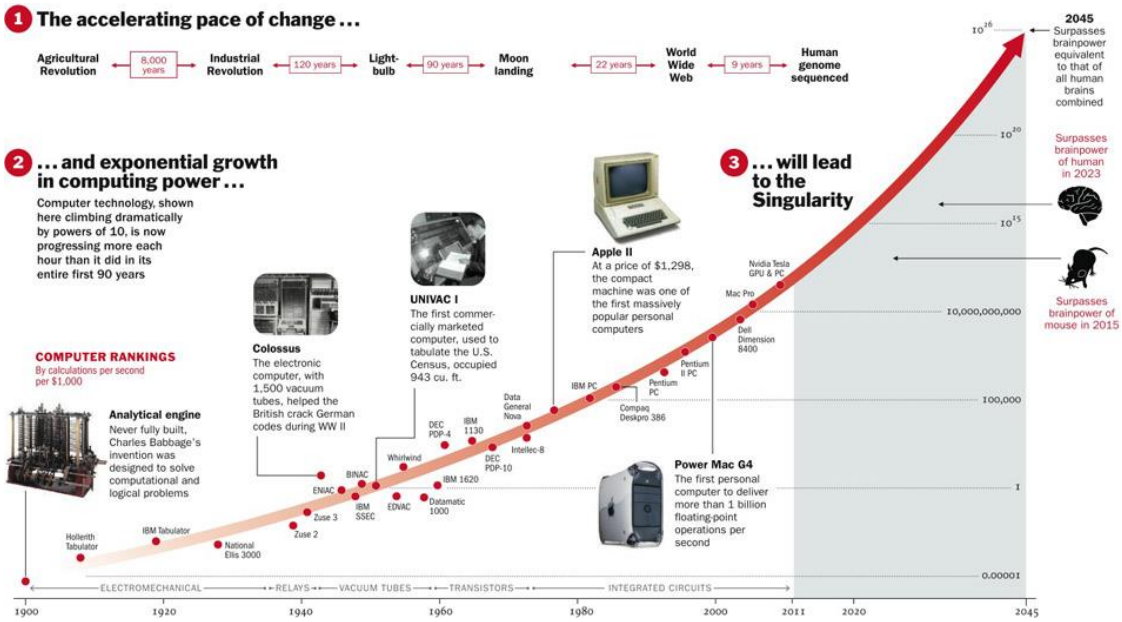


Figure 0.2: The accelerating pace of change (Source: TIME magazine)

This is WHY today more than ever in the past, major disruptions and systemic changes such as the transition to the circular economy, or the introduction of new technologies require a long-term perspective and challenging of existing mind-sets.

2. State of the Problem

The first decade of the second millennium has emphatically showed that we need to prepare for the non-preparable, and we need to foresee the unforeseen. The world is changing **rapidly** and in greater levels of **complexity (**Harari, 2015), thus quick reaction and resilient strategies are a necessity for businesses and policy makers.

Companies and other organisations as well as whole industrial sectors need to anticipate future developments in order to be prepared for them (Dufva et al., 2015). And while it is relatively easy to prepare for short term linear changes, longer term shifts in the socio-technical system and the impacts of the exponential technological disruptions are harder to cope with and are regarded as the "**black hole of strategy"** (Uotila, Melkas, & Harmaakorpi, 2005). Foresight is an approach to support the longer-term anticipation of alternative futures and for triggering responses to them (Georghiou, Harper, Keenan, Miles, & Popper, 2009).

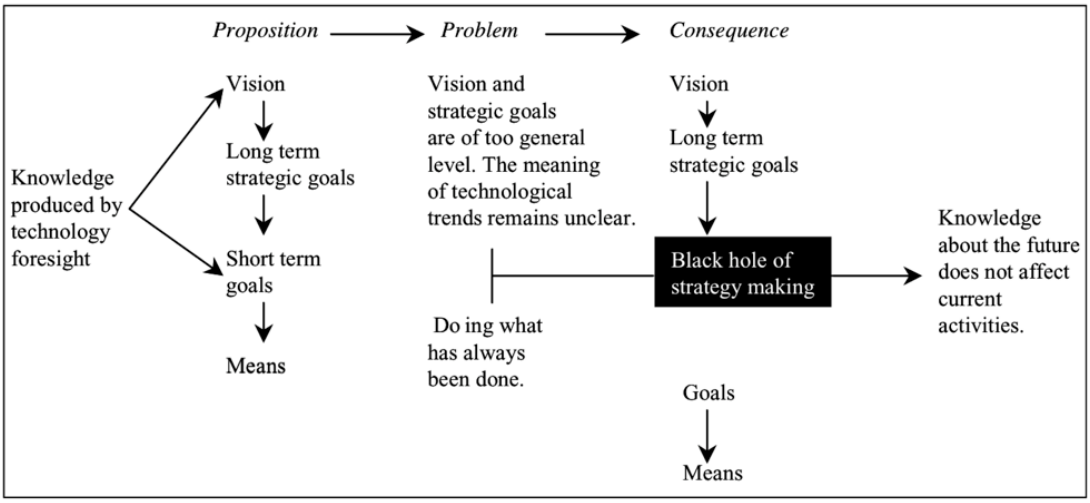


Figure 0.3: The black hole of strategy making (Source: Uotila, Melkas, & Harmaakorpi, 2005)

To address this problem of building a long-term strategy in a rapidly changing and complex environment, the case study of the economy and innovation in China is selected.

The innovation environment in China is a rapidly changing complex system, that is mainly driven by the exponential pace of the technological changes, but at the same time is affected by several diverse drivers and interconnected trends. Still several questions need answers. It is uncertain whether the Chinese economy and innovation will ever become a competitive world leader, and it is uncertain if the available financial resources and the central governmental planning are sufficient factors to ensure growth.

3. Aim of the Research

The main aim of this PhD thesis is to prove that in today's complex and rapidly changing environment, the utilization of foresight methodologies and scenarios offer a sound tool for understanding the system and build a successful long-term strategy that successfully addresses business, financial, social, technological, and other uncertainties.

4. Tasks (How the aim of the research will be achieved)

The above described aim of the thesis will be achieved through the following tasks:

1. Review (theoretical study) of the future methodologies.
2. Desk study reviewing various sources of information about China.
3. Implementation of initial analysis of the innovation and economic environment in China, through the utilization of established foresight methodologies.
4. Production of a preliminary set of future scenarios for China.
5. In-depth analysis of the innovation environment and dynamics in China.
6. Implementation of foresight methodologies to produce the final set of innovation scenarios for China.
7. Testing the usefulness of scenarios for strategic planning. This is achieved through the development and use of a novel serious role-playing game.
8. Review of the feedback received by experts.
9. Production of conclusions.

5. Object & Subject of the Research

The **main objective** of the research, is to prove that as today the pace of changes is faster than ever, it is important for organisations to utilise methodological tools that will help them to understand the complexity of these changes and allow them to achieve long-term resilience.

The subject of this PhD thesis is going to prove the validity of using scenarios to address the uncertainties regarding the future development of the complex innovation and economic environment in China.

China is a leading global actor, which is perceived both as a threat and as an opportunity by corporations, academic institutions and governments. For example, the Chinese market presents a great opportunity for European industries, but at the same time the process to enter the Chinese market entails several risks and requires a huge investment in resources and careful planning.

Moreover, in the rapidly changing global environment, China is a key driver of change, affecting heavily and in various ways the rest of the world. The post-war era has witnessed the economic miracles of Japan and South Korea that managed to become substantial actors in the global high-technology market. However, both countries did not have the dynamism and size to transform the global economy and to control the rules of the game. Today, in the beginning of the 21st century, two new countries, China and India, both (especially China) have the prospects or the potential to shift the balance of the global economy[2].

So far, China has primarily excelled at adopting technologies from elsewhere, as a 'fast follower' (Kostarelos, 2014; Springut et al., 2011; Fu et al., 2013; Government call for growth driven by innovation, 2013); however, in some fields it is on the frontier of technological knowledge, and the growth of published research is extraordinary. Regarding the commercialization of high tech innovative products, China with its large growth and excess liquidity, is eager to invest in new technologies to upgrade its production systems (Casey & Koleski, 2011; Cyranoski, 2014).

[2] The people concerned. (2014, July 15). *The Economist*.

China (as other emerging markets) is now completing the innovation cycle by rapidly signing deals with innovative start-ups to quickly commercialize their new technologies at a rapid tempo and to scale.

The current thesis is examining all the above-mentioned issues, and proposes a methodology to address the uncertainties of China's future.

6. Research Resources

During the research a broad range of primary and secondary research resources have been utilized, as briefly described here.

Primary sources

- Human resources: interviews, discussions and knowledge sharing with experts based in China or Europe;
- Survey results (e.g. from the 2 Delphi questionnaires shared with experts globally);
- Input received from experts in participatory workshops (2 participatory workshops in Shanghai provided input for the research);
- Crowdsourced info (the experimental use of an app[3] for collecting information about new trends in China);
- Direct observation (e.g. of new trends in the Chinese cities or conference presentations of European and Chinese experts);

Secondary sources

- Synthesis and analysis of raw data received through different channels by various stakeholders (e.g. Annex 8);
- Print media: Scientific journals, books, magazines, newspapers, special reports.
- Electronic sources: blogs, social media, videos.

7. Chronology of Research

The vast part of the research was funded by two consecutive European projects focusing on supporting collaboration with China in Research and Innovation:

- Dragon-Star (FP7): No.309794, 1 Oct 2012- 30 Sep 2015;
- Dragon-Star Plus (Horizon 2020): No.645775, 1 Feb 2015- 31 Jan 2018;

The research work for this PhD thesis was also conducted in two-phases:

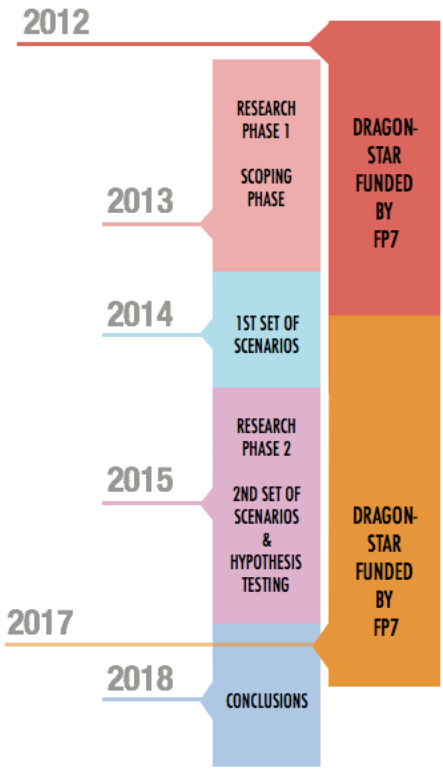
- 1st Research Phase, November 2013 – December 2014: The first scoping phase of the research was mostly based upon the 1st Delphi survey and analysis, as well as upon a broad and diverse pool of secondary information sources.

  The main output of this phase was the identification of the 16 drivers/trends affecting the innovation environment in China, and the production of the 1st set of scenarios for the future of China 2025 (see Section 5).

[3] An application, especially as downloaded by a user to a mobile device.

- 2nd Research Phase, February 2015 – January 2018: After the 1st scoping phase and the initial analysis, a more in-depth research followed in phase 2, that included participatory workshops, interviews, and serious games.
  A major part of this phase was conducted under the academic supervision of Dr. Daniela Ilieva, VUZF.

  The main outputs of this second phase included:
  - The final set of scenarios for the future of China (China 2030), that were used to test the hypothesis of this thesis.
  - The production of a serious role-playing game for strategy testing.
  - The verification of the main research hypothesis, about the value of using scenarios for long-term strategic planning in complex and rapidly changing environments.



8. Hypothesis (*main idea behind the research*)

The world today is more complex than ever before while the pace of change is faster than ever before, due to the technological discoveries and several megatrends causing major disruptions and systemic changes in all aspects of our lives.

In this global environment, companies and other organizations understand the value of long-term strategic planning, but miss the right tools to build a convincing long-term strategy. Traditional planning tools are better suited for short-term linear changes, and they cannot address sufficiently longer-term shifts in the socio-technical system and the impacts of this avalanche of technological disruptions (Dufva et al., 2015).

The hypothesis is that foresight, and especially scenarios offer a suitable method to create future-orientation, futures mindset and build a resilient long-term organisation strategy, that is regarded as the "black hole of strategy" (Uotila, Melkas, & Harmaakorpi, 2005).

9. Research Methodology

Futures studies consist of a vast array of methodologies and approaches and the area has been naturally called a 'very fuzzy multi-field (Marien, 2002), allowing a level of flexibility as regards as the methods used for a specific project.

For this specific case, the research toolbox combined a broad set of well-tested foresight methods - namely Delphi, participatory workshops, interviews, and scenarios, but also direct first-hand observations of the Chinese innovation and business environment during the last 10 years.

In addition, novel methods like crowdsourcing[4] (Co:tunity app[5]) and gamification[6] techniques were also applied and tested, and are presented in detail in the following sections.

"Traditional" Foresight Methods	"Novel" Foresight Methods
- Delphi; - Participatory workshops, interviews; - Historical analysis, environmental scanning, trend scanning; - Trend impact analysis & Cross impact analysis; - Scenario building;	- Serious Role Playing; - Crowdsourcing;

Usually, foresight projects utilize only a handful of methods, depending on the specific needs and available resources. In the case of this PhD thesis, a large number of diverse methodologies (traditional or new) were applied and tested. Most of the tools provided useful knowledge and provided inputs at different steps of the research, while other tools (like crowdsourcing[7]) were tested but provided poor results.

The research methodologies and the organizational structure of the research are presented in **Chapter II**.

10. Innovation of the research

Foresight studies have been implemented in various environments and for a diverse range of situations, while China has also been the focus of previous foresight studies.

However, the are several novel characteristics of this research that support its innovation:

- Usually, foresight studies utilise 1-2 different methods while this research combined and tested many diverse foresight methodologies, such as Delphi, participatory workshops, interviews, scenarios, crowdsourcing, serious games, observation, etc. That allowed a multidimensional rich knowledge production, and also permitted to reduce uncertainties of similar qualitative studies.

- A novel serious role-playing game (SES China) was developed (in cooperation with JRC/Policy Lab) and was utilised for simulating the future, for communicating the produced scenarios and finally for testing long-term strategies.

[4] The practice of obtaining information or input into a task or project by enlisting the services of a large number of people, either paid or unpaid, typically via the Internet.

[5] http://www.cotunity.com

[6] The application of typical elements of game playing (e.g. point scoring, competition with others, rules of play) to other areas of activity.

[7] The Co:tunity crowdsourcing app for the identification of innovation trends, was used by a limited number of Chinese users, due to technical limitations or cultural issues.

- The rather long (4-year) duration of this research, and the 2-phase research design, has allowed to follow the developments (in China) for a quite long period, and offered the opportunity evaluate over time the importance of initial findings (e.g. the importance of specific drivers), and to fine-tune the research during the 2nd phase.

11. Approbation of Methodology (Testing)

The objective of this PhD thesis is to prove that the use of scenario-based planning in today's complex and rapidly changing environment, offer a sound tool to organisations, for understanding the overall system and for building a successful long-term strategy that sufficiently addresses business, financial, social, technological, and other uncertainties.

The suggested methodology was tested for the case of China, and specifically for China's complex and rapidly changing innovation and economic environment. The results and the use of the methodology for strategic planning was successfully approved by a large group (~40 experts) of high level Chinese and European policy makers, including the EU's Minister Counsellor in China for research and innovation, the President of the Chinese Academy of Science and Technology for Development (CASTED), European embassies, Chinese government agencies, European and Chinese enterprises and academic institutions.

12. Reliability of Research

The reliability of any conducted research is about assessing the quality of the procedures used to collect data.

In the context of this thesis, the reliability of the acquired data is secured through the following measures:

- The two-phase research organisation permitted the preliminary evaluation of data, before the 2nd and final research phase.
- Different methods (Delphi, interviews, participatory workshops, secondary sources, observation, etc) were applied, in parallel, for collecting data and the outputs were regularly compared.
- A specific set of the same control questions was used in the 2nd Delphi questionnaire as well as in the 1st participatory workshop (Annex 3).
- The key megatrends were evaluated in two consecutive surveys (Delphi 1, Delphi 2).
- The final outputs of the phase 1, and phase 2 were validated by independent experts. The overall results of Phase 1 were provided for validation and recommendations to:
    - Associate Prof. Anthony Howell, School of Economics, Peking University, Beijing, China;
    - Mr Rikard Wallin, Managing Director, NCAB Group Sweden AB, Stockholm, Sweden;
    - Prof. Daoliang Lee, China Agricultural University, Beijing, China

  The final outputs of Phase 2 were evaluated by a broad group of experts in a workshop in Shanghai (Annex 5).

13. Scientific and Theoretical Significance

The peculiarities of the Chinese economic and innovation environment and the increased difficulty for performing the research (language barriers, cultural differences, lack of reliable data, dynamic environment with many weak signals, etc), required a research approach that combined several different foresight methodologies that were used in various steps of the research. These special requirements have however produced several scientific advances as presented briefly bellow (detailed description at section 10.1):

i. Novel Scenario Development approach. A two-stage scenario formulation, has proved useful and can be applicable in similar complex systems.

ii. Trends/Drivers Template. A specific format to present Trends/Drivers has been proposed.

iii. Multidimensional Scenarios. The dynamics of the economic and innovation environment in China, requested a multidimensional approach to address not only technological and socioeconomic aspects, but also integrate business model innovations, environmental challenges, etc, and offer an integrated approach.

iv. SES China – Exploring Future. A unique platform in the form of a serious game (SES China) has been developed (*Annex 6*), with the support of the JRC/Policy Lab.

v. SES China – Strategy & Vision tool. SES China besides being a tool for exploring the future and engaging with scenarios, at the same time it is a unique tool for drafting and testing long-term strategies.

vi. Serious Game – Gamification in China. Other versions of SES had been tested by JRC with western participants, but was never tested in Asia. Thus, it was the first time a serious game was tested with Chinese high-level officials, proving that the SES China platform is also suitable for use by non-western policy makers, beyond any cultural differences.

14.Practical Applications

The objective of the thesis was to prove that in complex and rapidly changing environments, scenarios is a suitable tool for long-term planning. The research has confirmed that foresight and specifically scenarios can support the longer-term anticipation of alternative futures and for triggering suitable responses to them.

Scenarios by themselves do not determine strategy, but a strategy needs to be developed in light of a set of scenarios, and using scenarios to test a strategy can function like an insurance policy.

Moreover, the use of a serious role-playing game, like SES China, can offer an alternative modern tool (beyond any cultural differences) to policy makers for understanding scenarios and testing strategies.

The proposed methods are suitable for use by any kind of organisation (private corporations, academic institutions, government agencies) operating in dynamic, complex, and rapidly changing environments.

15.Conclusions and Recommendations

The research outcome has confirmed the basic hypothesis that in today's complex and rapidly changing environment, the utilization of foresight methodologies and scenarios offer a sound tool for building a successful long-term strategy and address uncertainties.

The combination of performing economic foresight through developing scenarios, and the use of gamification techniques (SES China) has indeed been proven to be an efficient and robust planning tool for addressing China's urban Economic Foresight & Scenario Thinking as a Planning Tool for Addressing China's uncertain environment.

The same methodology could be replicated in various situations offering a useful tool for developing long-term strategies in complex and continuously changing environments, especially in cases where managers need to establish robust and responsive strategies. Various strategies can be tested against alternative plausible scenarios, become fine-tuned, and finally refined to become more robust and more responsive to future needs, while an interesting future step would be to use the developed methodology for testing the robustness of existing corporate strategies towards China.

The work performed in the context of the PhD thesis is presented through the following structure:

CHAPTERS	**STRUCTURE (Sections)**
CHAPTER I *Background Information*	**1. Terminology & Main Concepts** All the concepts utilized or cited throughout the thesis will be analytically presented.
	2. Future Methodologies The main foresight methodologies will be presented in the section and will be compared to provide an overview of the sector.
	3. China The Chinese research and innovation environment will be presented, as well as the main trends and drivers shaping China's future.
CHAPTER II *Description of the Research*	**4. Research Methodology** This section includes a detailed presentation of the research methodology utilized for the current thesis.

	5. Organization of Research The two-phase organisation of the research is explained. The structure of the performed Research will be analytically presented, as well the interconnections between the different research methods.
CHAPTER III *Presentation of Results & Conclusions*	**6. Trends/Driver Analysis** The main tends and drivers identified during the first phase of the research (presented at section 3), are evaluated towards their impact and probability to occur, and their interconnections were analysed with using established foresight methodologies.
	7. Preliminary Analysis & Scenarios: China 2025 The 1st phase of the research concluded with the formulation of the initial set of scenarios for the future of China by 2025. That scenarios, and knowledge acquired became the basis for the 2nd phase of the research that required more in-depth analysis of the current and future innovation landscape in China.
	8. The Innovation Landscape Today The second phase of the research (including desk study, media analysis, Delphi, interviews, participatory workshops, and observation) provided a more detailed and precise analysis of the current innovation environment in China, and it is presented in this section.
	9. Innovation Scenarios: China 2030 Further elaborating the information collected during the 2nd phase of the research, the final set of scenarios for the future of China have been presented. The scenarios were produced taking into account all the primary and secondary research performed in the context of the current thesis. In addition, for the validation of the research and for testing the main assumptions, gamification concepts have been applied. A serious board role-playing game has been developed and used with a large group of stakeholders.
	10. Conclusions The results of the research are presented and discussed, as well the final overall conclusions. The scientific discoveries achieved during this research are briefly presented and explained. Also, the overall conclusions regarding the main objective of this PhD dissertation is analytically presented.

CHAPTER I: BACKGROUND

Introduction

The first chapter aims to provide all the necessary background information, that is needed to a full understanding of the thesis argument, and of the methods used.

This first chapter includes information on the main concepts and terminology utilised throughout the thesis (Section 1), as well as, an overview of the future studies field, and of the main foresight methodologies utilised by foresight practitioners around the world (Section 2).

Furthermore, Section 3 of this chapter provides information about China and its peculiar and rapidly changing business and innovation environment. In addition, Section 3 concludes with a presentation of the 16 key drivers and trends that are shaping the future of China, which were identified during the 1st scoping phase of the research.

The format of analysis and presentation of these drivers is one of the key scientific contributions of this PhD thesis. This format includes a short presentation of the trend or driver, some examples proving the validity of the trend, any existing countertrends, the driving forces and main actors, the expected future development of the trend and the main consequences for our case.

1.0 TERMINOLOGY – MAIN CONCEPTS

In this first section of the thesis, the main terms and concepts that utilized throughout the thesis will be described, explained, and defined. The objective of this section is to provide the necessary background information for understanding the terms and typology used.

An important part of the PhD research is the production of long-term innovation scenarios for China, so the concept of innovation and its underlying mechanisms will be briefly explained, as well as the concept of foresight and its importance.

The main foresight methodologies utilized are scenario and scenario planning, and as they are essential many steps of the research, are also explained here in detail.

Finally, the production of scenarios requires the identification of megatrends, so the term "megatrend" that appears in various parts of this thesis, will be also clarified and specific examples will be provided.

1.1 Innovation

Building scenarios for the long-term innovation future of China, is a key topic of the current research, thus defining innovation is of critical importance.

The simpler and easiest definition of innovation is provided by the Cambridge dictionary "**(the use of) a new idea or method**". According to the OECD ("Defining innovation - OECD," n.d.), An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations:

- ***Product innovation:*** A good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user friendliness or other functional characteristics.
- ***Process innovation:*** A new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- ***Marketing innovation:*** A new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- ***Organisational innovation:*** A new organisational method in business practices, workplace organisation or external relations.

Today, it is widely accepted that innovation is central to the growth of output and productivity and the creation of a dynamic knowledge-based society, however there are great limitations in understanding how it is affected by the world economy and globalization (including the free flow of knowledge, new markets, and access to finance) (OECD & Eurostat, 2005).

In this respect, OECD & Eurostat (2005) recognize that in order to develop policies to support innovation appropriately, it is necessary to better understand several critical aspects of the innovation process, such as innovation activities other than R&D, the interactions among actors, and the relevant knowledge flows.

In addition, it is recognized as particularly difficult to understand the drivers and trends affecting the innovation system, and to interpret them correctly. This problem of understanding the innovation mechanisms becomes even more difficult when the objective is to foresee the development over a long-time span of more that 10 years, which is the focus of the current thesis. To understand the mechanisms that shape a complex and rapidly changing system, like the innovation environment in China.

In order to investigate the long-term development of the innovation environment in China, it is necessary to apply foresight methodologies. So, the "foresight" term and concept is explained, in detail, in the next section.

1.2 Foresight

The forces of nature, social and political dynamics, scientific discovery, and technological innovation largely determine the future. However, as human capacity has evolved, our choices are also increasingly shaping the future. Society cannot control the future, but it can influence the course of history. This influence makes worthwhile the effort to consider the balance between what is desirable and what is possible.

To study the future is to study potential change - not simply fads, but what is likely to make a systemic or fundamental difference over the next 10 to 25 years or more. Studying the future is not simply economic projection or sociological analysis or technological forecasting, but a multi-disciplinary examination of change in all major areas of life to find the interacting dynamics that are creating the next age (Glenn & Gordon, 2009).

In this context, foresight is a systematic, participatory, prospective and policy-oriented process which, with the support of environmental and horizon scanning approaches, is aimed to actively engage key stakeholders into a wide range of activities anticipating, recommending and transforming technological, economic, environmental, political, social and ethical futures (Georghiou, Harper, Keenan, Miles, & Popper, 2009). In other words, Foresight is the knowledge or insight gained by studying future possibilities.

Key approaches to foresight include monitoring trends, developing forecasts and scenarios, checking assumptions and mental maps (Concepción et al., 2014). Foresight involves taking a longer and broader view of decision-making. Foresight enables organizations, agencies, and communities to more wisely create their futures and is often used to provide early warning of emerging issues, understand challenges and opportunities, clarify vision and goals, and check the appropriateness and robustness of strategies.

1.3 Megatrends

As mentioned above the concept of trends and megatrends are often used in foresight methodologies, and especially in scenarios. The terms and their characteristics are explained here in detail.

Trend *(according to the Cambridge dictionary)* **is a general development or change in a situation or in the way that people are behaving.** It is critical to understand that a trend is a long-term transformational process and not a short lived fad of the short that characterizes the clothing and FMCG (fast-moving consumer goods) industries (Figure 1.1.). If an analogy with meteorology is used, trends would be climate changes rather than variations in the weather (Lindgren & Bandhold, 2003).

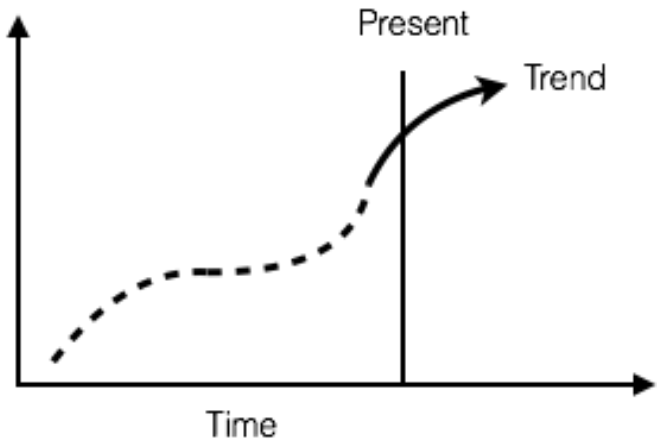


Figure 1.1: A typical trend development

The concept of **megatrend** was first introduced by John Naisbit, in the book Megatrends (Naisbitt, 1982). A **megatrend** is again a long-term transformational process, but with global reach, broad scope, and a fundamental dramatic impact. More specifically there are three dimensions that define a megatrend: time, reach, and impact (Vielmetter & Sell, 2014).

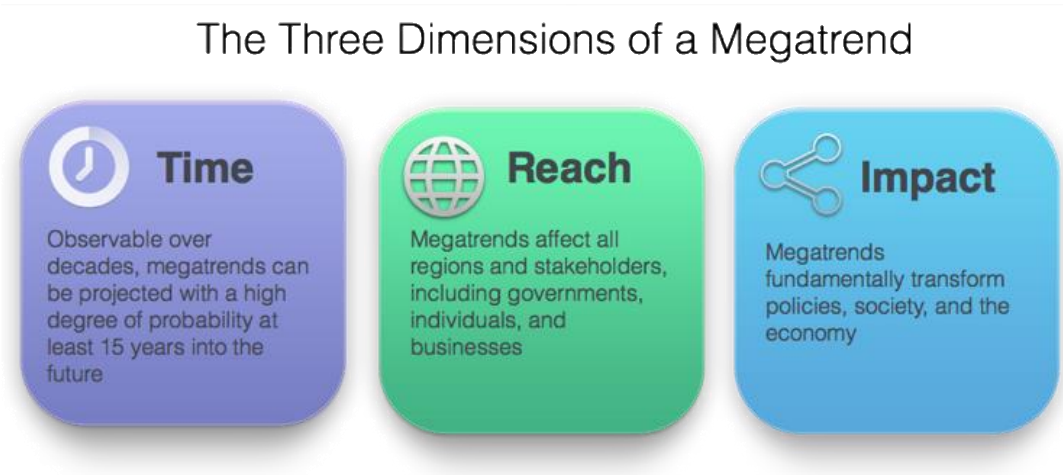


Figure 1.2: The three dimensions of a megatrend.

Some of the main megatrends today are Urbanization, Climate Change, the rapid Technological developments (including Big Data, information technology, biotechnology , etc), the growing demand for resources (food, water, and energy), the

ageing global population, and the globally increasing middle class. A detailed description of some of the main Megatrends is presented in Annex 9.

Besides the established trends and megatrends, it is also important to check for weak signals of emerging trends (called ***minitrends***) that promise to become significantly important within 2-5 years, but are not yet generally recognized.

Trends, megatrends, and minitrends play an important role for composing future scenarios. Their development and cross-impacts are the stepping stones for building the alternative scenarios that illustrate plausible futures. The concept of scenarios, the different scenario categories and their practical use is explained in the next section (1.4).

1.4 Scenarios & Scenario Planning

Scenario or scenarios in the context of foresight are consistent pictures, descriptions, stories illustrating future situations, future scenes. In other words, scenarios are alternative descriptions of different possible futures that help decision makers consider the implications of these future possibilities for planning and decision making today.

Scenarios describing future situations are usually linked to the present in cause/effect logics. In other words, scenario is the coherent articulation of hypotheses for the evolution of variables in a given horizon and the road leading to it. However, there is no single definition of scenarios. Different practitioners have proposed different definitions:

- "An internally consistent view of what the future might turn out to be" (Porter, 1985).
- "A tool [for] ordering one's perceptions about alternative future environments in which one's decision might be played out right" (Schwartz, 1991).
- "A disciplined method for imagining possible futures in which organizational decisions may be played out" (Shoemaker, 1995)

It is clear however, that a scenario is not a forecast, neither is a vision. it is simply not possible to predict the future with certainty. A scenario is a well-worked answer to the question: "What can conceivably happen?" or "What would happen if …?" (Lindgren & Bandhold, 2003). Scenarios are powerful tool that help us to perceive futures today. The scenarios challenge our mindsets and oblige us to consider a set of potentially uncomfortable futures.

Figure 1.3 illustrates the differences between the three main categories of futures. In general, the longer the time, the greater the possibilities for several different futures to occur. The number of possible one-week future is limited, but the number of possible alternative futures in 30 years is enormous. By studying the different futures, other are preferable, more desirable (F*igure 1.3*), while some other are more probable than others. However, the focus is further ahead, the it becomes quite complex to predict the development of the system. Scenarios help but some order in this chaos.

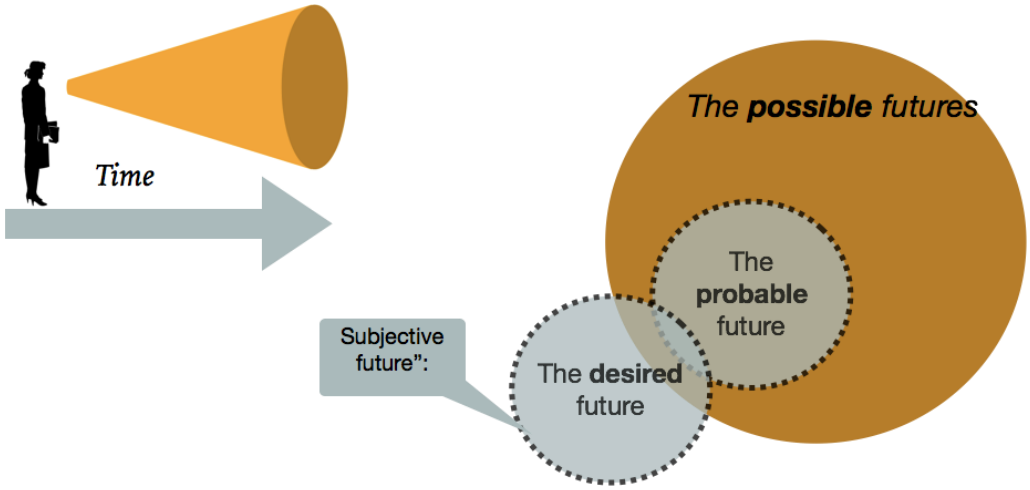


Figure 1.3: The relations between possible, probable and desired futures.

1.4.1 Objective of Scenarios

The main purpose of using scenarios in foresight is to outline what the future might be – not will be – to show alternatives due to uncertainty and to make decision making more robust and future-proof, and to sensitize decision makers with regard to the uncertainties of the future and to enable them to become future fit.

A scenario is never a prediction or a forecast, but a way of organizing many statements about the future; it is a plausible description of what might occur. Scenarios describe events and trends as they could evolve. Good scenarios are plausible, internally consistent and sufficiently interesting and exciting to make the future real enough to affect decision making.

1.4.2 Scenario Types

There is no consensus on the scenario typologies, however several typologies reflect the view that future studies explore possible, probable and/or preferable futures (Borjeson et al. , 2006). Taken into account this approach, we could define three (3) main scenario categories (Figure1.4). This classification of the scenarios, is related with the structure and syntax of the focal question set by the scenario users. Scenario users, can be those who generate scenarios, those who use already existing scenarios and those to whom scenarios are directed, even though they may not have asked for them. For example, different scenarios are produced by a "What will happen?" type of question, while also different category scenarios are produced by "what can happen?", and "How can a specific target be reached?" types of questions.

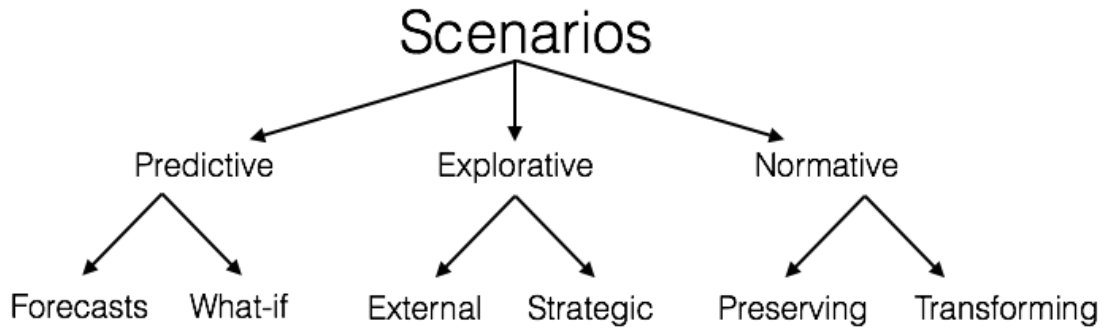


Figure 1.4: Three scenario categories, six scenario types

According to this approach the three main scenario categories are the following:

- **Predictive scenarios** (*What will happen?):* Predictive scenarios consist of two different types, distinguished by the conditions they place on what will happen. *Forecasts* respond to the question: What will happen, on the condition that the likely development unfolds? *What-if* scenarios respond to the question: What will happen, on the condition of some specified events?

The aim of predictive scenarios is to make an attempt to predict what is going to happen in the future. The concepts of probability and likelihood are closely related to predictive scenarios since trying to foresee what will happen in the future in one way or another has to relate to the (subjectively) estimated likelihood of the outcome.

Predictive scenarios are primarily drawn up to make it possible to plan and adapt to situations that are expected to occur. They are useful to planners and investors, who need to deal with foreseeable challenges and take advantage of foreseeable opportunities.

- **Explorative scenarios** (What can happen?): Explorative scenarios are distinguished between external and strategic and aim to explore situations or developments that are considered possible to happen. Typically, a set of scenarios are worked out in order to span a wide scope of possible developments.

Explorative scenarios resemble what-if scenarios, but the explorative scenarios are elaborated with a long time-horizon to explicitly allow for structural, and hence more profound, changes. Explorative scenarios can help explore developments that the intended target group in one way or another may have to take into consideration. This can be in situations when the structure to build scenarios around is unknown, e.g. in times of rapid and irregular changes.

There are two types of explorative scenarios. *External scenarios* focus only on factors beyond the control of relevant actors, and are typically used from policy makers and planning entities for strategy development. The external scenarios can then help the user to develop robust strategies, i.e. strategies that will survive several kinds of external development. Policies are not part of the scenarios but external scenarios

provide a framework for the development and assessment of policies and strategies. One specific way of doing this is through *scenario planning*, a methodology described in section 1.4.3. On the other hand, *strategic scenarios* incorporate policy measures and aim to describe a range of possible consequences of strategic decisions.

- **Normative scenarios** (How can a specific target be reached?): In the case of normative scenarios, the study has explicitly normative starting points, and the focus of interest is on certain future situations or objectives and how these could be realised. Normative scenarios consist of two different types, distinguished by how the system structure is treated. Preserving scenarios respond to the question: How can the target be reached, by adjustments to current situation? Transforming scenarios respond to the question: How can the target be reached, when the prevailing structure blocks necessary changes?

In *normative preserving scenarios*, the task is to find out how a certain target can be efficiently met. In *transforming scenario* studies, the starting point is a high-level and highly prioritised target, but this target seems to be unreachable if the ongoing development continues.

1.4.3 Scenario Planning

Scenario planning is a strategic planning method that some organizations use to make long-term plans under uncertain conditions, based on alternative scenarios. Scenario planning is particularly useful for areas of non-linear change, for example when product categories are reaching a level of over-maturity and need to be replaced with something new or in the face of rule breaking competition that is creating a new business logic (*see figure 1.4*).

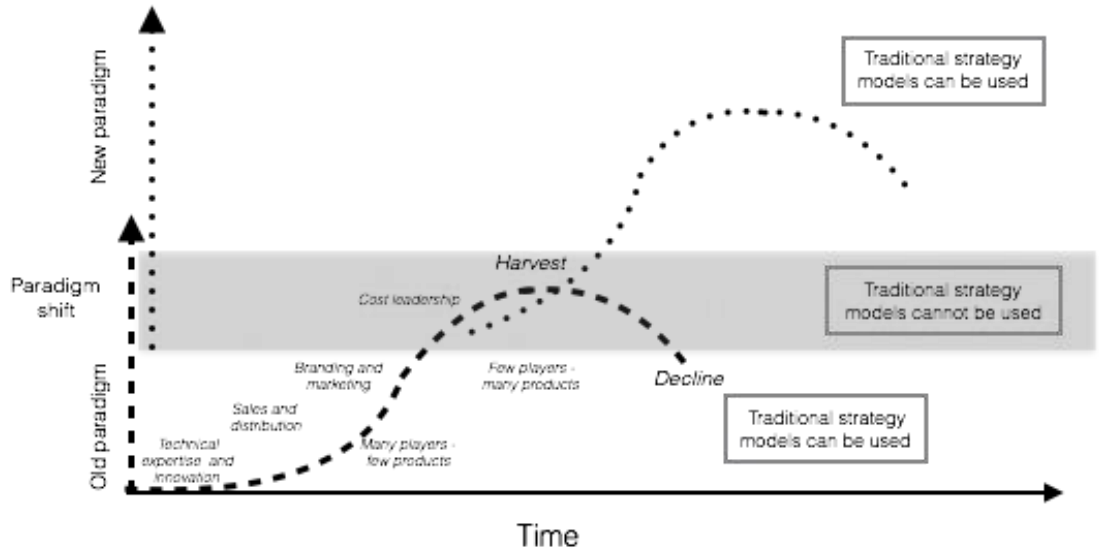


Figure 1.5. Scenario planning is well suited to the task of dealing with paradigmatic, non-linear change (Mats & Bandhold, 2003).

In a scenario process, managers invent and then consider, in depth, several varied stories of equally plausible futures. Today, scenarios and scenario planning have been proven to be important planning tools for governments, public organisations and private corporations, as their operational environment have gradually became more complex. One of the most prominent cases is Shell. Shell International Petroleum Company (Royal Dutch/Shell Group, in the Netherlands) used scenarios before the 1973 oil shock. The method proved useful in allowing Shell to anticipate the rise and subsequent fall of oil prices. In the mid-1980s, Shell created scenarios that focused on the future of the Soviet Union because that country was a major competitor in the European gas market.

Section 1 has clarified the concept of innovation and briefly presented the area of future studies, and the concepts of megatrends and scenarios. It has also explained the difficulty to conceptualize and "see" all the possible long-term futures, and the related complexity of long-term planning.

Next, Section 2 will offer a brief overview of the main future methodologies that are utilized by practioners around the globe, and demonstrate their basic characteristics. Some of those methodologies have neem utilized in the current research.

2.0 FUTURE METHODOLOGIES

The purpose of futures methodology is to systematically explore, all plausible futures in order to improve decisions, and offer tools to better manage our ignorance of the future (Figure 2.1). It includes analysis of how these conditions might change as a result of the implementation of policies and actions, and the consequences of these policies and actions. Futures research can be directed to large- or small-scale issues, in the near or distant future; it can project possible or desired conditions. It is not a science according to the narrow definition of science, as the outcome of the foresight studies depends on the methods used and the skills of the practitioners. Its methods can be highly quantitative or qualitative. It helps to provide a framework to better understand the present and expand mental horizons.

Businesses use futures methods to enhance understanding of future markets. Social leaders use them to develop and test both possible and desirable future visions. Future visions can help generate long-term policies, strategies, and plans, which help bring desired and likely future circumstances into closer alignment.

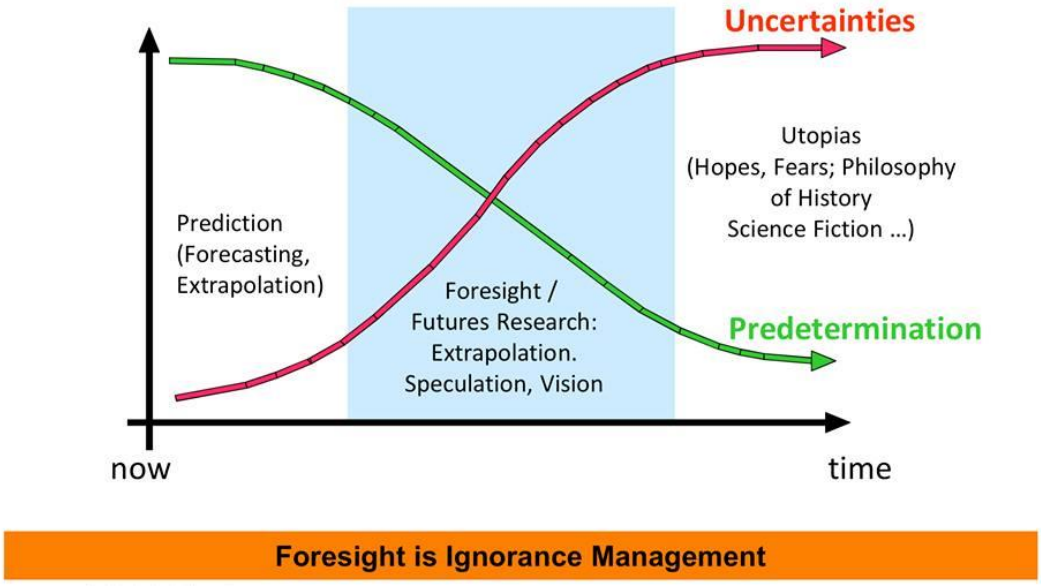


Figure 2.1: Foresight is ignorance management (Source: Z_punkt The Foresight Company).

In any case, it is important to underline that the value of futures research is less in forecasting accuracy than in usefulness in planning and opening minds to consider new possibilities and changing the policy agenda. Its purpose is not to predict the future but to help us make better decisions today via its methods that force us to anticipate opportunities and threats, and to consider how to address them.

2.1 Foresight History

"Foresight" activities are dated back to Ancient Egypt (3000 B.C.) where experts had used various techniques to produce harvest predictions. Similar "foresight" activities were practiced in the world-famous Oracle of Delphi in Ancient Greece (from about 800 B.C.), while in the following years several controversial forecasters have appeared, like Nostradamus (1503-1566). All this period, forecasting was mostly serving the natural human need to anticipate the fear of the unknown future. From the sixteenth century to the eighteenth century, a wide-range of forecasts and plans was used to improve general decision making and anticipate future trends (Jemala, 2010).

Modern foresight is built on the assumptions that 1) multiple futures are possible (i.e. that future developments are uncertain and unpredictable), 2) drivers can be identified and studied, and 3) the future can be influenced (Rohrbeck, Battistella, & Huizingh, 2015).

The birth of modern foresight (Rohrbeck et al., 2015) dates back in 1950s, with several countries initiating foresight exercises (mostly focusing on the fields of science and technology), but also corporations.

State Foresight

Initial national foresight efforts are traced back to China, the USA, and Japan around the 1950s, followed by similar efforts in France, The Netherlands, Germany and UK in the late 1980s, focused mainly on S&T[8](Jemala, 2010). A more structured application of foresight, came later, in the late 1980s, in South Korea, France, and partly UK, followed by a fast diffusion in the late 1990s.

In Europe, foresight activities became popular in many of the new member states (Czech Republic, Hungary, Cyprus, Bulgaria, Romania, Poland, Malta, Estonia) but with varying success, intensity and scale (Jemala, 2010).

So far today, Japan has one of the longest continuous histories of foresight, performed by NISTEP. The first national foresight took place at 1971 (Saito, 2017), and the process is repeated every 5 years[9], allowing the validation (or not) of previous projections. NISTEP has actually found out that more than 60% of the projections had been realized in the last 20 years (Jemala, 2010).

In the case of Bulgaria, the first-ever foresight initiative was developed, in the context of the EU funded ForeTech project, for the purpose of introducing the use of foresight as a tool for policy development at national, regional and sectoral level (Damveraki, 2011).

[8] Science and Technology

[9] The last one took place at 2015 "The 10th S&T Foresight" .

Corporate Foresight

Corporate foresight involves multiple stakeholders and aims on laying the foundation for future competitive advantage.

The birth of corporate foresight has two main routes: 1) the French "prospective" school founded by the philosopher Gaston Berger, and 2) the "foresight" school based on the work of Herman Kahn at Rand Corporation(Rohrbeck et al., 2015). Herman Kahn was initially part of the U.S. Air force producing scenarios for the strategy of opponents, and later refined scenarios and Delphi as tools for business prognostication (Schwartz, 1997, Rohrbeck et al., 2015).

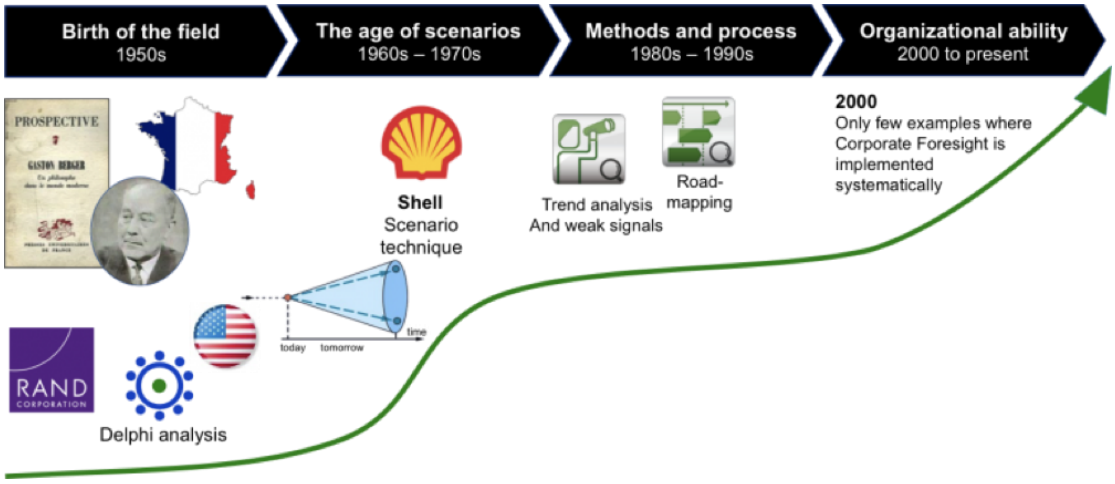


Figure 2.2: The birth of Modern Foresight (Rohrbeck et al. 2015)

The area of corporate foresight received a great push during the 1960s and 1970s by the work of Pierre Wack and other planners at Royal Dutch/Shell Group, who produced scenarios for the future of oil prices. Initially, Wack's scenarios were disregarded by Shell's directors until a critical moment that changed the history of foresight. That critical moment for corporate foresight, was the "Yom Kippur" war in the Middle East, in October 1973, that caused a global oil crisis, and knocked down the strategies of the "Seven Sisters"[10] , the 7 biggest oil companies at that time. Only the weaker of the 7 companies, Shell, was prepared to address change, reacted successfully, and quickly become the second largest and most profitable of the 7 sisters (Schwartz, 1997). Inspired by Shell's success, other companies such Motorola, General Electric, and UPS established scenario-planning processes, that became accepted as the most powerful techniques (Rohrbeck et al., 2015).

[10] Anglo-Iranian Oil Company (now BP), Gulf Oil (later part of Chevron), Royal Dutch Shell, Standard Oil Company of California (SoCal, now Chevron), Standard Oil Company of New Jersey (Esso, later Exxon, now part of ExxonMobil), Standard Oil Company of New York (Socony, later Mobil, also now part of ExxonMobil), Texaco (later merged into Chevron).

As described above, the foresight field has developed as a tool to address the growing complexity of the world and the increasing (exponentially) pace of changes. Naturally, the area of corporate foresight was further professionalised in the following decades, supported by the increasing uncertainty in the corporate world, due to globalization and the technological discoveries. It has gradually become one of the most popular strategic planning tools for establishing common visions, strategies, and long-term plans on the government and business levels among policy-making bodies and corporate managers (Jemala, 2010).

Furthermore, an interesting theory, presented by Jemala (2010), suggests that foresight has actually evolved as a consequence of increasing uncertainties related to globalization and technological progress (As graphically presented above in *Figure 2.3*).

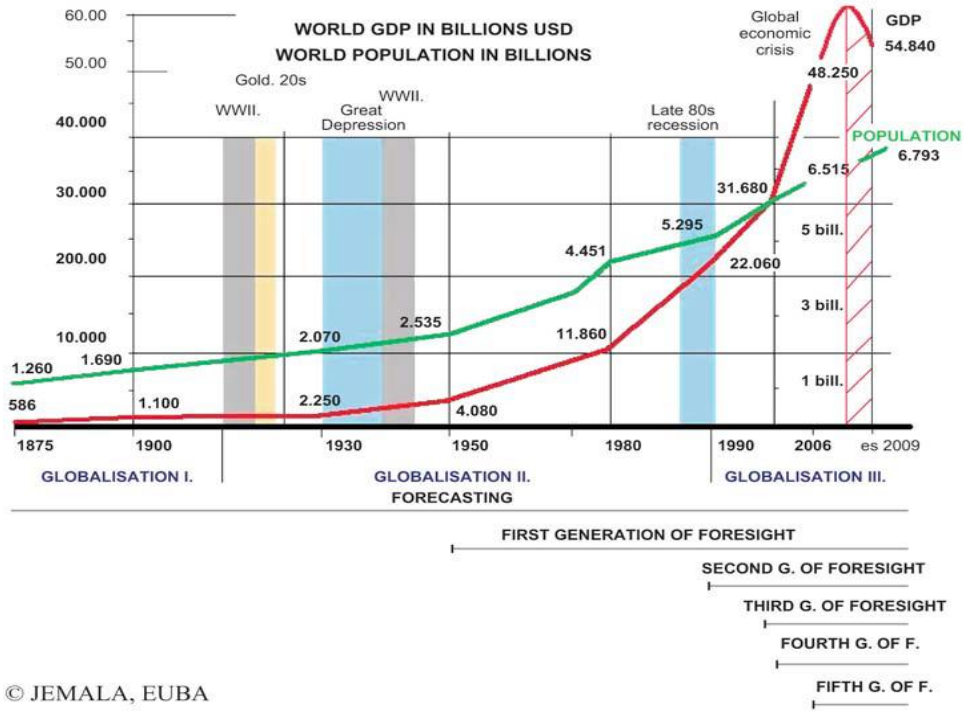


Figure 2.3: Correlation between globalization, crisis, and foresight.(Jemala, 2010).

2.2 Foresight Methodologies - Classification

Foresight studies rely on a wide variety of methods, that can be adjusted and applied in different ways. A foresight exercise is highly dependent of the methodologies selected to be used, and the skills of the foresight practitioners in charge. However, it is important to emphasize that not one method is a panacea. Each method is best suited to certain specific objectives, context, resources, culture and the mindset of the team and participants, and will prove inadequate if these conditions are not met. Each method is best suited to certain objectives, context, resources, culture and mindset of the foresight team and participants, and may prove inadequate if these conditions are not met or change.

As it is clear from the above, foresight consist of a vast array of approaches and the area has been naturally called a 'very fuzzy multi-field (Marien, 2002). The Millennium Project (Glenn & Gordon, 2009), in a study funded by the Rockefeller Institute, under the auspices of the United Nations, identifies 39 foresight methods, while Popper (2008) collects 33 foresight methods and classify them between quantitative, qualitative and semi-quantitative methods (table 2.1):

- **Qualitative:** Methods providing meaning to events and perceptions. Such interpretations tend to be based on subjectivity or creativity, often difficult to corroborate (e.g. brainstorming, interviews).
- **Quantitative:** Methods measuring variables and apply statistical analyses, using or generating (hopefully) reliable and valid data (e.g. economic indicators).
- **Semi-quantitative:** Methods which apply mathematical principles to quantify subjectivity, rational judgements and viewpoints of experts and commentators (i.e. weighting opinions).

Table 2.1: Foresight Methodologies classified by their nature*

Adapted from "Handbook of Technology Foresight" (Popper, 2008)

Qualitative	Quantitative	Semi-quantitative
Backcasting	Benchmarking	**Cross-impact analysis**
Brainstorming	**Bibliometrics**	**Delphi**
Citizens panels	Indicators / time series analysis	Key / Critical technologies
Conferences/workshops	Modelling	Multi-criteria analysis
Essays /Scenario writing	**Patent analysis**	Polling / Voting
Expert panels	**Trend extrapolation / impact analysis**	Quantitative scenarios / SMIC
Genius forecasting		Stakeholder analysis
Interviews		
Literature review		
Morphological analysis		
Relevance trees /logic charts		
Role play / Acting		
Scanning		
Scenario /Scenario workshops		
Science fictioning (SF)		
Simulation gaming		
Surveys		
WOT analysis		
Weak signals /Wildcards		

In **bold are the methodologies used in the current study*

A second classification, the "Foresight Diamond", is suggested again by Popper (Popper, 2008), that distinguish the foresight methodologies taking into account the level of creativity and interaction required for each method to be applied *(Figure 2.4):*

Creativity methods require a mixture of original and imaginative thinking and rely heavily on the skills of individuals. Examples include Wild Cards [Mendonca et al., 2004; Van Rij, 2013], or Scenario Writing.

Expertise-based are based on the skills and knowledge of individuals on a specific topic. Expert-based methods are often used to support top-down decisions and provide recommendations. A typical example is the Delphi method.

Interaction-based methods are bottom-up, interactive, and democratic offering the space for knowledge sharing and synthesis. A typical example is the participatory Scenario Workshop.

Evidence-based methods attempt to explain and/or forecast a phenomenon with the support of sound documentation. Typical examples include bibliometrics, patent analysis, and data mining.

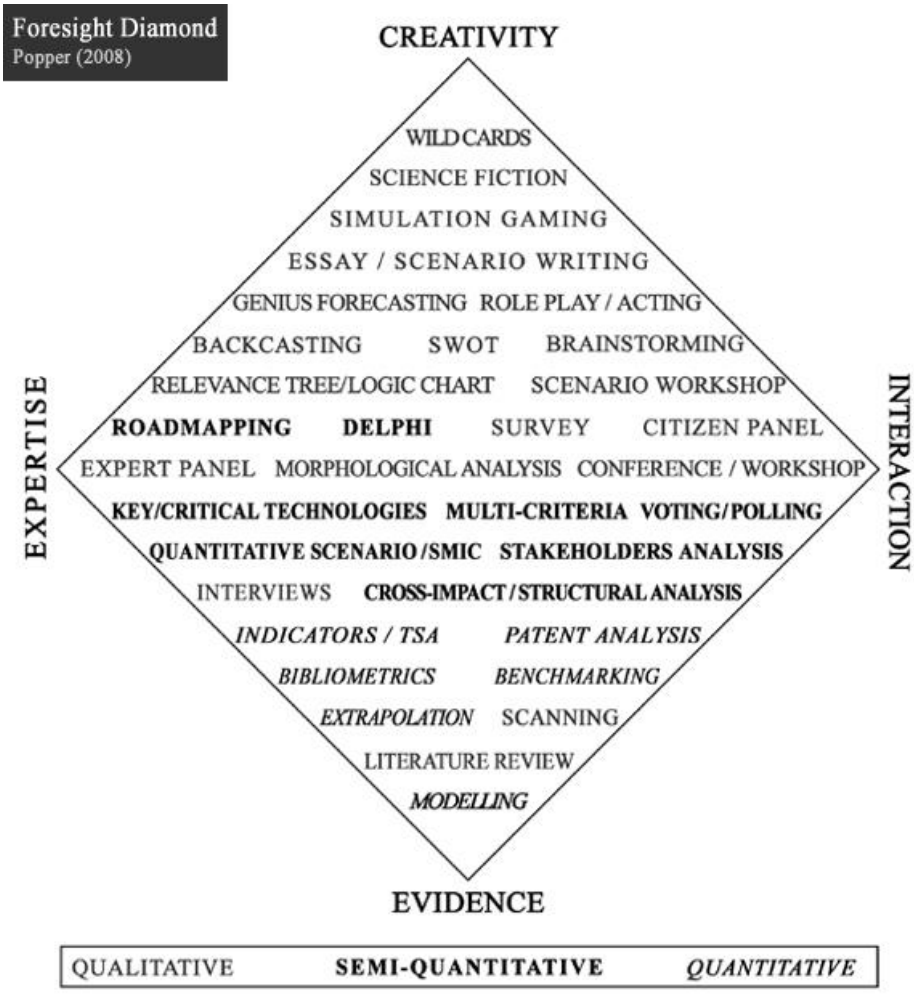


Figure 2.4: The foresight diamond

2.3 Main Methods description

Keenan & Popper (2008) performed an extensive analysis of over 800 foresight exercises performed around the world, and analysed the foresight methodologies applied. According to their findings, the foresight methodologies most frequently used are *Environmental Scanning, Expert Panels, Scenarios, Trend Extrapolation, and Delphi,* that are briefly described here:

Environmental Scanning

Environmental scanning involves observation, examination, monitoring and systematic description of the technological, socio-cultural, political, ecological and/or economic contexts of the actor in question – a country, industry, firm, organisation, etc. (Popper, 2008). A generic model of an environmental scanning process is presented in *Figure 2.5* developed by the Millennium Project for the Kuwait Oil Company (Glenn & Gordon, 2009).

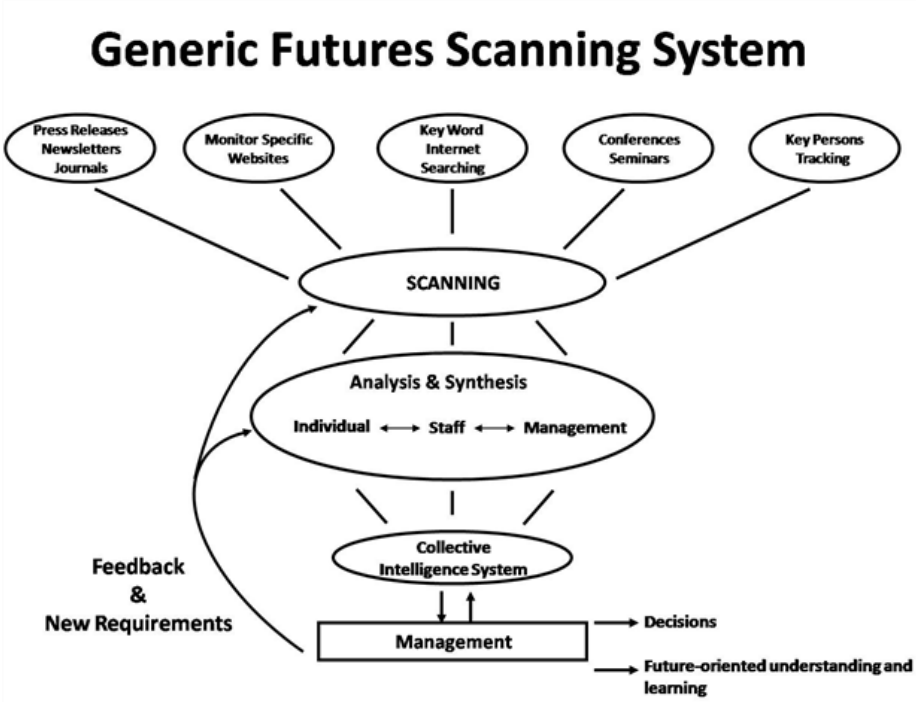


Figure 2.5: Environmental scanning of the Kuwait Oil Company (source: Millennium Project)

Expert Panels

Expert panels are groups of people dedicated to analysing and combining their knowledge concerning a given area of interest. They can be local, regional, national or international. Panels are typically organised to bring together "legitimate" expertise, but can also attempt to include creative, imaginative and visionary perspectives (popper, 2008). Participants in such a panel could be asked, systematically, to provide observations and judgments about important developments that are underway or expected

Scenarios

Scenarios are consistent pictures, descriptions, stories illustrating future situations, future scenes. In other words, scenarios are alternative descriptions of different possible futures that help decision makers consider the implications of these future possibilities

for planning and decision making today. According to the scenario methodology stories are built around carefully constructed "plots" that illustrate the differences between the three main categories of futures (Probable, Desired, Possible) (Lindgren & Bandhold, 2003).

Trend Extrapolation

This is among the longest-established tools of forecasting. It provides a rough idea of how past and present developments may look like in the future – assuming, to some extent, that the future is a kind of continuation of the past. Recently, the concept of Megatrends has become popular to refer to macro level phenomena which include various (sometimes conflicting) sub-phenomena (e.g. globalisation, ageing, climate change).

It is usually combined with *Impact Analysis* aiming to identify potential impacts that major trends or events would have on systems, regions, policies, people, etc (Popper, 2008). Almost all methodologies focus on trends and crosscutting relationships; surprises are at best treated as something additional. It may be argued that the inclusion of Wild Cards in foresight is now even more relevant than before (Glenn & Gordon, 2009):

1. **Trends**: driving forces that provide fundamental direction to the future. Trends may span from low uncertainty steady trends, to high uncertainty trends causing disruptive changes (Figure 2.6).

2. **Cross-impacts**: trends interacting with each other

3. **Wild Cards or Black Swans**: low-likelihood, high-impact surprises

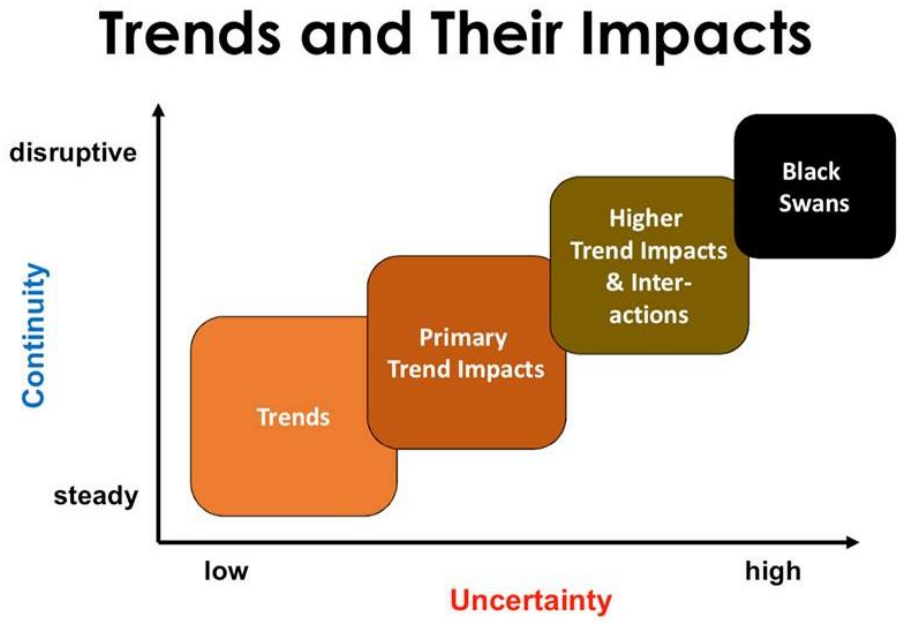


Figure 2.6: Trends and their impacts (Source: Z_punkt The Foreisght Company)

Delphi

The Delphi method marks the renaissance of the Futures Studies back in 1960s, at the RAND think tank, in Santa Monica, California (Glenn & Gordon, 2009). The Delphi method was designed to encourage a true debate, independent of personalities, that sometimes manipulate discussions in face-to face meetings, and anonymity was required in this original version of the Delphi.

The Delphi method is based on structural surveys and makes use of information from the experience and knowledge of the participants, who are mainly experts. It therefore yields both qualitative and quantitative results and draws on exploratory, predictive even normative elements. Although the basic Delphi methodology is the same, several applications may be implemented to better address the topic of research. In any case, because the number of respondents is usually small, Delphis do not (and are not intended to) produce statistically significant results; in other words, the results provided by any panel do not predict the response of a larger population or even a different Delphi panel. They represent the synthesis of opinion of the particular group, thus the selection of the experts is crucial.

2.4 Summary

Futures studies consist of a vast array of methodologies and approaches and the area has been naturally called a ‘very fuzzy multi-field (Marien, 2002), allowing wide flexibility as regards the methods used for a specific project from different foresight experts.

Glenn & Gordon (2009) have mapped around 40 different foresight methodologies (and several variations of them), that are applied in foresight projects around the world. The selection of the methods for every project, is mostly subjective and it is related with the expertise of the foresight team, and the available resources.

Furthermore, Keenan & Popper (2008) analysed the foresight methodologies applied in over 800 foresight exercises around the world, and found interesting correlations between the methods used and the political tradition of the regions or countries (open, face-to-face dialogic process versus relatively closed, anonymous data generating process.), and also with the local cultural traditions.

Nevertheless, the most important aspect is not the method(s) utilized, but to make good use of the process, and receive benefits in introducing futures thinking and improving the strategy of an organisation/corporation/government.

The value of the exercise is not developed until the end, or after the end of the process. Foresight, as with subjects like innovation and training, demonstrating the benefits in financial terms is difficult and measuring effectiveness equally so. And as with innovation and training, long-term tracking of the organization actively going through the process may be the only practicable route to assess the success of the process (Horton, 1999).

Section 2 offered a brief introduction on foresight history , the foresight methodologies and of their classification. However, as it is clear from the above, Futures studies consist of a vast array of studies and approaches and the area has been naturally called a 'very fuzzy multi-field (Marien, 2002).

Next, Section 3 provides a rather detailed overview of China's innovation environment, and the main drivers and trends shaping future developments. This set of drivers and trends have been identified during the first scoping phase of the research.

3.0 CHINA

3.1 Introduction

Ten years ago, this research would have been written on American laptop, probably designed and engineered by IBM. However, the company that revolutionized the PC market, sold its manufacturing arm to Lenovo in 2004 [Vielmetter et al. 2014.]. So here we are today, typing using "Made in China" computers, another signal of the rapid changes taking place globally, with China becoming a rising star.

Today China is the second biggest economy after USA, and is expected to become the largest economy by mid century [Fan et al., 2014; Franklin & Andrews, 2012; Hawksworth & Chan, 2013; Hu, 2011; Stephens, 2013]. In addition, China became the world's largest trading nation in 2013, overtaking the US in what Beijing described as "a landmark milestone" for the country [Anderlini et al., 2014].

What is however more interesting, especially in China, is the an on-going structural change of the national economy, based on a shifting from low-labor manufacturing, to services, internal consumption and production of high-tech products [Cyranoski, 2014; Chi, 2013]. This transformation of the Chinese economy is on-going and still remains to be seen whether China will manage to become a global actor in added-value high tech products.

During a large part of human history, China led the world in science and technology. However, western stereotypes of a backward and unchanging China have produced a rather unattractive image of the country. Yet during and after the industrial revolution China slipped far behind. It is only in the last few decades that it has once again caught up. Today, change is happening very fast and according to data announced by OECD, China is ahead of the EU for the 1st time in % of GDP spending on Research and Development [UNU-MERIT at al., 2014]. Nonetheless, the picture is complex.

It's true that China has primarly excelled at adopting technologies from elsewhere, as "fast follower", however, in some fields it is on the frontier of technological knoweledge, and the growth of published research is extraordinary. Regarding the commercialization of high tech innovative products, China with its large growth and excess liquidity is eager to invest in new technologies to upgrade its production systems (Cyranoski, 2014). China (as other emerging markets) are now completing the innovation cycle by rapidly signing deals with innovative start-ups, and by rapidly signing deals with innovative start-ups to quickly commercialize their new technologies at a rapid tempo and to scale.

Another important initiative, China's Foreign Experts Program- the 1000 talents program administered by the State Administration of Foreign Experts Affairs is playing and is further expected to play a major role in transforming China into an innovative powerhouse in the future. The plan provides lucrative incentives to Chinese nationals

who are living abroad to return to China to carry out research within their respective fields, especially in STEM (Science, Technology, Engineering and Math).

A more detailed analysis of China's business and innovation environement was performed by the author, and the main findings are briefly presented in this chapter.

3.2 China's Innovation Landscape: Driving Forces & Trends

The in-depth analysis of China's business and innovation landscape (Christofilopoulos & Mantzanakis) has revealed 16 global megatrends, national trends and driving forces that play a critical role in the future development of the country (Figure 3.1).

Figure 3.1: Megatrends, Trends, and Drivers shaping China's innovation landscape.

The 16 drivers are presented in detail in the following pages. A specific format is designed by the author, to present all the drivers with the same identical way that includes the description of the Driver/Trend, examples, any countertrends, the driving forces, the main actors, the expected future development of the trend, and the main consequences (Table 3.1). The main objective of this specific format is to provide, in a simple way, proof of the long-term importance, and impacts of the trend/driver, and to allow the reader to make further assumptions and to realize the cross-impacts.

The importance of 16 drivers[11] has been validated by external experts through the Delphi survey (*Chapter III, section 6*). The experts have evaluated and confirmed both the importance and plausibility of these drivers, and provided input for the description and the analysis of their impacts.

The description of the trends, their impacts and their future development is based on the secondary research and on the author's views based on his experience of the Chinese innovation and business environment.

Table 3.1: Format for Trend/Driver description

Driver/Trend title	
Description	A short description of the Driver, Trend or Megatrend is provided.
Examples	Examples of the driver are provided. The examples demonstrate the development of this specific Driver/Trend and/or of its impact(s). A real life example helps the reader to understand the trend/driver.
Counter Trends	Any counter trend that may reduce or cancel the impact of this specific trend/driver. It is important to identify the counter trends for understanding the main factors that act oppositely and may potentially pause the effects of this trend/driver in the future.
Driving Forces	The driving forces that act as catalysts for the development of the specific Trend/Driver.
Actors	The main actors in China or abroad, related with this specific Driver/Trend are named. e.g. In the case of China the Government is usually an important actor.
Future	An estimation of the future development of this specific Driver/Trend is provided.
Consequences	The direct impacts of the Driver/Trend are briefly presented.

[11] For simplicity we are using the word "driver" in this section, but is also includes Megatrends and National Trends affecting the Chinese innovation landscape.

The first driver to be presented is National Economy. Its main characteristics and future development is presented in the following section, using the above presented format.

Driver 1 - National Economy

Description: *The performance of the national economy is directly connected with private and public investment in R&D, and it is an important driver that will define Chinese research performance in the years to come.*

Today, China is the second biggest economy after USA and it is expected to become the largest by mid-century. In addition, China became the world's largest trading nation in 2013, overtaking the US in what Beijing described as "landmark milestone" for the country. China's fast development over the past 30 years has been propelled by cheap labour, huge savings and large scale investments, which has resulted in a widening income gap and low consumption level.

Figure 3.2: Busy crossroad in Chengdu, South-West China (Photo: Epaminondas Christofilopoulos)

The Chinese economy is currently undergoing a structural change characterized by a Shifting priority from rapid GDP growth to sustainable and inclusive growth, and from an export – oriented (cheap labour manufacturing) economy fuelled by foreign investments to one in which China's domestic market (increased consumption) is the major engine deriving growth and is based on capital-intensive high-tech and service industries.

China will probably continue its economic growth in the next decade and beyond, due to a combination of factors such as China's solid industrial foundation, newly-built world-class infrastructure, huge savings, high rates of investment (mainly foreign direct investment), large domestic market, human resource advantage, investment in education and finally, the country's commitment to making the transition towards a domestic demand-driven and environmentally-friendly mode of economic growth.

On the other hand, It will be difficult for China to maintain the same high growth rates if rapid structural changes are not implemented in order to create a more sophisticated economy, such as: tax incentives for entrepreneurial innovation, a more decisive role of the market forces in allocating resources, a further opening of the country by widening investment access, a tradable national currency (renminbi), addressing public sector debt, democratizing the domestic market, protecting IPR, etc.

Example 1: *The General Secretary of the Communist Party of China's Central Committee*[12]*, Hu Jintao, stated in his report to the 18th National Congress, that by 2020, on the basis of making China's development more balanced, coordinated and sustainable, the GDP and per capita income should be doubled in comparison to 2010, and for this, China needs to maintain an annual growth of 7.2%.*

Example 2*: Luggage sales in China can be a predictor of economic growth. Samsonite expects a growth in Chinese sales despite cooling of the economy. The company has more than doubled its sales in China in recent years, from $91.8 million in 2010 to $192.2 million in 2013 (Wassener, 2014), while expects to further double its sale Sales in China by 2022, which now account for more than 10 percent of Samsonite's total revenue (Wei, 2017).*

Counter Trends: In the 21st century, China will need to address the social and environmental costs of three decades of rapid economic growth: depletion of resources, social peace, polarization of income, shadow banking, and the increased gap between rich and poor.

Driving Forces: Bilateral economic relations, Foreign Direct Investment (FDI), technological development, cheap labour, urbanization, domestic consumption, shift in growth pattern, R&D investment, domestic capital, currency policies, etc.

Actors: Chinese Government, enterprises and institutions, foreign banks and domestic investors, etc.

Future: The economy will continue its growth but at a slower pace, overcoming some minor crises.

Consequences: In order to implement the required changes, China will need to invest more in developing domestic high-tech innovations, to secure technological exports, and to maintain a competitive advantage. Further research will be required on urbanization, alternative materials and energy. China's moving towards an open economy could create cyclical effects and economic bubbles that would affect R&D investments.

The next driver to be presented is the framework conditions for research and innovation, that are set up by the Chinese government.

[12] **Hu Jintao** held the offices of General Secretary of the Communist Party from 2002 to 2012, and President of the People's Republic from 2003 to 2013. He was a member of the 14th to 17th CPC Politburo Standing Committee, China's de facto top decision-making body.

Driver 2 - Framework Conditions (for Research)

Description: The current main guiding policies for Science, Technology and Innovation include the Medium and Long Term S&T Development Plan (2006-2020) and the Five-Year-Plans for Science and Technology Development (current plan 2011-2015). These plans aim to transform China into an innovative society by 2020. Critical challenges in environment, energy, agriculture, employment and indigenous innovation capabilities have been ranked as of highest importance. In this direction, focus will be on breakthroughs that are required in biotechnologies, ICT, new materials, advanced manufacturing, renewable energy, marine science, laser technology, and aerospace technologies.

However, the R&D framework is characterized by weaknesses identified also by the Ministry of Science and Technology (MoST), such as government micro-management in entrepreneurial activities, the lack of policy transparency and the ineffective intellectual property law enforcement, among others. While R&D investment is increasing rapidly in China, the necessary structural changes required for the modernization of the research framework are not implemented at the same pace. Issues of openness (thoughts, ideas, etc.), the strict hierarchical order, the questioned system of incentives, research integrity, the malfunctioning funding system, and the limited interconnection with business world, are issues which need to be addressed.

The final outcome of the national effort to catch up with the leading technology and innovation countries is still questioned, and is directly related with several parameters like:

- The set-up of policies focused on effective competition;
- the structure of the business sector and its strategic orientation towards innovation;
- the ongoing modernization of the current agile regulations that will allow the economy to seize opportunities, and address any crises;
- the skills development effort, that includes policies in all levels of education;
- the strengthening of national and international networking to promote innovation;
- the nurturing of innovation in major urban centres in key priority areas (green technologies, health and medical services, urbanization technologies).

Beijing is planning and slowly implementing regulatory and structural reforms for improving the efficiency of the current system, however the success of the current plans and the pace of the reforms are under question.

Example 1: *The Minister of Science and Technology, Wan Gang*[13]*, at the 18th National Congress of the Communist Party, declared that the top priority is the building of a transparent system for the management of research funds.*

Example 2: *Change is coming to the institute that has been at the heart of China's scientific development since the communist State began. The Chinese Academy of Sciences (CAS) is making unprecedented structural reforms to foster collaboration and turbo-charge research.*

[13] Wan Gang is former president of Tongji University (2002–2007) and the Minister of Science and Technology since 2007.

Counter Trends:

1. Openness: Openness in a broad sense, including thought, expression, social acceptance, attraction and retention of the brightest foreign minds.
2. Confucian legacy: In "western" society, the values of independent thinking and dialectic discourse are deeply ingrained, while the Confucian legacy in China demonstrates a strong respect for the hierarchical order.
3. Publication incentives: The current scientific publication incentives system that besides others, rewards publications with bonuses that excess $30,000, leads to cases of academic corruption and abuse of funds.
4. Technology Transfer bureaucracy: Lengthy procedures for State-owned institutions to commercialize research results.

Driving Forces: Policy changes, cultural changes, global communications, CAS reforms, R&D funding, large enterprises & SMEs, international collaborative research.

Actors: Ministries, research institutes, academies, regional & local government, private sector etc.

Future: Strong government policy and investments will continue to guide research, but will also limit it, unless important framework changes take place. In the case of social unrest, research will also be affected. China's large market size will allow rapid scaling up of successful technologies to achieve economies of scale and reduce unit costs.

Consequences: China can become a high-income country by 2030 through a strategy which combines high levels of investment with rapid advances in disruptive technologies. China's spending on R&D is on a steep upward trend. This spending will increase the generation of ideas and foster innovation.

The commercialization of ideas will flourish and drive productivity only when enterprises make innovation a central axis of their business strategies. Capacity building of Chinese workforce will be enriched, the potential gains in reputation for Chinese cities will come to be seen as science hubs, and research can greatly contribute to industrial upgrading. An increase in R&D is being complemented by investments in the physical infrastructure supporting technological upgrading.

The next driver to be presented is the private sector investment on R&D, which is the main R&D investor in China. In 2016, 130 Chinese companies were among the list of the Global Innovation 1000 (from 123 in 2015) (PricewaterhouseCoopers, 2016).

Driver 3 - Private R&D Investment

Description: China is still an absorptive state, attracting and profiting from global knowledge. However, in order to maintain a substantial growth rate, China is obliged to become an industrial leader, investing in novel technologies and ideas.

In China business-funded R & D accounted for the largest share of total R&D expenditure, close to 75% of the total in 2014 (EUROSTAT, 2017). As the R&D spending by European and Japanese companies declines, Chinese companies are in the leading position as their R&D spending growth increased at 18.6%, higher than the 8% growth of North America (PricewaterhouseCoopers, 2016).

As a result: 1. High-tech exports of private Chinese companies (non SOE[14] & foreign) have increased (although there is space for further increase), 2. New international technology-based brands have been flourished, and 3. A steady growth in the number of trademarks registered overseas has been witnessed.

The private sector in China will invest more on R&D by 2025, as Chinese companies are increasingly focusing on efficiency and quality, so as to become technology leaders and not only technology and ideas absorbers. SOEs in China have currently edged EU 28 in terms of R&D intensity, falling behind Korea, USA, Japan and other OECD countries, but heavily spending to catch up with an annual growth rate of 18% since 2000. Enterprises have become the main players regarding R&D output, reflecting China's push in terms of IT, electronics, photo electronics, microelectronics, telecommunications (e.g. 5G), health, automotive, railways, aerospace, defense, energy (including nuclear), and manufacturing industries.

Example 1*: In 1995, 63.4% of the total transactions on the technology market were realized by enterprises. By 2009 that percentage had risen to 77.3%. In 2009, 86.6% of all contracted technology was exported by enterprises (both joint ventures and domestic).*

Example 2*: BASF recently announced a new $110 million expansion of its innovation campus in Shanghai. By 2020, around 25% of BASF's R&D staff will be based in China (Wilson, 2014).*

Counter Trends: Slowing economic growth, accompanied by the stressed financial situation of companies (especially private), who already have steadily falling returns on investment. In addition, a foggy IPR system could make them reluctant to invest in R&D and other long-term projects, preferring short-term activities away from basic research and start-ups.

Driving Forces: Property and IPR rights' system and laws, financial system and capital availability even for high-risk innovative projects, education and research framework, China's position in global value-added chains by developing and producing high-tech products.

Actors: SMEs, State-owned enterprises, large and medium-size enterprises, regional and Government funding, Venture Capital and other funds, foreign investors, Foreign Multinational Enterprises

[14] State Owned Enterprises

Future: Private R&D investments will continue to increase addressing technological needs and future challenges. China will transform into a competitive producer of high-tech products and services.

Consequences:

• More competitive companies

• National Economy improvement

• Increase in venture Capital companies and funds

• Increase of the stock market alternatives for high-tech and high-risk investments,

• Competition with the rest of the world for highly-skilled manpower will remain intense,

• More Chinese brands will compete in the global market,

• R&D activities will be added to corporate innovation strategies, especially for firms active in ICT, Agro, Biotech, Energy, Materials, Environment, Aerospace, etc.

Ensuring the safe flow of energy and raw resources is a key government priority in China. This is Driver No 4, that is presented next.

Driver 4 - Energy & Materials

Description: As the Chinese economy continues to grow, the need for (cleaner and more efficient) energy and the quest for raw and alternative materials are rising. At the same time, the globally growing scarcity of natural resources (petrol, water, and rare earth materials) will add additional pressure on efficient use of resources or producing alternative materials.

China is the world's most populous country and the largest energy consumer in the world. Rapidly increasing energy demand has made China extremely influential in world energy markets. Coal is a highly important energy source for China, and China is the largest producer and consumer of coal in the world, accounting for almost half of the world's coal consumption. Naturally, China's electricity generation is dominated by fossil fuel sources, and especially coal.

China is the world's second-largest consumer of oil behind the United States, and the second-largest net importer of oil as of 2009. At the same time, China's largest oil fields are mature and production has peaked, leading companies to focus on developing largely untapped reserves in the western interior provinces and offshore fields. The Chinese government has made the expansion of natural gas-fired and renewable power plants as well as electricity transmission a priority. China possesses the world's largest capacity for renewable energy generation. It is a world leader in small hydroelectricity generation. It has been doubling its wind-driven turbine capacity every year since 2005. In addition, it has become the world's largest manufacturer of solar panels. However, renewable energy sources might prove to be incapable of dealing with the increasing energy needs. It should also be noted that China is currently a moderate nuclear energy producer; while government plans nuclear capacity to reach 70 GW by 2020.

There is an increasing desire for rare earth metals, fueled by the increasing demand from local industries. China has reduced or even banned the export of some scarce raw minerals and is investing in land mines in Africa and other continents.

Furthermore, climate change, resource depletion and biodiversity risks will increase investment in key areas of low–carbon and sustainable innovation, that will enable China to lead globally in these sectors as they grow.

Concerned that past and current economic growth patterns are environmentally unsustainable and that the environmental base needed to sustain economic prosperity may be irreversibly altered, the Chinese authorities proposed a new approach toward green development in the 12th Five-Year Plan. The plan emphasizes continued rapid growth, together with ambitious targets for energy efficiency, natural resource management, and environmental sustainability.

Example 1: *The Three Gorges Dam hydroelectric facility, the largest hydroelectric project in the world, started operations in 2003 and completed construction in 2012.*

Example 2: *In 2012, China invested US $65.1 billion in renewable, a 20 % increase from the previous year.*

Counter Trends:

• Excessive dependence on administrative mechanisms to deal with environmental and natural resource management issues.

• While a green development strategy will be of considerable benefit in the long run, in the short term it will conflict with other economic objectives (for example, meeting employment and industrial targets for the five-year plan).

• A slower financial growth or a financial meltdown will delay the developments.

Driving Forces: Scarcity of resources, uneven geographical distribution of water resources; rapid economic development and urbanization with a large and growing population; poor water resource management, climate change and other environmental problems, energy demand, new technological breakthroughs.

Actors: Government, Chinese industries, society, regulatory bodies, International Organizations

Future: This trend seems quite certain to continue at a similar pace as the demand for energy and resources will steadily increase until 2025.

Consequences:

Technological breakthroughs, unpredictable as they may be, are more likely in some areas, (such as clean water, energy storage, and biotechnologies), than in other less critical areas.

• New business opportunities will be created in the areas of alternative materials and energy production and storage, but much will depend on how effectively government policies will motivate firms to innovate and seek technological breakthroughs.

• NOCs (National Oil Companies) are going to invest more in Enhanced Oil Recovery (EOR) techniques. In order to secure and diversify energy supply, and to develop technical expertise in unconventional resources, Chinese NOCs are expected to invest in international projects and form strategic commercial partnerships with IOCs (International Oil Companies). It is particularly expected to increase investments in Middle East, Africa, Latin America, North America and Asia.

• China is building 40% of the world's new nuclear plants, and plans to increase its nuclear power by 20 times over the next two decades and lessen its dependence on coal. A relatively new technology "is expected to become more important by 2025" (Schwartz, 2011). A technology like pebble bed reactors or Gen IV nuclear power plants that can burn nuclear fuel without producing plutonium. China has already been investing in this technology and is likely to invest more in the future.

• The hunger for oil will be the cause for conflict and for increasing territorial disputes in the East China Sea (China-Japan) and in the South China Sea (especially China-Vietnam). Refer to the recent developments between Japan and China.

• Of highest importance will be the research on alternative materials. It is already recognized as a priority area by the CAS. New super-strong biological materials could take the place of steel and ceramics, while fairly complex products could be produced with the use of biotechnology-based processes.

• Nanotechnology – using nanofiltration technology, nanomaterials and nanoparticles in the areas of desalination, water purification and wastewater, treatment and using nanosensors to monitor – shows particular promise for water resources management.

• To meet its seemingly limitless electricity needs, China is turning to its solar industry, which already leads the world in panel production, and is gearing up to produce gigantic solar plants.

• Efforts for the production of hydrocarbon fuels from bacteria will be reinforced, and production could be expected to start around 2030.

The key actor in China is the government that comprises of a complex top-down pyramid with central, regional, and local actors. Governance is the next driver to be presented.

Driver 5 - Governance

Description: Chinese officials aim for the country to be able to enjoy stable governance and peaceful society for the years to come. Authorities have defined the meaning of the Chinese dream: national prosperity and a better life for the people, by doubling the GDP and per capita income so that by 2020/2025 China will be become the world's biggest economy, and a more harmonious nation, with socialist modernization, and with Its military and economic strength playing an even more important role on the global stage.

A strong government (national and regional) policy and Investment will continue to guide research, but will also limit it, unless important changes take place, acting on or reacting to several challenges, addressing difficult political reforms, like avoiding the "middle income trap", balance between the official centralized planning methodology and a decentralized one, and the move from an economy based on export-oriented labor intensive industry to one based on capital-intensive high-tech industry

During the last few decades, the performance of the Chinese government has been considered successful if one takes into account the impressive development of the country. There is however great uncertainty with regards to future prospects for greater transparency, fair justice and better protection of civil rights [The World Bank, 2013]. Chinese civilization has a long and influential history and still the Chinese government and people are committed to continuing and expanding China's influence on the progress of humanity. In 1978, China gradually stepped onto the road towards establishing a socialist market economy system. Entering the 21st century, it embarked on a new development stage, starting the full-scale construction of a modern and harmonious society by pursuing its policy of reform, opening up its market and rebuilding the nation.

On November 8th, 2012 China began the once-a-decade process of changing its leaders, with the launch of the 18th National Congress of the Chinese Communist Party (CCP). Mr. Xi inherited an economy that is likely to have recorded its slowest rate of annual economic growth since the late 1990s. He believes that it is time for China to become a "moderately well-off" society with "economic opportunity for all" and focus also on "social harmony", dreaming of the rejuvenation of the Chinese nation as a strong and prosperous party-state that has global influence. The new leaders of China are young, ambitious, experienced and result-driven. Government efforts will continue to promote reforms designed to build an innovative and corruption-free government under the rule of law.

China's political system is complex. The country is essentially run by two parallel systems of government that interlock at every level: the CCP hierarchy and the State one. The Chinese system-unlike that of the Soviet Union-is mixed and flexible and, despite imperfections, is designed to serve the nation and its people. The CCP could be described as a deeply meritocratic institution, a characteristic that is rooted in the Confucian political tradition. According to this tradition, CCP practices- not always successfully – meritocracy at all levels of governance and thoroughly and constantly tests its people's skills and talents to ensure successful management (Weiwei, 2012). The main modern guiding socio-economic principles that set the governance principles in China are described in the "Scientific Outlook on Development". The "Scientific

Outlook on Development"[15] shifts the focus of the official agenda from "economic growth" to "social harmony" and describes the way forward.

The government employed a mix of fiscal, administrative, and employment policies to maintain social stability during a period of rapid economic and structural change. Changing the development model is an urgent issue because the economy has exhausted the potential for acquiring and applying technology from abroad, the role of the government needs to change fundamentally. As enterprises take a leading role, the government needs to adopt a more supportive and facilitating role.

A better innovation policy in China will begin with a redefinition of government's role in the national innovation system, moving towards institutional development and an enabling environment that supports economy-wide innovation efforts within a competitive market system. The Chinese government should take urgent measures to ensure that every Chinese enjoys economic opportunity.

Example 1: *The "Great Firewall" is China's nexus of surveillance and censorship that checks for anti-government activity and allows or blocks access to specific sites. Currently in China, Facebook, Twitter and Instagram are blocked, while access to Gmail is problematic. In this context, it seems to be a trend, especially between domestic social networks (E.g. SinaWeibo) to apply self-censorship (Ansfield, 2012).*

Example 2: *At the 12th National People's Congress on 10 March 2014, Zhou Qiang, president of the Supreme People's Court warned that corrupt judges damage litigants and the credibility of the court. With the backing of the President Xi Jinping, Mr Zhou called for the establishment of "an impartial and authoritative socialist judicial system" (Board NYT, 2014).*

Counter Trend: It's well known that implementing reforms in China is a complex matter and most likely a dominant one over the coming decades. In this context it is only wise to keep peoples' expectations modest. Although the new leadership team has already clearly demonstrated that it is very different from the previous administration and could find a way to buck history and surprise us on the upside., some signs that this is going to be extremely difficult exist. One such pursuing reform is the interested implementation of the Shanghai Free Trade Zone (SHFTZ), which was envisioned by the state as a good practice to be followed in the future, but ended up not only generating much speculation that the leadership was following the timeworn practice of confining economic experimentation up to the limits of a pilot project but also arose vast dissatisfaction among investors unable to participate in the zone. Chinese history has shown that many times produced unplanned consequences, which required far more extreme measures to contain the chaos.

Driving Forces: Co-operation inside CCP party; transparent state and regional structures; public participation in decisions; middle class reactions; income gaps and other disparities; external international environment.

Actors: Government and local authorities regions and big cities, party officials, public sector enterprises, actors of innovation, cultural institutions, intellectuals, middle class

[15]The **Scientific Outlook on Development**, is one of the guiding socio-economic principles of the Communist Party of China (CPC) and the central feature of former Party General Secretary Hu Jintao's attempts create a "harmonious society."

Future: This is a very uncertain trend. The State will try to push and continue in the same direction due to substantial reforms in governance and in the juridical system, combined with substantial improvement in civil rights. But when, how and what would be the results will certainly be different from what will happen in real life. The question arises whether China is able to maintain a socialist rule while at the same time boost open innovative environment; given that it is a goal that its leaders want to accomplish soon.

Consequences: More transparent policy making and judicial system, open innovative environment, increase in high- tech patents, consuming innovative products will rise exponentially, global cooperation will increase

Urbanization is a huge global Megatrend, but at the same time is also an enormous trend in China driven by a strong governmental policy to move people out from rural areas to the cities. This trend and its impacts are described in the next section.

Driver 6 - Urbanization

Description: China's urbanization over the past three decades is a massive phenomenon of scale and speed. In the 1980′s, in a very much "different" China, there were fewer than 200 million inhabitants in "urban" areas (a fifth of the total population). However, by 2011, 700 million inhabitants (half of the total population) were living in urban areas, while the figure is expected to further grow in the future, as 250 million migrant workers are expected to move to the cities by 2030. The main driver behind this massive population move is the urgent need to transform the economy and society from a rural, agricultural society to an urban, industrial one, and from a command economy to a market-based one (Chi,2013).

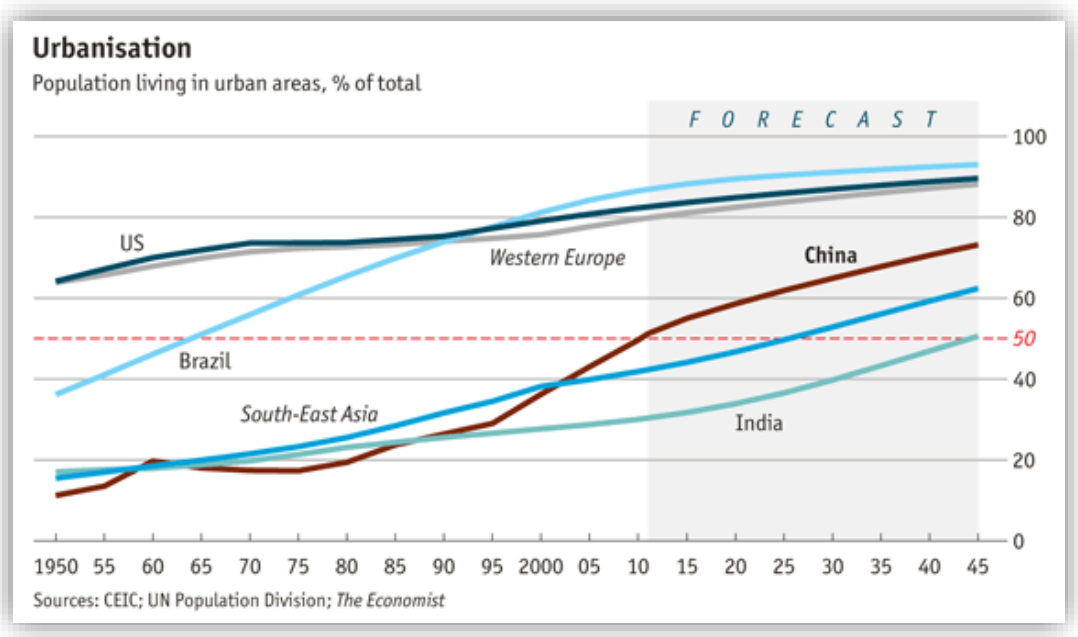


Figure 3.3: Urbanization trends (source: The Economist)

At the same time (2010), total sub-national government debt has reached 26% of GDP, according to the National Audit Office (Fromlet, 2013). Such indirect borrowing played a key role in financing important infrastructure investments and thus supporting industrialization and urbanization. Debt financing will remain important for China's urbanization drive, which demands continuing large infrastructure investments (Miller, 2012, & Orlik, 2013).

In addition, the urbanization process has caused many serious side effects (e.g. environmental and social implications) and urged the need for changes in the household registration system (Hukou), in land ownership regulations, and in land transfer mechanisms.

Example 1: *Urban residents spend nearly four times than rural residents. In 2010, rural residents spent US$600 per year.*

Example 2: *52% of the Chinese population lived in cities in 2012, but only 27% of them had an urban "Hukou", or household registration. This means that large numbers of people do not have equal access to services reserved for the urban population, such as education and health care.*

Counter trend: Environmental degradation; unbearable economic burden for cities budget; Slow modernization of the regulatory framework; Slowdown of the economy; insufficient restructuring of social security systems.

Driving Forces: A **c**entrally-managed process to boost domestic consumption and reduce costs. The need to improve the quality of human capital. Better paid urban jobs.

Actors: Government, Migrant workers, Urban Middle Class

Future: By 2025, China is forecasted to have 200 cities with populations of over one million (while America has 9), and about 60% of China's people will live in cities (UN estimations). Moreover, the urban middle class (and middle income) is expected to double from the current 23% to about 45% of the population.

Consequences: During the 12th Five-Year Plan period (2011–2015), the country is expected to invest US$ 300 billion in basic infrastructure. But this strong urbanization trend will also require further research on new urban technologies and applications (e.g. transportation systems, environment, efficient energy, housing, water sustainability, urban agriculture, ICT tools). So far Europe is a leading provider of urban technologies, but China is moving fast, utilizing its vast research capacity and the availability of a huge test bed.

Finally, a growing urban middle class will further increase domestic consumption and expand the request for life-style products and services.

It is broadly accepted that the provision of a level playing field for all citizens is crucial for creating the necessary conditions for the innovation and research to flourish. Thus, Human Rights is the next driver to be presented in the next section.

Driver 7 - Human Rights

Description: The last few years have witnessed a mixed picture of progress in human rights conditions in China. On the one hand, several human rights reports have stated that China's record has remained rather poor. None of the groups suffering the greatest persecution have experienced notable improvement in overall treatment, according to these reports. On the other hand, the Chinese government has established laws aimed at reducing some of the most serious human rights abuses, protecting property rights, and promoting government transparency, and continued to develop mechanisms for consulting with non-State policy experts. In addition, the Chinese Communist Party (CCP) and local governments have considered or have already taken minor steps towards abolishing the re-education through labor system or laojiao[16] , making elections more transparent, and enabling rural migrants to gain official residency status in some large cities.

Freedom of speech and human rights are affecting research and innovation performance in different ways. China will not be able to become a global technology leader until it moves towards freedom of expression and encouragement of critical thought: 1) free society encourages people to be skeptical and ask critical questions, 2) innovation is mostly the product of individual thinkers through a bottom-up process, 3) free society attracts foreign talent.

Different driving forces are pressing towards improvements, however to break the current status quo will not be an easy task. In the last five years, China's urban middle class have become vocal in defense of their property interest, the environment and their overall wellbeing, urging for changes.

In the same direction, the Chinese leadership is displaying a will to improve the country's old-fashioned legal system, aiming to establish a system that will safeguard people's rights and interests. Furthermore, the State has invested tens of billions of dollars to build a fast, cutting-edge national internet infrastructure, aiming to bring China into the information age.

Nevertheless, it should be underlined that any changes are not necessarily towards a western-style democracy. China follows a different political model based on meritocracy and not on popular election. Meritocratic governance is deeply rooted in China's Confucian political tradition, and the future will probably see improvements of the current system including opinion surveys, internal evaluations, and small-scale elections.

Example 1: *At the 12th National People's Congress (10/3/2014), Zhou Qiang, President of the Supreme People's Court, warned that corrupt judges damage the credibility of the court and, having the backing of President Xi Jinping, proposed specific reforms that will transfer power from provincial authorities to the central government.*

Example 2: *On-line discussions have occasionally led to systemic political change. In March 2003, Sun Zhigang, a migrant worker, was beaten to death by the Guangzhou police. The case has received widespread publicity in chat rooms and microblogs that eventually brought six police officers and officials to justice.*

[16] *Re-education through labor (RTL), laojiao, is a system of administrative detentions which is generally used to detain persons for minor crimes such as petty theft, prostitution, and trafficking illegal drugs, as well as religious or political dissidents such as unregistered Christians or Falun Gong adherents.*

Counter Trends: Censorship, corrupt judicial system, Resistance from CCP members or other political groups

Driving Forces: Internet, rising urban middle class, globalization

Actors: Chinese Government, Chinese Middle Class, Civic institutions, NGOs (e.g. Amnesty International), International Organizations.

Future: Besides some positive signs, the future of civil rights in China remains highly uncertain. A slow process of moderate improvements is expected, but drawbacks cannot be excluded.

Consequences: The quality of the performed research and the capability of China to innovate are directly connected to human rights conditions in the country, and the freedom of communication, and of travelling

In today's interconnected world, the growth or decline of the global economy has direct effect on the national economies. This driver is going to be presented in the next section.

Driver 8 - Global Economy

Description: Global growth by 2025 will accelerate thanks to the contribution from the emerging economies. On average, annual growth is projected to be accelerating towards 3%, while China and India will be two of the largest economies in the world. Considering growth driving factors such as the size of the Chinese work force, the ongoing convergence in the productivity levels with the U.S. and the strengthening of the country's currency exchange rate, China along with India and other emerging economies are very likely to dominate future growth. Even if China's population will reduce and be aged, its productivity would still remain ahead of the US. Other growth inducing factors such as Yuan evaluation, high savings rates and investments could boost development higher, around 5-6% for the next 15 years according to many scholars.

Globalization used to be everyone's favorite word. Technology breakthroughs, cost reduction, liberalization of policies and asset investment around the globe were some of the signs and basic parameters that boosted global economy. Although this was not the first time in the world's history that international trade of products and services was so open and free, some incidents like the internet bubble, the terrorist attacks on 9/11 and the recent financial crisis that hit severely mainly the western countries, hindered the increase of international transactions.

As the global value-added chains for products and services became more sophisticated, complicated and fragmented, the recent change in the rate and scope of globalization, has brought some negative consequences, mainly in the countries hit by the crisis. Enterprises and countries today are more interconnected, and countries that are open, (having improved their policies and legal systems), would most probably continue business as usual – just as before the 2008-2009 crisis. The world would most probably continue the same way, but more cautiously, since this is a major trend in the global arena.

Example: *China, India, Malaysia, Thailand and Indonesia all demonstrate rapid rates of growth and as their education and policy systems develop, these are likely to be sustained over our forecast horizon.*

Counter Trends:

• Capital and money markets have already forgotten the recent crisis, and are all experiencing increases in asset prices, as high-risk offerings are looking for better yields, due to increased liquidity in the financial system.

• Increased income gaps at a global level could create protectionism.

• High insecurity increases costs and time for processing trade and other free services around the world, diminishing the benefits of globalization.

Driving Forces: Financial liquidity, demographic changes, local conflicts, resource scarcity, climate change, large income gaps, a seismic shift in the global attitude: 'me' versus 'us' mentality.

Actors: Global Institutions, Markets, countries, social movements.

Future: The world economy could grow and emerging economies like the BRICS might be underpinning such growth. Global institutions could create safety nets mainly in the financial products sector for the benefit of global balance. The recently reduced globalization pace could on the one hand reduce the growth rate, but on the other, could

impose some ethical rules to avoid future intense incidents. In this respect, China will be the main engine due to the considerable increase of the middle class, savings and investments in addition to being a trusted member in the global value-added chains.

Consequences: More income for the middle class could create a huge market for new high-end tech products; copying western values could increase start-ups and entrepreneurship, but could also decrease the 'us' value.

As China grows stronger in economic, political, and military terms, it is expected to use this power in the global geopolitical arena. The next trend refers to the possibility of new regional tensions due to this power shift towards China.

Driver 9 - Peace & Conflict

Description: This trend refers to the cases of regional tensions, verbal confrontations, and small-scale armed conflicts that have been tending to increase during the last decade.

Most analysts believe that, as China continues to grow economically, it will attempt to dominate Asia the way the US dominates the Western hemisphere, driven by the need to secure more resources. An immediate effect of this situation is growing defense spending in the region, following the growing wealth of the South East and East Asian countries. In 2013, Asia spent $232bn on military budgets, up from $262bn in 2010, with China growing more dominant (military spending in China grew 43.2% from 2008 to 2013).

It should be noted that the biggest risk for the future a possible accidental killing that could escalate a small- scale incident into a minor armed conflict.

Example 1: In 2010, China held the biggest ever naval exercises in the South China Sea. For the first time since the fifteenth century, China has a predominant naval presence in the southern seas.

Example 2: An on-going dispute between six countries that claim the oil-rich Spratly islands in the South-East China Sea has been a catalyst for military investments, especially for ships and submarines.

Example 3: The recent (2013) tension between Japan and China has seriously hurt Sony mobile phone sales in China, which fell dramatically according to data from IDC researchers. Sony had to increase its marketing budget by 50% to address this issue.

Counter Trends: US-Japan-EU coalition.

Driving Forces: Need for (energy) resources, Rising power of China

Actors: China, USA, EU, Japan, Russia, South Korea, North Korea, Vietnam, Malaysia, Singapore, Philippines, UN, ASEAN, NATO.

Future: A more powerful China can be expected to try to push the USA out of the Asia-Pacific region. Beijing's neighbors (India, Japan, Vietnam, Singapore, South Korea and even Russia) will eventually join with the US to address Chinese power. This will increase regional tension, insecurity and the risk of war.

Consequences: The escalation of conflicts (even without any serious incidents) will affect the regional economics (especially imports and exports of consumer products). The situation will drive an arms race and will focus research on defense applications, aerospace, vehicles, communication, but also on alternative energy sources and materials. It is also expected that there will be a request for co-development of defense technologies. This will also mean that the defense industry has to adapt to the needs of the Asian countries and this might prove to be either an opportunity (defense sales) or a serious risk for Europe.

Another possible consequence from the escalation of regional tensions, especial for multinational companies based in China, is the imposition of embargos from the international Community or various penalties from Beijing.

In relation with the previously presented driver, China is heavily investing on Space and Defense technologies. This driver is presented next.

Driver 10 - Space & Defense

Description: The space exploration and the further development of defence technologies are going to be important drivers for the Chinese research by 2025. China, recently, became the third country to guide a spacecraft onto the moon (Vance, 2015), while has even more ambitious plans for a manned mission to moon.

Space exploration, for China, will be a key driver for enhancing technological expertise, military strength and country status.

Peter Schwartz suggests that it is plausible to see, in the near future, a new space race, with China playing the role of the Soviet Union during the 60′s. We also might see a race to Mars or to stake claims to mineral rich Asteroids.

At the same time, the strategic upgrade of the operational capacity of the People's Liberation Army (PLA), will boost defense related research. We have seen during the last years the deployment of the first Chinese aircraft carrier, and the tests of intercontinental missiles, as well as new war airplanes. The military power it is a necessary tool for China, as re-entering in the global politics arena.

Example: *The Chinese Navigation System, called Beidou, came from a technology partnership between Beijing and the European Union. The Chinese essentially supported the European satellite-navigation initiative, called Galileo.*

Counter Trends:

• An agreement with other space agencies (US, EU, Russia) for common missions might reduce pressure.

• In the event that Japan, China, Vietnam and South Korea reach an agreement for the exploitation of the East and South Chinese seas, then the most important regional tension will relax. The same stands for the situation with Taiwan.

Driving Forces: National pride, exploitation of mineral rich asteroids exploitation of the fossil fuels in the South East Chinese seas, emphasizing power, supports the national foreign policy, support China's Vision.

Actors: PLA, Chinese Government, South Korea, Japan, Vietnam, Taiwan, Global community.

Future: Very likely continuation in the same direction. Serious risk of small scale regional conflicts that could be potentially escalated.

Consequences: Increased need for technologies on telecommunications, navigation, military, space, aircrafts, shipping, etc.

A conflict will affect the national economy, foreign investments, reduce investment on research and transfer focus on defence industry and related research topics.

Both local (in China) and global environmental problems enjoy great interest, and are the focus of policies and research efforts. This trend is presented next.

Driver 11 - Environment

Description: Local environmental problems (e.g. atmospheric pollution, contaminated water) and global environmental implications (e.g. climate change) will affect research in China by 2025. Moreover, China is expected to become a test bed for new environmental technologies.

The trend is closely related to the heavy and rapid industrialization process that took place in China during the last 20 years, while it is also fueled by the on-going centrally-driven Urbanization process. New sprawling cities are rapidly emerging, meaning land competition for residential use, longer commuting times, climbing carbon emissions, and choking pollution.

It should be also underlined that environmental activism is a growing trend in the Chinese society (assisted by the rise of microblogs), and it's further feeding the need for radical solutions in the environmental problems. At the same direction is the pressure put by the rising of the urban middle Class in China that requires a clean and secure environment.

Finally, we shall expect greater global pressure on issues related to climate change, which could require serious changes in the production processes and on the mitigation of the climate change effects. The pressure could come by global organizations (e.g. UN) or in the form of regulations e.g. from the EU.

Example: *The regular smog events in Beijing have raised awareness and have great pressure on the government to deal with the air pollution issue. The Institute of Public and Environmental Affairs (IPE) is a non-profit organization that has developed two pollution databases (water & air) to monitor corporate environmental performance and to facilitate public participation in environmental governance (www.ipe.org.cn).*

Counter Trend: If the government addresses seriously the environmental problems, this might reduce future pressure.

Driving Forces: Safer and better environment, government plan for "Beautiful China"

Actors: Urban Middle Class, Public Awareness, Activism, NGOs, Microblogs, UN, EU, Government, 77 environmental protection courts nationwide, International Organizations

Future: Very likely continuation in the same direction.

Consequences: Increased need for technologies to deal with air pollution, contaminated land & water, low carbon alternative energy sources (not coal), smart and greener transportation, etc.

The "one child rule" in the past decades and the gradual transformation of the modern Chinese society is creating a demographic bomb, that will be explained in the next section.

Driver 12 - Population (*Demographics*)

Description: In the years to come, China is expected, by most analysts, to face a huge demographic shift. It will be acute and rapid and will raise future challenges, not only to social policies, but also to the economy. With rising life expectancy and with total fertility rate very low, China is "growing old before growing rich".

As the population ages, the growth rate of the labour force will slow down, and in some cases it will even decline, leading to higher dependency ratios and lower growth. The old-age dependency ratio[17] (Figure 3.4) will double over the next 20 years (The Economist, 2012), reaching that of USA and Scandinavia's level today. Both the 11th and 12th Five-Year Plans recognize the limitations of the current growth model and place emphasis on addressing inequality and enhancing the basic safety needs of the population.

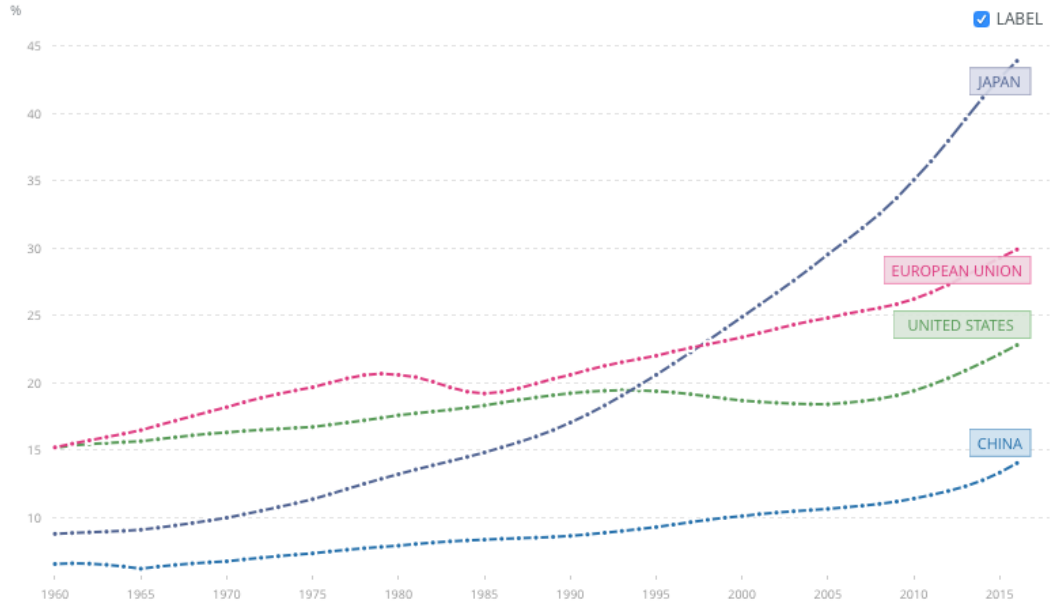


Figure 3.4: Age dependency ratio, old (% of working-age population) (data source: World Bank, 2017)

The population demographics are uneven, overstated by rapid ageing, as a result of the single child policy, and by the large number of highly-mobile workers within the country, while health infrastructure is inconsistent, with excellent medical centers in the east of the country, whereas more rural areas lack basic sanitation. Some of these inequalities are consequences of market reforms and past failures to deal appropriately with the provision of public goods. Others, however, are consequences of policies that institutionalize inequality of opportunity (i.e. hukou system). The inequalities across the population are reflected by large gaps between the richest and poorest citizens, and between urban and rural areas. Part of the rising income and consumption inequality is based on structural changes as labour moves from rural areas to the urban centers where

[17] Ratio of those aged 65 and over, to those between the ages of 15 and 64. The dependency ratio compares the difference between those not in the labor force with those who are working, or can work full-time. It is a yardstick geared to measure the pressure on taxable income going to support entitlement programs like Social Security.

they could find employment in the capital-intensive manufacturing sector which represents a major part of China's export industry-oriented economy.

The rapidly aging population will also need a range of elderly care and long-term care services, which are currently underdeveloped in China. Historically, aged care in China has been primarily the responsibility of the family, but the State has provided some help for the poorest elderly people (known in rural areas as wubao people and in urban areas as the "three no's[18]). Developing health restructuring is one of China's major challenges in the years to come, a complex and politically-challenging reform, a challenge intensified in China by population aging and the rise of non-communicable diseases.

Example:

• *China has experienced the kind of fertility transition over the past 40 years that typically took more than 100 years in developed countries (Uhlenberg, 2009).*

Counter Trends:

• Chinese and international experience demonstrates that health sector reforms are complex and politically challenging and especially that holds more than true in China due to country's rapid pace of population aging.

• Analysts and scholars believe that economic growth will be slower due to population aging and increase in services as well, unless general levels of productivity growth would increase.

Driving Forces: Demographic policies; Middle class values; Pace of structural changes and investments in safety nets and infrastructure; Technological implementations mainly in health care.

Future: It seems that this trend will inevitably happen that is population will be older. With a more complex economy at least in some parts of the country (cities) that will require the government to take measures that enhance safety nets for old age people and support workers to better manage risks inherent in a more flexible labour market, reform pension and unemployment insurance systems, expanding long-term care, and strengthening labour market institutions to enable wage bargaining and dispute settlement mechanisms that balance the interests of workers and employers.

Consequences:

• Slower growth, lower savings rates, and investments, and a better educated human capital to increase labour productivity.

• A shift in health-care strategy from curative to preventive care, The fiscal costs of health and pension programs will need to be limited through greater emphasis on primary care rather than hospitals, structural reforms, and efficiency improvements in service delivery through information and communications technology (ICT),

• Innovation will be an important mechanism for controlling costs while raising quality and expanding access to health care.

[18] People who have no working ability, or no stable income, or no dependable providers.

• Urbanization and aging will accelerate a rapid increase in the prevalence of non-communicable disease over the coming decades, implying a major increase in demand for both curative and preventive health care.

A strong focus of the Chinese government is to achieve, by 2025, the transition from "Made in China" to "Created in China", by supporting the creation of new innovations. An essential part of this process, and for the creation of a level-playing field for international and national businesses is the protection of IPR rights. This driver is presented in the next section.

Driver 13 – Intellectual Property Rights

Description: Prior to the industrial revolution in Europe, China led the world in technology. Over the last few decades, the country has been focusing mainly on manufacturing capabilities and cost innovation – imitating products, but also integrating innovation for lowering product prices - in major product categories.

Figure 3.5: A "Yanpeng Armani" store in a Donguan hotel (Photo: Epaminondas Christofilopoulos)

During the last few years, China has been spending heavily on R&D in an effort to take the lead in technological and novel products by 2025 to 2030. With that vision in mind, the protection of IP rights is crucial. The country has started a local patent office just at the beginning of the 1980s. However, different levels of IPR infringement are occurring every day, mainly due to poor law enforcement. Chinese companies, and especially SOEs, have been very aggressive in terms of technology-used competition. In recent years though, the increased interaction and co-operation with counterparts from all over the world (especially from the West) has made them more conscious about IPR issues. Also the country has made extensive progress in IPR protection in order to promote its dream of becoming a technology-edge country, by implementing reforms in 2008 to support the creation and operation of a modern and sophisticated IPR system, (regulations, trademarks, copyrights and patent laws), which largely meets WTO requirements.

Despite regulatory reforms, enforcement hasn't kept pace with improvements in the legal framework. The problem of law enforcement is sharper in West China and other locations far away from Shanghai and Beijing, but as more and more Chinese firms file court cases against violation of IP rights by other Chinese firms, the awareness of IPR protection will be further raised and protection rendered more effective. While past improvements in the Chinese IPR protection system were largely driven by pressure from abroad, in the future, change will be increasingly driven by domestic pressure.

The recent data regarding patents are impressive. International trademark filings by Chinese companies have grown rapidly (from 2.598 in 2000, to 35.637 in 2012), reflecting an ambition to build international brands. Invention patent applications are

also growing. For example, Chinese priority patents inside China occupy a rising share against foreigners from 173.000 in 2005 with 54% of the total, to 653.000 in 2012 with 82% of the total). A number of incentives granted by local and central governments have pushed them to codify more of their intellectual property. Despite that huge increase, the number of granted patents (as a percentage of the total filings in the country) increased, showing a relative increase in patents quality. This is partly due to the efforts of the Chinese authorities to reach international standards.

As China wishes to boost technology-based innovation in the future, it is expected that the country's IP regime will eventually provide a reliable, transparent, and fair system that encourages and protects innovation, regardless of the nationality or location of the creator / innovator.

Example 1: *American Superconductor Corporation (AMSC) supplied power systems and software to the Chinese wind turbine manufacturer Sinovel and is now suing it for $1 billion after it paid an AMSC engineer to steal its source code.*

Example 2: *Nearly 2.38 million patent applications were accepted and over 1.31 million authorized in 2013. At the same time, 37,660 patent disputes were resolved from 2009 to 2013 nationwide.*

Counter Trends:

• Poor implementation of IPR laws

• Insufficient effort and resources on dealing with IPR

Driving Forces: China's ambition to become the world leader in innovation; spillover effects of R&D investments; competition and law enforcement.

Actors: Chinese authorities (national, regional and local), domestic enterprises, SOEs, foreign enterprises, Chinese innovators, Chinese courts, IPR regulators, Patent Agents, Investors, MNCs, WTO, EU, USA.

Future: As the number of Chinese innovators grows, PRC officials have recognized that China's aspirations for indigenous innovation are unlikely to be met without a far more credible intellectual property (IP) protection regime that protects the creators of new technologies. In addition, as Chinese enterprises become more and more innovative, they would be affected by the lack of efficient IPR protection and will push for changes. An efficient patenting system that reflects the experience of the West will accelerate the growth of China's innovation capabilities, and will encourage MNCs to establish R&D centers in China. Proper IPR policies will support the transfer of research-and-development results from public organizations to the Chinese economy. IPR infringements are happening every day, and this will continue in the future but at a lower level.

Consequences: The creation of a dynamic and open innovation system.

The growing global connectivity is allowing the easier transfer of goods, people, and ideas, and act as a catalyst for innovation. The trend is presented in the next section.

Driver 14 - Global Communication

Description: Information and communications technologies (ICT) are rapidly shaping a new R&D landscape. For example, they facilitate co-resourcing, networking, cloud computing, simulation, and virtual environments. ICT has changed the way research and innovation move forward, by allowing with a click of a button, unprecedented networking, creativity sharing as well as infrastructure, (such as computing power), as well as utilizing new ways of disseminating information and acquiring funding.

The increasing availability of information and the growth of communication capabilities have been major factors in the globalization of the 20th century. Internet enables creativity, innovation and has created new governance structures, increased openness, and participation. Latest developments in ICT are the Creative Commons (universal access to research and education), the Internet of Things, 5G, Broadband developments and Cloud Computing.

In that context, communication between Europe and China is increasing at a rapid rate. R&D collaboration has been developing radically over the last few years. Europe and China share a strategic interest in further increasing combined efforts that will enhance the quantity and quality of research results and technological innovation in both Europe and China, particularly in tackling global challenges. EU and China have signed many official agreements, and some of them are related to R&D activities, pointing out that access to information and a satisfactory / minimum communication flow between the two sides are key requirements for international collaboration, mainly in the R&D&I global value chains.

Internet connectivity, VoIP, file sharing, streaming media, social networking, mobile communications, satellite TV and 24/7 new media will be broadly available, reaching not only the new Chinese middle class and the R&D communities, but the majority of Chinese citizens as well. Advanced communication and access devices will continue the evolution of the Chinese society, by allowing individuals to not only communicate irrespective of their location, but also to access a wealth of information, and also enable e-governance in all aspects.

Example: *The Europe-China Standards Information Platform, (CESIP), is a one-stop-shop for market access information to help businesses internationalize and ultimately strengthen trade between European and Chinese small and medium-sized enterprises. The new CESIP platform provides detailed information about European and Chinese standards and market access requirements.*

Counter Trend: Globalization and ICT have created a new open world. However, in recent years, there have been a number of risks and threats, like hacking, unclear IPR context, and break-out of local disputes and terrorism. These factors have created various concerns in the field of networking and co-operation arising from the use of ICT and other new technologies, in the context of R&D global value chains.

Driving Forces: Global governance, ICT and other Technology developments, Globalization

Actors: Chinese Government, EU, International Institutions, Multinational Companies, Education Institutes, Research & Innovation Institutes, etc.

Future: In the next ten to fifteen years, wireless communication, (including both wide-area networks and satellite connectivity), new software and applications will likely enable further collaboration between researchers from around the globe in order to

access data, information and R&D infrastructures and outputs. Intelligent sharing, access and processing of information activities will be improved, as well as increase of security and use of encrypted technologies.

Consequences: Competition will foster the restructuring of industries. Institutions will be stimulated, with major impact on innovation and growth. ICT will account for a significant share of total R&D spending, patent applications and firm start-ups. The global nature of the Internet will further spur the pace and scope of research and innovation and encourage new kinds of entrepreneurial activity. The costs of transmitting information will be significantly reduced, boosting the diffusion of information and ideas. Economic development will be affected through productivity improvements and continued economic expansion from global Internet commerce.

English is the standard language in academic literature, but also the basis for international communication. The vast part of the Chinese population has no or limited knowledge of any foreign language, and this an obstacle for communication and research cooperation. This driver is presented in the following section.

Driver 15 - Language Skills

Description: The slogan "Education needs modernization and modernization needs education" reflects the dilemma facing China as it undergoes a rapid transition from a largely agrarian society to a modern globalised economy.

After the launch of China's reform and opening-up policies during the late 1970s, China began to attach more importance to English as a lingua franca to contact with the outside world (Zhang, 2017). The modernization of the Chinese education system, the great interconnection with the global culture, and the greater financial capacity of the rising middle class, rapidly makes proficiency in foreign languages a standard skill for young Chinese.

Although education has always been held in high regard in China, the force of globalization and the emergence of a new era of technology, driven by internationalization, have accelerated the process. In order for China to develop an economy that focuses on the production of goods for foreign trade, and to respond effectively to the forces of globalization, the education system must develop students' knowledge and skills to international standards. Yet the estimates for the amount of people from China speaking English range from a staggeringly low 10 million English "speakers" to 300 million English "learners." Even at the higher end of the spectrum, this still only amounts to around 22% of the population speaking English, the "global language" ("What about English in China? - VoiceBoxer," 2016).

China has made learning English part of its economic strengthening strategy with its introduction into primary, secondary and tertiary education. In 2010, there were estimated to be over 100,000 native English-speaking teachers in China, workers in a market worth three billion dollars annually. Increasing numbers of teachers, teacher educators and researchers are now beginning to devote themselves to the study of language teaching with young learners. Research into primary school English teaching and teacher training are urgently needed to ensure a better understanding so as to better inform and improve practice.

To protect other foreign languages taught in schools, special support will be given to keep the present number of schools teaching Russian and Japanese or other foreign languages within the same areas. As indicated from the World Language Map, Chinese is spoken by the majority of people in the world. But with the rapid economic development in recent years, Chinese people are enthusiastic about learning foreign languages. A list of the top foreign languages learnt in China is: 1) English, 2) Japanese and Korean, and 3) French and German. Lately the Russian language has been gaining popularity in China.

Example: *The Confucius Institute at the University of Vienna, was founded in September 2006 as a cooperation between the Office of Chinese Language Council International (Hanban), the Beijing Foreign Studies University and the University of Vienna. The Institute is devoted to introducing the Chinese language and culture and promoting the dialogue and exchange between different societies and cultures. With its expertise and activities it has become a meeting place and platform for many joint projects.*

Example: *Foreign language schools are shifting their mission from cultivating language expertise to preparing well-rounded students, versed in foreign languages and culture. Tianjin Foreign Languages School, launched in 1964 as one of the first batch of foreign language schools under the supervision of then premier Zhou Enlai, is*

focusing more on the comprehensive skills of students than the mastery of languages alone, in an attempt to foster greater expertise and the development of open and tolerant mind-sets. Forty-nine of the school's students were accepted by overseas universities and colleges in 2012 and 35 in 2013.

Counter Trends:

1. Lack of enough qualified foreign language teachers.

2. Short supply of foreign language teachers.

3. Emerging automatic translation technologies / applications.

4. Conflicting trend from Chinese expecting from foreigners to learn the Chinese Language

5. Lack of interest, especially as more people are learning Mandarin

6. Poor teaching methods

Driving Forces: Globalization, modernization of the Chinese education system, the great interconnection with the global culture, need for foreign trade, emerging urban middle class, etc.

Actors: Domestic and international universities, government, schools, teachers and professors, middle class

Future: In the coming years, the percentage of the Chinese speaking foreign languages will steadily increase.

Consequences: Improving labour skills, increase in international co-operation in research field, international students‘ mobility

Primary, secondary, and higher education are crucial for improving human capital, and improving China’s innovation performance. This driver is presented in the next section.

Driver 16 - Education System

Description: China's social development over the past three decades has been impressive. Since the founding of the PRC in 1949, China has shifted from a major power with low literacy rates or with large part of population at low literacy level to an equally major power with universal primary education (1949-77), and subsequently from a major power with universal primary education to a human resources powerhouse (1978-2000). Throughout this process, the PRC has turned its huge population from a burden into a significant advantage. This achievement marked the transition of higher education in China from a system of elite education to a system of mass education. Fast forward 30 years to 2013, and the country is almost unrecognizable. The country has universalized compulsory primary education and expanded participation in higher levels of education. Since this expansion, educational enrolments have increased rapidly, with large increases in high school attainment and above. It produces almost 13 % of the world's scientific papers and has 25 % of the R&D workforce worldwide, while over six million of its students will graduate this year from higher education. China has also opened up its system of higher education to the outside world, becoming the Asian country with the largest number of foreign students.

However, according to the latest OECD data, the level of upper secondary attainment among adults between 25 to 64 years of age is one of the lowest (22.3 %, ranking 42/42), while one of the lowest is also the percentage of today's young people expected to graduate from upper secondary programs (76.4 %, ranking 24/29). Similarly, in China, the total compulsory instruction time for primary students and for lower secondary students, is one of the shortest among OECD and partner countries. On the other hand, the ratio of students to teaching staff at the upper secondary level is especially high. (16 students per teacher, ranking 7/35), while Chinas one of the most attractive destinations for foreign students compared to other OECD and partner countries (2 %, ranking 10/40).

Developing education, especially higher education, in an open manner is important as China seeks to secure its position in the world. In pursuit of this goal, the government is attempting to raise the gross enrolment rate at senior secondary institutions to 90 percent by 2020, putting the number of students in these schools at 47 million. By then the gross enrolment rate of higher education is also expected to reach 40 percent. At 2008 the number of college-age individuals began to decrease, a trend that will continue for at least few years.

China still lags behind from the rest OECD and partners countries in most of the indicators. However, the figures are gradually improving, indicating a strong potential for further growth that will, in the future, fuel R&D performance and economic growth. The Chinese education system is undergoing continuous reforms and although the system has substantially improved, it is uncertain whether the government will make the necessary structural changes at all levels (primary, secondary, higher education), in order for China to become a competitive knowledge-based economy.

By 2025, China will be the world's largest power in terms of population that has received higher education. Already by 2020, nearly 200 million Chinese citizens will have college degrees. Without a doubt, education has been one of the most important factors in the Chinese economy's rapid growth.

Example: *The quality of university training is improving rapidly: China now has 22 universities in the top-ranked 200 universities of the world, compared with 12 just eight years ago.*

Example: *Inequality in China's education system seems to be on the rise. The percentage of students at Peking University of rural origin has fallen to 10 % in the past decade, in comparison to 30 % in the 1990s.*

Counter Trends:

• Hukou system reforms are necessary to provide suitable education to urban immigrants' children.

• The rising inequality in compulsory education for children of different demographic status, namely, residential areas, social categories and income groups.

• Around one-third of citizens mistrust the educational system.

• The education system does not encourage creativity.

• Scarcity of public education resources.

Driving Forces:

• Decisiveness to become a leading innovative nation and therefore to catch up with and, ultimately, to overtake the West, by shifting production from labor-intensive to skill-intensive activities.

• Rising urban middle class

• Globalization

• Education Reforms.

Actors: Ministry of Education, Chinese Government, educational institutions, research institutions, domestic and foreign universities, urban middle class, etc.

Future: Possibly, China will become an innovative knowledge economy only if government makes the necessary structural changes

Consequences: China a world power in terms of human capital, harmonious society, equal access to education for all, technological progress, human capital accumulation.

Chapter I: Conclusions

Chapter I contained a description of the main terminology utilized thought the PhD thesis, and briefly presented the foresights methods that will be utilized to perform the research. The importance of foresight and scenarios for long-term strategic planning in times or areas of high uncertainty were also briefly explained.

Chapter 1 (Section 3) also provided a thorough presentation of China and the main drivers that are changing and driving its innovation and business landscape, as they were identified during the first scoping phase of the research:

- National economy;
- Framework Conditions (for research)
- Private R&D Investment
- Energy & Materials
- Governance
- Urbanization
- Human Rights
- Global Economy
- Peace & Conflict
- Space & Defense
- Environment
- Population (Demographics)
- Intellectual Property Rights
- Global Communication
- Language Skills
- Education System

The description of the above factors that directly or indirectly affect the Chinese innovation landscape, has also revealed the complexity of the system. Different actors, trends, counter trends, and drivers are creating several uncertainties as regards the future of the Chinese innovation landscape. It is also certain, as it has proved several times in the past[19], that predictions based on linear projections of the current situation have little or no accuracy at all.

In this complex and rapidly changing environment, alternative methods are required for understanding the coming changes and building a resilient long-term strategy to deal with alternative futures. Scenarios and scenario planning offer this needed toolbox to private and public corporations to address the complexity of the system and better prepare for a set of alternative plausible futures.

The next chapter will present in detail the methodology utilized for this study, as well as the overall research structure.

[19] For example, the 2008 global crisis or the 1989 the collapse of the Soviet Union.

CHAPTER II: METHODOLOGY

Introduction

This chapter describes the foresight methodologies (section 4) that will be utilized in order to analyze the innovation and business environment in China, and produce the scenarios of China's long-term future (2030), but also for testing the importance of scenarios for strategic planning.

These methods will provide the tools for identifying the important trends, the main actors and especially the uncertainties that define the future of China. Moreover, established foresight methods are used to produce the scenarios for the China's uncertain innovation environment and for engaging policy makers in a long-term discussion.

Nevertheless, and besides the traditional tools novel methods were developed and tested, like crowdsourcing methods, and gamification techniques, while the overall two-phase organization of the research, was also novel and (proved to be an) efficient approach.

In addition, the overall organization of the research (section 5) is presented in order to provide a clear overview of the how the work was structured and executed. The work was structured in two phases, a first pilot phase, for scoping the main characteristics of China's present and future and testing some foresight methods. The second phase was the core research, with a full application of foresight methods.

4.0 FORESIGHT METHODOLOGIES

As explained at Chapter I, foresight studies are usually implemented through the combination of various methods, that are selected to better address the specific needs or limitations (e.g. available resources & time) of a specific project.

In this case, the in-depth analysis of the innovation environment in China, the identification of the mechanisms, the uncertainties and especially the future developments were performed using a plethora of traditional foresight methodologies and some novel ones (crowdsourcing & serious games).

The following sections provide a short description of the futures methodologies utilized in the various steps of the research work.

4.1 Contextual Environmental Analysis

Although future studies concern the future, it is always important first to understand the past and present of the environment and to identify the main actors, drivers and trends that play (and have played) important roles.

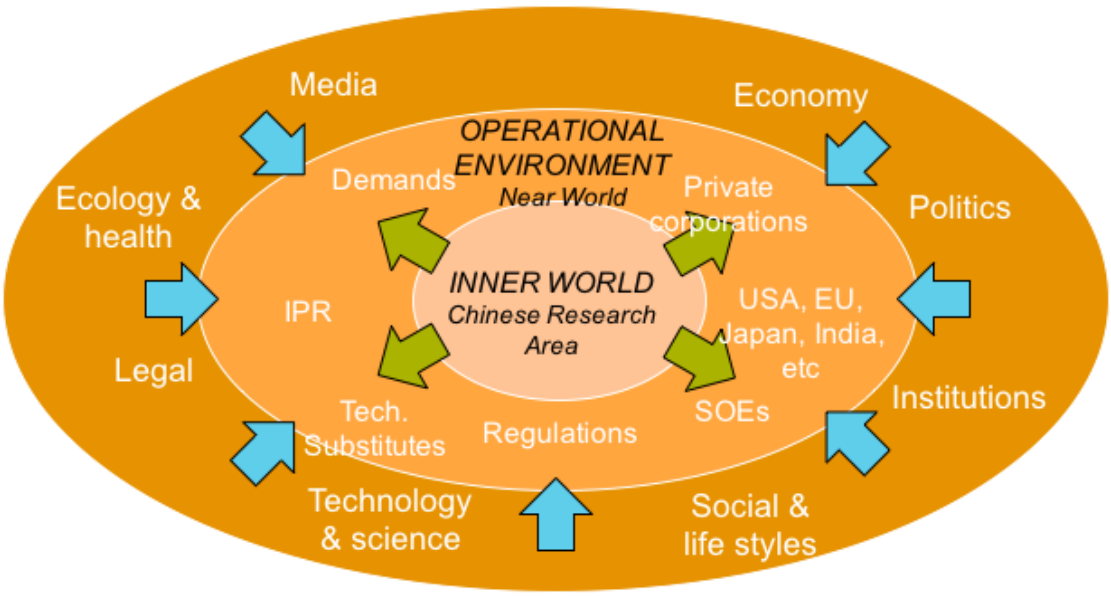


Figure 4.1: Contextual Environmental Analysis

The contextual environmental analysis includes the identification of the main actors and stakeholders that may play important roles in the specific future development. It also includes and analysis of the history and driving forces that affected the past and current development. Last but not least, it includes the spotting and analysis of the main trends affecting the future of our topic of interest.

The trends may be identified, prioritized and analyzed with different methods such as participatory workshops, media scanning, Delphi, expert panels or focus groups.

4.2 Observation & Media Scanning

Observation is a data collection method in its own right, and was an important element in the current thesis, as the author's work was focusing on China and was often travelling to China during the last 10 years. It is not rare the case in science, that important findings have been accidental and captured from observations of the failures of other data collection methods.

Figure 4.2: A Mobike, a sharing economy model spotted in Shanghai (Photo: Epaminondas Christofilopoulos)

Media scanning is a popular method for continuous monitoring of a topic, or for an occasional source of knowledge and inspiration in scenario planning process (Lindgren & Bandhold, 2003). It includes the scanning of printed media (newspapers, magazines, etc), internet sites (scientific, business, blogs, etc), social media (twitter, Instagram, etc), tv and radio channels. All the collected information is regularly classified and assorted around topics of interest.

In the case of this thesis, over 300 sources of information have been used for the deeper understanding and analysis of the environment, as

4.3 Trend Impact Analysis (TIA)

Trend Impact Analysis (TIA) are among the longest-established tools of forecasting (Popper, 2013). TIA is a forecasting method that permits extrapolations of historical trends to be modified in view of expectations about future events (Glenn & Gordon, 2009).

TIA provides a rough idea of how past and present developments may look like in the future – assuming, to some extent, that the future is a kind of continuation of the past, by mostly focusing on Megatrends, macro level phenomena which include various (sometimes conflicting) sub-phenomena (e.g. globalisation, ageing, climate change).

TIA allows to systematically examine the effects of possible future events that are believed important. The events can have a wide span to include technological, political, social, economic, and value-oriented changes.

Consider, for example, a manager interested in tracking the price of raw material delivered from an overseas source. An extrapolation of available historical data could certainly be used for a forecast, but the manager might feel that too many contingencies make an extrapolation of past trends unrealistic. TIA is a method analyzing the consequences of future developments on this future trend.

4.4 Cross-Impact Analysis (CIA)

Cross-impact analysis (also called structure Analysis) is basically a method that helps the process of scanning the field of possible futures to reduce uncertainties.

CIA attempts to work systematically through the relations between a set of variables, rather than examining each one as if it is relatively independent of the others. CIA requires that a set of key variables are determined in order to understand the system that is of concern. Usually, expert judgement is used to examine the influence of each variable within a given system, in terms of the reciprocal influences of each variable on each other – thus a matrix is produced whose cells represent the effect of a variable on each other (Popper, 2013).

CIA helps us understand how different trends or actions affect each other or to analyze the interrelationships between variables within a system (Lindgren & Bandhold, 2003). A cross-impact analysis is useful when we need to identify the key variables and drivers of our system. It also offers a clear picture of which trends are drivers and which are dependent.

4.5 Delphi Survey

The Delphi method marks the renaissance of the Futures Studies back in 1960s, at the RAND think tank, in Santa Monica, California (Glenn & Gordon, 2009). The Delphi method was designed to encourage a true debate, independent of personalities, that sometimes manipulate discussions in face-to face meetings. Anonymity was required in this original version of the Delphi, in the sense that no one knew who else was participating. Further, to eliminate the force of oratory and pedagogy, the reasons given for extreme opinions were synthesized by the researchers to give them all equal "weight" and then fed back to the group as a whole for further analysis. These aspects: anonymity and feedback, represent the two irreducible elements of the Delphi method (Glenn & Gordon, 2009).

The Delphi method is based on structural surveys and makes use of information from the experience and knowledge of the participants, who are mainly experts. It therefore yields both qualitative and quantitative results and draws on exploratory, predictive even normative elements. Although the basic Delphi methodology is the same, several applications may be implemented to better address the topic of research. In any case, because the number of respondents is usually small, Delphis do not (and are not intended to) produce statistically significant results; in other words, the results provided by any panel do not predict the response of a larger population or even a different

Delphi panel. They represent the synthesis of opinion of the particular group, thus the selection of the experts is crucial.

The typical steps of a Delphi process are graphically presented in Figure 4.3:

a) a steering committee designs the process, the questions, and selects the experts;
b) According to the expertise and the specific requirements experts are distributed to different panels;
c) A set of questions is put to experts (usually in electronic form), and feedback is collected.
d) The feedback replies from experts, are collected, analyzed, and summarized.
e) The analysis is then send again to experts for feedback.

Of course, this is a very generic description of the process that is usually adapted according to the specific needs, the number of experts, the length of the questionnaire, the resources available, and the survey means (electronic or paper).

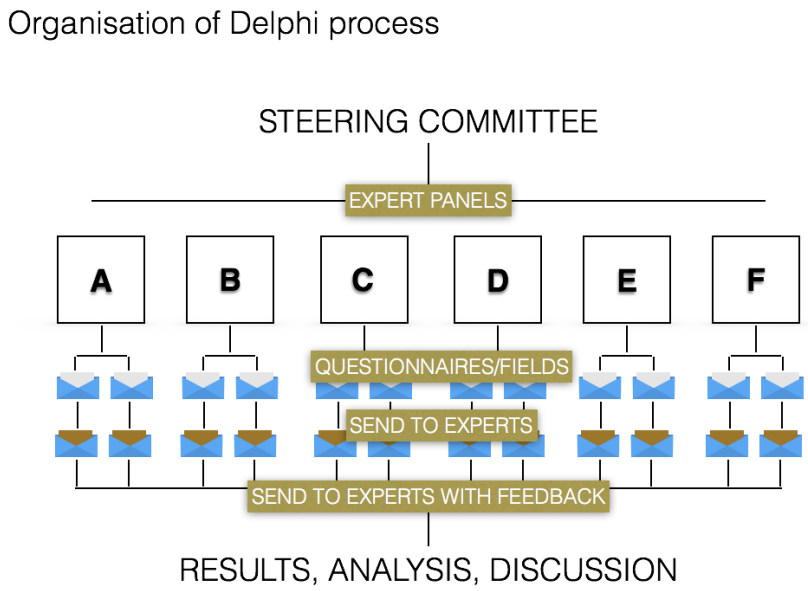


Figure 4.3: Organisation of a Delphi process

Strengths and Weaknesses

Delphi studies are difficult to be executed, usually due to the problematic selection of experts and/or the poor design of the Delphi questionnaire. In addition, multi-round Delphis require great time investment and commitment from the experts, and sometimes participants drop out during the process.

In addition, a great weakness of the Delphi is the subjective understanding of the Delphi questions, due to linguistic barriers or cultural differences, thus the phrasing of the questions is critical to the success.

On the other side, a correctly designed and executed Delphi allows the objective judgment of issues requiring judgement, making it ideal for questions seeking consensus, or for identifying specific issues of disagreement. However, might produce problematic results in issues where there is no consensus.

Today the Delphi is applied in a more flexible framework and describes various interview-based methods where participants are asked to assess future prospects. The main value of the method lies mainly on collecting the views of a broad group of experts allowing to identify all possible trends/drivers/uncertainties, and less on the actual trends or uncertainty analysis.

4.5.1 China Delphi Description

For the needs of the current research, two one-round[20] Delphi 's have been designed and implemented in order to collect expert views on trends, drivers, business models and uncertainties that are driving the innovation environment in China.

The first Delphi was mostly focusing to the trends & drivers changing the overall business & innovation environment in China, and produced the basis for evaluating the main drivers and trends changing China's future.

The second Delphi has mobilized a greater number of experts and focused on further understanding the various emerging business models, and especially the various future cooperation opportunities with China. More details on the two Delphi's is provided in the next paragraphs.

4.5.2 China Delphi 1: identity

The objective of the pilot Delphi survey was to confirm and evaluate the role of 16 drivers and trends identified through the initial analysis of secondary sources of information and personal observations.

The Delphi questionnaire consisted of a set of 1 open and 32 closed questions regarding the importance and the probability of 16 drivers and actors that affect the innovation environment in China (see Annex 2).

41 experts around the world participated in this pilot survey, coming from the areas of innovation and foresight. The feedback from the experts was given anonymously.

4.5.3 China Delphi 2: Identity

In the context of the foresight work a second Delphi was performed to validate the five Megatrends identified by the desk analysis of sited work and to check the future importance of various emerging business model and markets.

In addition, the Delphi method was utilized to investigate the future technological perspectives of Europe and China, and to identify specific promising technological areas for bilateral cooperation.

The Delphi questionnaire (see Annex 3) consisted of 55 questions distributed in 4

[20] *The one-round Delphi's, receive feedback from the experts in one round and not in multiple rounds.*

parts :

- Part 1 - Megatrends: *for evaluating the identified megatrends and investigating other important driving forces.*
- Part 2 - Disruptive Technologies: focusing on Europe's technological future.
- Part 3 - Disruptive business models: focusing on identifying new disruptive business models and markets.
- Part 4 - China: for investigating future opportunities for collaboration with China.

The questionnaire was build and distributed on-line using the **google forms** platform, and was sent by email to specific experts and expert networks (e.g. the Millennium Project, and the Europe Foresight Network). In total, **77 experts**, from **29 different countries** and diverse technical and professional backgrounds, have provided feedback to the Delphi questionnaire. It should be also underlined that 40% of the experts had a strong foresight background. The main characteristics of the sample are presented in the following graphs.

Figure 4.4: The sex and foresight experience of the Delphi experts

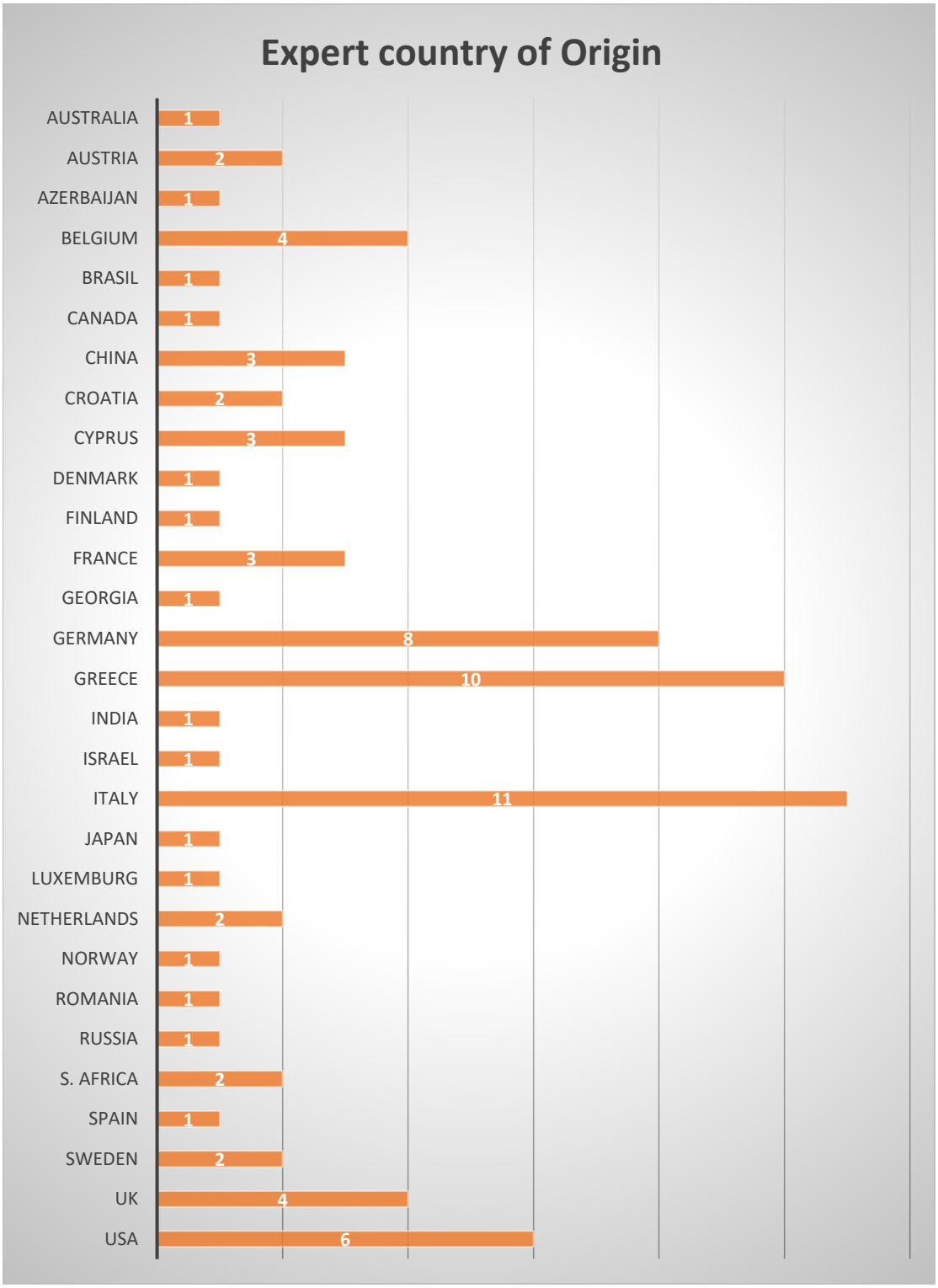


Figure 4.5: The country of origin of the Delphi experts.

The findings of the Delphi questionnaire are presented in ANNEX 3

4.6 Scenarios

Scenarios in the context of foresight are consistent pictures, descriptions, stories illustrating future situations, future scenes. Scenarios describing future situations are usually linked to the present in cause/effect logics. In other words, scenario is the coherent articulation of hypotheses for the evolution of variables in a given horizon and the road leading to it. However, there is no single definition of scenarios. Different practitioners have proposed different definitions:

- "An internally consistent view of what the future might turn out to be" (Porter, 1985).
- "A tool [for] ordering one's perceptions about alternative future environments in which one's decision might be played out right" (Schwartz, 1991).
- "A disciplined method for imagining possible futures in which organizational decisions may be played out" (Shoemaker, 1995)

It is clear however, that a scenario is not a forecast, neither is a vision. it is simply not possible to predict the future with certainty. A scenario is a well-worked answer to the question: "What can conceivably happen?" or "What would happen if …?" (Mats & Bandhold, 2003). Scenarios are powerful tool that help us to perceive futures today. The scenarios challenge our mindsets and oblige us to consider a set of potentially uncomfortable futures.

Objective of Scenarios

The main purpose of using scenarios in foresight is to outline what the future might be – not will be – to show alternatives due to uncertainty and to make decision making more robust and future-proof, and to sensitize decision makers with regard to the uncertainties of the future and to enable them to become future fit.

A scenario is never a prediction or a forecast, but a way of organizing many statements about the future; it is a plausible description of what might occur. Scenarios describe events and trends as they could evolve. Good scenarios are plausible, internally consistent and sufficiently interesting and exciting to make the future real enough to affect decision making.

Scenario Planning

Scenario planning is a strategic planning method that some organizations use to make long-term plans under uncertain conditions, based on alternative scenarios. Scenario planning is particularly useful for areas of non-linear change, for example when product categories are reaching a level of over-maturity and need to be replaced with something new or in the face of rule breaking competition that is creating a new business logic (see Figure 4.6).

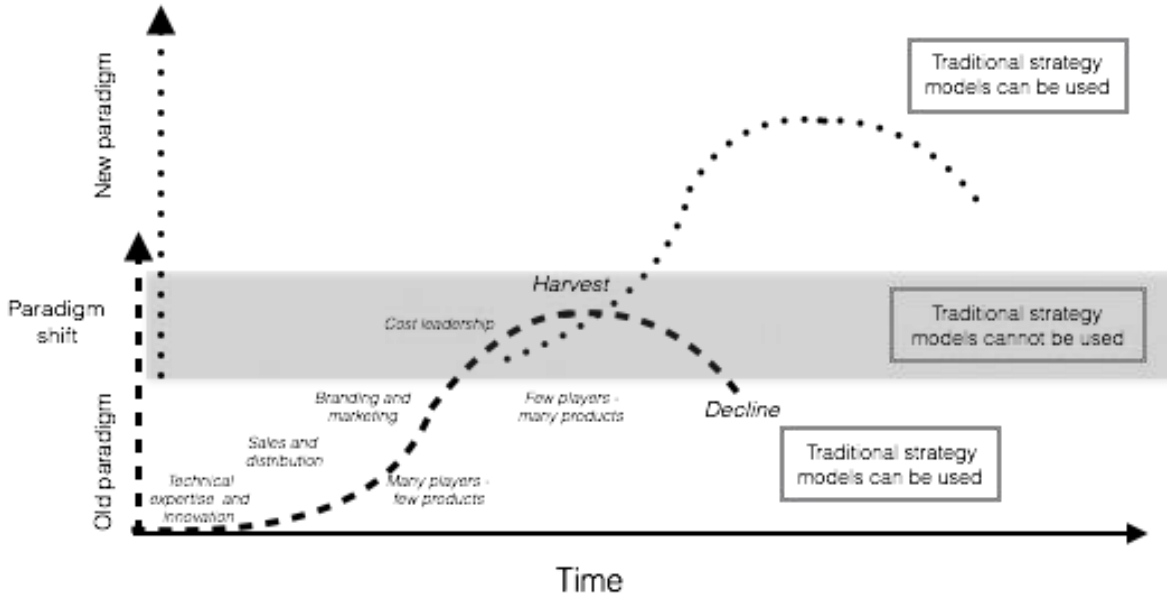


Figure 4.6. Scenario planning is well suited to the task of dealing with paradigmatic, non-linear change (Mats & Bandhold, 2003).

In a scenario process, managers invent and then consider, in depth, several varied stories of equally plausible futures

4.7 Participatory Workshop

Participatory workshops are events lasting from a few hours to a few days, in which there is typically a mix of talks, presentations, and discussions and debates on a particular subject. The events may be more or less highly structured and "scripted": participants may be assigned specific detailed tasks, or left very much to their own devices.

This participatory full-day workshop was held on May 22nd 2015 in Shanghai to explore different possible futures for innovation in China toward 2030 using the scenario approach.

The 21 participants represented European multinationals, start-ups, academia, and European national science and innovation agencies. The workshop was divided into two parts. In the morning, the participants discussed China's current innovation capabilities, challenges that may drive innovation toward 2030, and trends in business model innovation. In the afternoon, drivers, options, and scenarios were discussed and analyzed, resulting in a scenario map for Chinese innovation in 2030.

4.8 Scenario Exploration System (SES)

While participatory foresight studies are widely regarded as enriching experiences for participants, their strategic efficacy and impact on policy makers over time is not as clear. In order to address this problem, the Joint Research Centre of the European

Commission has developed a serious game to allow stakeholders to have a first-hand experience of several plausible alternative futures and their effects on future policies (Bontoux et al. 2016).

SES falls in the category of qualitative role-playing foresight methods and requires reflection, imaginary interaction and creativity. Such methods try to answer questions such as: If I were person X, how would I deal with problem Y? Or, if we were country X, what would be our position with regards to issue Y?

SES gives diverse stakeholders a role-playing opportunity to engender individual and collaborative foresight from unfamiliar and contrasting perspectives. Complementing this role-playing game dynamic, each game participant is responsible for co-creating a shared narrative during gameplay, and these world-building dynamics can be used to create powerful learning environments for analysis and predication modeling, evaluations, and education (Bontoux et al. 2016). The main physical elements of the JRC SES are presented in Figure 4.7.

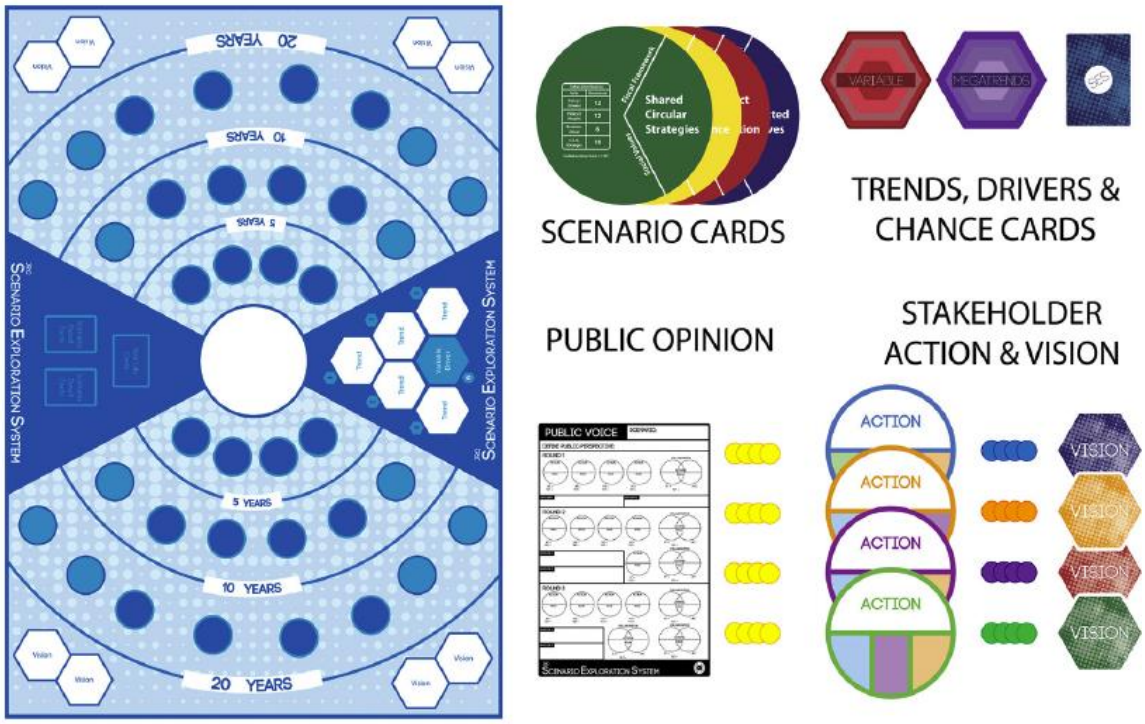


Figure 4.7: The main physical elements of JRC SES

The researcher cooperated with Laurent Bontoux from the JRC Policy Lab, and produced a novel version of the game, the SES China Edition V1.0. The Chinese edition of the game is based on the scenarios of China's innovation future produced in the context of this research. The purpose of the Scenario Exploration System (SES) is to have participants experience and act through plausible alternative futures, by thinking and conversing systemically outside of their usual frame of reference. The SES uses

two contrasting scenarios to challenge the assumptions of the participants and offer them space to respond to alternative and changing framework conditions. Over the course of a session in the *China 2030* edition of the SES, **four *explorers*** representing ***two Governmental Policy Makers*** (one from Europe and one from China***), an Industry*** and ***a Research or Technological Organisation (RTO)*** act over three rounds to reach their visions in a 15 year time horizon

The SES China edition V1.0 was used in a participatory workshop organized in Shanghai, with the participation of over 40 Chinese and European stakeholders (**ANNEX 5**). The main elements of SES China Edition V1.0 are presented in **ANNEX 6**. The objective of this workshop was to engage with policy makers in China (Europeans and Chinese) and get their feedback on possible long-term actions to support bilateral cooperation.

The workshop was divided into two parts. In the morning, participants were presented the China 2030 scenarios, while in the afternoon session was organized with JRC and engaged European and Chinese stakeholders in a discussion over the China 2030 scenarios and the strategies for cooperation.

4.9 Secondary Data

Data collected by third parties are always an important source for the research and a valuable supplement to primary data collection. Secondary data were used to understand the state of the art and design the research methodology but also were used for validating research findings.

In the context of the study several sources of secondary information have been studied from various sources including electronic and print media publications, websites and blogs, Chinese and Western social media, books, reports, etc.

Part of the desktop analysis was also bibliometric analysis that included the statistical analysis of journal publications, as well as a patent analysis that included an analysis of patent applications (see ANNEX 6).

4.10 Observation

Observation is a data collection method in its own right, and beside all the other data collection and analysis methods used, observation is always an important element. The author has travelled to China over 60 times in the last 10 years, and has been using a research diary noting various observations, chance findings and important references.

Over time observations in China were related to changes in:

- Physical infrastructure (e.g. new technology parks and incubators);
- Social and business behavior (e.g. more people are having tattoos or drink coffee);

- Offered services and products (e.g. pastry products are now widely offered in contrast with the situation few years ago);
- Business concepts and models (e.g. multiple examples of sharing economy business models and e-payment based services);
- Communication means (e.g. WeChat is the main business and social communication platform);
- Changes in news coverage (e.g. last years Chinese media draw a lot of focus on Chinese technological breakthroughs)

All the main future methodologies utilized throughout the research have been presented in this section (4).

Next, Section 5 includes a presentation of the overall organization of the research, and explains this novel two-phase approach that proved to be essential for a deeper understanding of China's complex environment.

5.0 ORGANISATION OF RESEARCH

5.1 Overall Research Organization

The foresight work on China has been implemented in two phases as presented in Figure 5.1. The Chinese environment is so complex, with so many interrelated parameters so it was decided to formulate the research in two distinct phases. The objective of the 1st phase (scoping phase) was to identify and understand the overall dynamics of the Chinese innovation system (systems thinking), while the second phase of the research was more focused and allowed the deeper understanding of the role of the different actors.

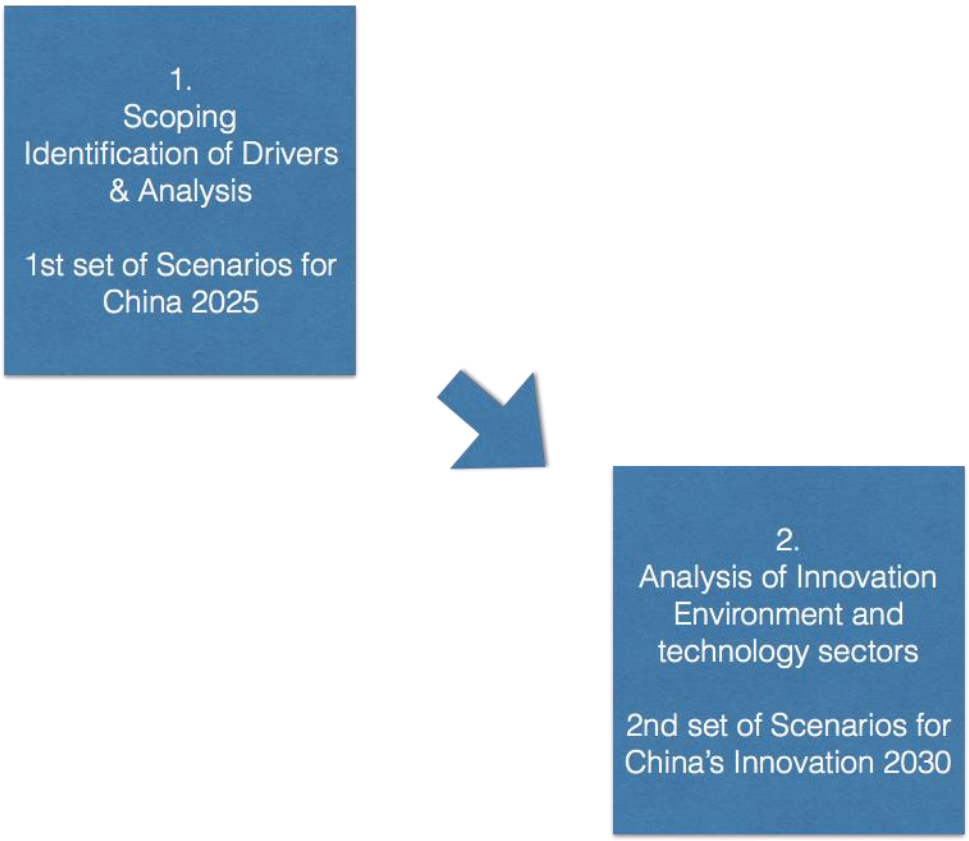


Figure 5.1: China Foresight – work phases

Phase 1: The objective of the first scoping phase was to understand the Chinese RTD environment, and identify the main drivers and trends that are shaping the research environment in China. The overall work of *phase 1* was coordinated by Epaminondas Christofilopoulos (FORTH), and implemented in cooperation with Phemonoe Lab.

Phase 2: After having the basic understanding of the main trends and drivers changing the research landscape, the objective of the second phase was to dig dipper and understand the innovation dynamics of the Chinese innovation environment, and identify specific opportunities for collaboration between EU and China. The overall

work of *phase 2* was coordinated by Epaminondas Christofilopoulos (FORTH), and implemented in cooperation with KAIROS Future and Phemonoe Lab.

The organization of the research in these two phases is presented in more detail in the following sections.

5.1 Research Phase 1

The main interest of phase 1 (exploratory phase) was to understand the Chinese research and innovation environment, and especially the trends and drivers that are transforming the future of Chinese research.

The methodological approach is based on the TAIDA approach developed by KAIROS Future (Lindgren et al. 2003.), and includes several traditional and modern trend scanning and foresight tools (e.g. crowd sourcing). A combination of a desk-study analysis, media scanning, a Delphi study, as well as a crowd-sourcing tool have been utilized in different steps of the work, to identify, define and analyze 16 critical drivers that play a substantial role in transforming the R&I landscape in China, and construct four plausible scenarios of the future.

The overall work was structured upon the following steps *(Figure 5.2):*

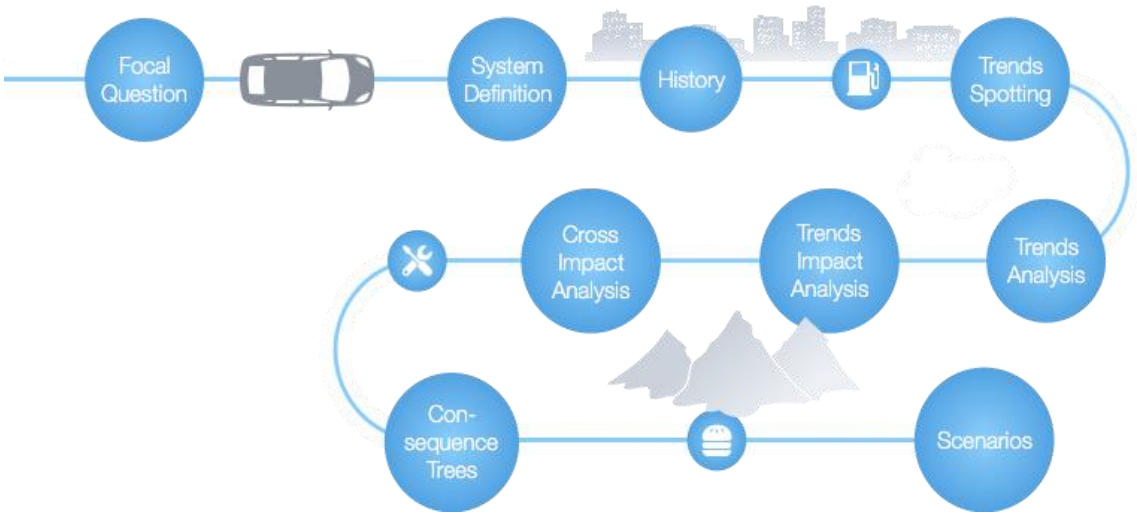


Figure 5.2: The research steps of Phase 1.

a. The main task was to produce plausible scenarios about the Future of Research in China in 2025. Thus, the first step was to define the focal question: "What are the main factors that will affect the Research (R) & Innovation (I) Environment in China up to 2025?". Having that in mind, the trends scanning in this first phase was limited to identify the main factors that will shape the research environment in China during the next 15 years.

b. The Inner World, the Near World and the contextual Environment of our system (the innovation environment in China), were identified and analyzed.

c. The historical development of the System affecting the research in China was studied in order to better understand the current and future trends, and identify unexpected developments.

d. The next step of the work was focusing on identifying the trends and driving forces that affect, directly or indirectly, the research environment in China. The trends have been identified through different tools: secondary desktop research, media scanning, media watch, guruing (interviews with experts), on-line questionnaires. In addition, a crowd sourcing platform, Co:tunity was also utilized throughout the study[21] (*Figure 5.3*).

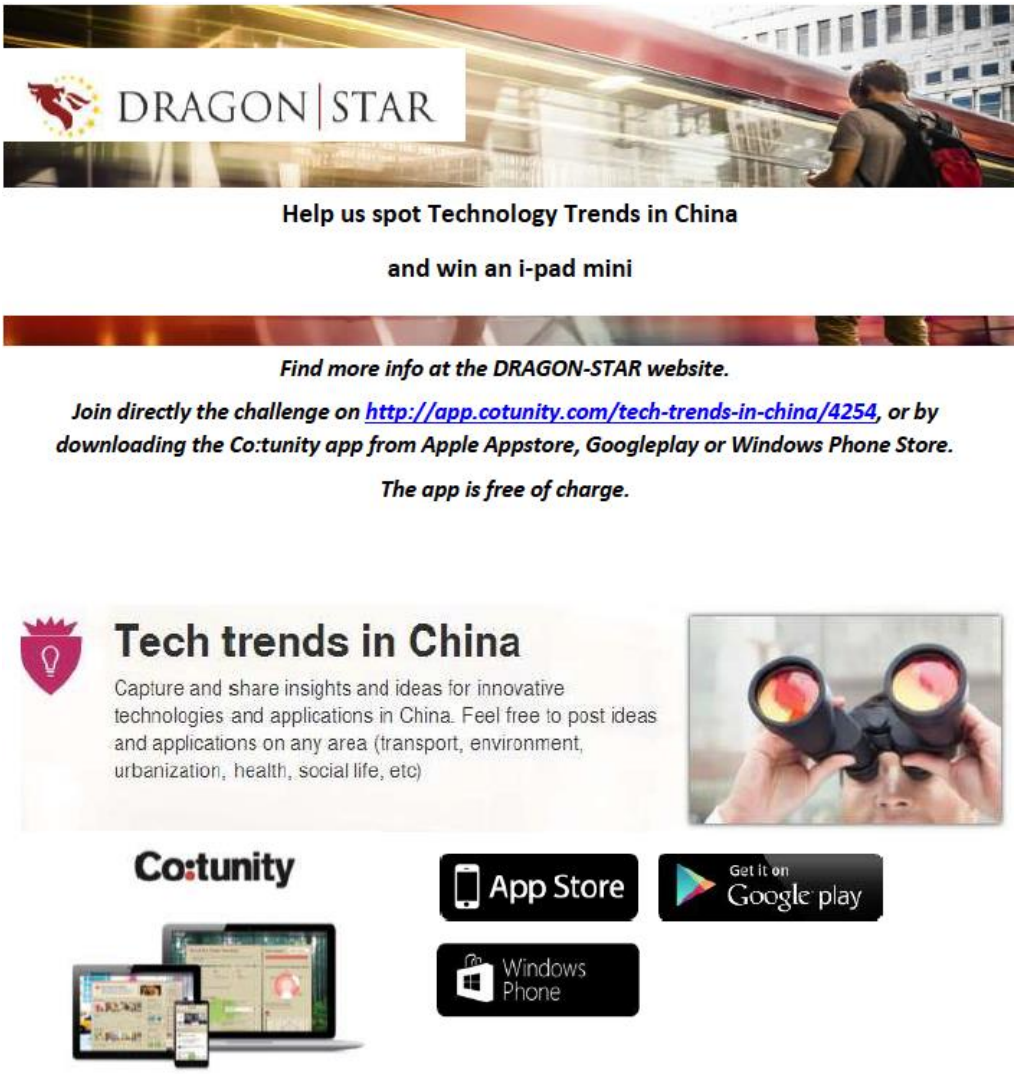


Figure 5.3: Crowd-sourcing for identifying trends and weak signals using the co:tunity app.

e. The evaluation of the identified trends (in terms of importance and plausibility) took place through a Delphi study, through an on-line questionnaire, by a group of experts around the world (China, Europe and Globally). The questionnaire was sent to a broad list of experts: futurists (members of the Millennium Project Network), and project managers and researchers involved in EU funded research projects (with European and Chinese partners). 41 experts evenly distributed around the globe, and coming from different backgrounds (research, business, consultancy, etc), have finally provided feedback by filling the Delphi questionnaire.

[21] Co:tunity is a multi-functional Smartphone and web application for collaborative trends potting and innovation developed by Kairos Future. URL: www.cotunity.com (last accessed 12/12/2015)

f. The driving forces behind the selected trends and their main consequences have been analyzed. In addition, tailor-made input on the current technological and innovation trends in China was provided by KAIROS Future. This information was essential for identifying specific technological areas of high importance and for composing the final scenarios. An in-depth analysis of the impact of the main selected trends on the focal question was performed.

g. Further, analysis of the influence of the different trends was made. The outcome of this analysis has fed the scenario-making process. The final report and the produced scenarios were validated by 3 independent experts, who provided comments and corrections on the suggested scenarios and trends:

- Ass. Prof Anthony Howell, School of Economics at Peking University, Beijing, China;
- Mr Rikard Wallin, Managing Director at CAB Group Sweden AB, Stockholm, Sweden;
- Prof. Daoliang Lee, China Agricultural University, Beijing, China

5.3 Research Phase 2

After the initially mapping and understanding of the main trends and drivers changing the research landscape in China that took place in Phase 1 of the research, the objective of 2nd Phase of the research was to dig dipper and understand the innovation dynamics of the Chinese innovation environment, and identify specific opportunities for collaboration between EU and China.

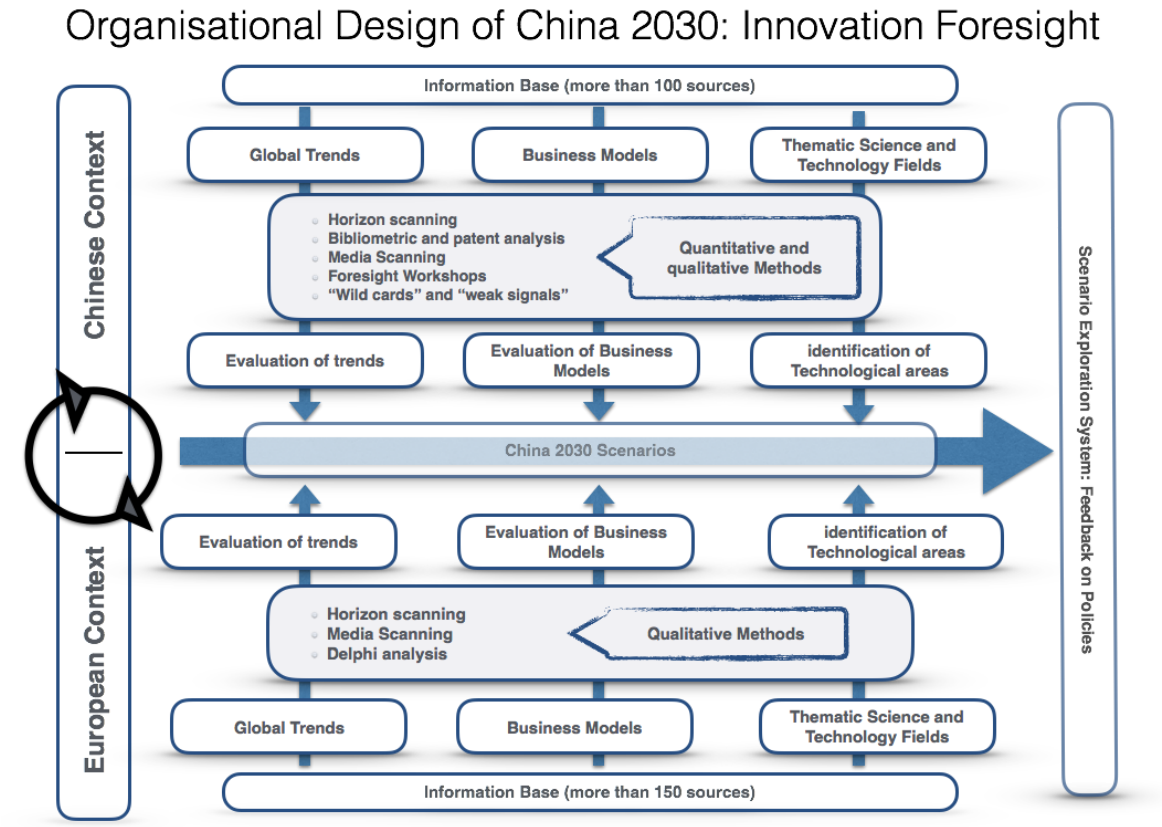


Figure 5.4: Organisational design of the Phase 2 research

The overall structure of Phase 2 is presented in Figure 5.4.

The work of phase 2 is composed from two parts (the European and the Chinese context) that are implemented in parallel and feed each other. The main steps are presented below:

Table 5.1: Research organisation	
Chinese Context	**European Context**
1a. Horizon Scanning	**1b. Horizon scanning**

A large base of more than 100 sources of information has been analysed. This desk study, was including English and Chinese books, journals, newspapers, websites, blogs, and social media. Special focus was drawn upon Global trends, new established Business Models in China, and technological areas. This part also included: • A secondary review of the main global trends affecting future developments. • An analysis of the new business models in China. • An analysis of the dynamics of the different scientific and technological areas in China. **2a. Media Scanning** It included the scanning of printed media (newspapers, magazines, etc), Chinese internet sites (scientific, business, blogs, etc), Chinese social media, tv channels, etc. **3. Bibliometric and Patent analysis** A bibliometric and patent analysis was implemented to identify trends in specific scientific fields. **5. Participatory workshop 1** A participatory workshop was organised in Shanghai to identify specific trends & business models in China, and produce draft future scenarios.	A large base of over 150 sources of information has been analysed. This desk study, was including books, journals, newspapers, websites, blogs, and social media. Special focus was drawn upon Global trends, emerging Business Models and key technological areas. This part also included: • A secondary review of the global trends. • An analysis of the globally emerging business models. • An analysis of the future development **2b. Media Scanning** It included the scanning of printed media (newspapers, magazines, etc), internet sites (scientific, business, blogs, etc), social media, tv channels, etc **4. Delphi Analysis** A Delphi analysis was designed and implemented to collect western views on global megatrends, emerging business models, promising technological areas in Europe, and specific fields offering opportunities for bilateral cooperation with China.

6. Scenarios The final set of 4 future scenarios for China's innovation landscape has been drafted.
7. Scenario Exploration System (SES) development In cooperation with the EU's Joint Research Centre (JRC), a serious board game was produced to assist stakeholders to explore future scenarios and test strategic actions.
8. Participatory workshop 2 & Scenario Exploration System application A second participatory workshop was implemented in Shanghai to validate the produced scenarios and test SES China edition.

Chapter II: Conclusions

Chapter II contained a description of the main research methodologies utilized for this research project and an analytical description of the research structure.

The research work was performed in two phases:

- **Phase 1** was the pilot phase aiming to understand the Chinese RTD environment, and identify the main drivers and trends that are shaping the research environment in China. The first set of scenarios was produced in Phase 1.
- **Phase 2** was aiming on acquiring a deeper understanding of the Chinese innovation landscape, and to produce the final set of scenarios focused on innovation only.

Chapter II also presented in detail the specific research methods used throughout the project. The main characteristic of the current work is the plethora of **qualitative** (e.g. workshops, interviews, horizon scanning), **quantitative** (e.g. bibliometric and patent analysis, and trend impact analysis), and **semi-quantitative** (e.g. Delphi) research methodologies that have been applied for collecting and analysing data.

Last but not least, besides the established methods, a new tool was developed in cooperation with JRC's Policy Lab. The Scenario Exploration System China Edition, is a serious board game that was specifically developed to explore China's innovation future, and allows to test strategic actions in the framework of different

In the next chapter, Chapter III, the results of the research are analytically presented and discussed. Chapter III also includes the main overall conclusions and the scientific discoveries achieved.

CHAPTER III: RESULTS & ANALYSIS

Introduction

Chapter III aims to present in detail all the main results produced in the various phases of the research, as well as the main conclusions drafted.

Specifically, Chapter III includes:

- An analysis of the main trends/drivers and their interconnection (Section 6);
- The outcome of the 1st phase of the research, an initial analysis and scenarios of the overall future of China 2025 (Section 7);
- An analysis of the current innovation landscape in China, from secondary and primary sources of information (Section 8);
- A thorough presentation of the innovation scenarios for the innovation landscape in China by 2030. Outcome of phase 2 of the research. (section 9).
- The same section (9) also includes a description of the application of SES China, a role-playing platform, that engaged stakeholders from Europe and China in future's thinking and allowed the modulation and testing of policies against the alternative scenarios.
- Finally, section (10), summarizes the conclusions and the scientific discoveries that were performed in the context of the PhD's research.

6.0 TRENDS/DRIVER ANALYSIS

6.1 Drivers Evaluation

The evaluation results of the 16 drivers are presented in the following graphs, on a scale from one to ten in terms of the importance and the probability of a driver to occur. Although most of the drivers have received a high mark both in terms of their importance and their probability (this is natural as we had preselected drivers of importance), but still there were several interesting results extracted by the evaluation process. (Figure 6.1), the most influential are considered to be: the increasing need of energy and resource efficiency; the structure and operation of the education system; the environmental implications; the framework conditions (the national regulatory framework for research); the stability of the government and societal peace; and the language skills.

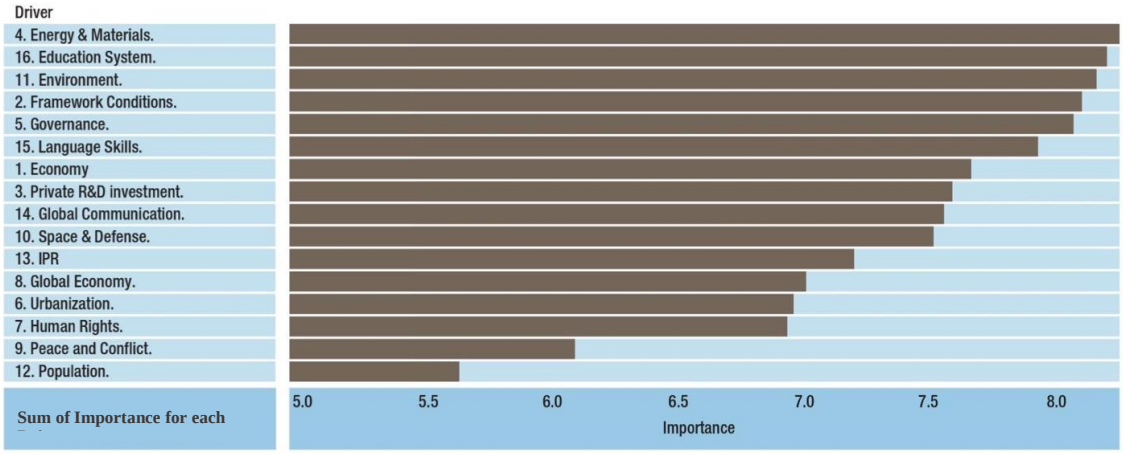


Figure 6.1: Trends Evaluation, Importance

In addition, A very low importance rating is given to the population growth and Urbanization, although its major process transforming the Chinese Society (Mai, 2013). However, it seems that the serious indirect effects, of this process on research, are not that obvious. Very little importance is also given on Human Rights and on the possibility of a serious military conflict in the region. The Economy and the Private Investment are also relatively low, maybe because they are taken for granted from the experts.

In terms of the probability, *Figure 6.2* presents schematically the ratings given by the experts (10 is representing the higher probability).

The highest, probability is given naturally on ongoing clear trends like the rise of Global Communication and Connectivity, and the Chinese Urbanization process. Moreover, it is broadly expected that issues like the environmental degradation the space race, and the Need for Resources will continue to play an increasing role in the future. On the

other side, it is worth mentioning that there are very low expectations for positive changes on issues like Human Rights, Governance, and the Education System as well as on IPR. Finally, it is also important to underline that risks are expected to affect both the Chinese and the Global Economy.

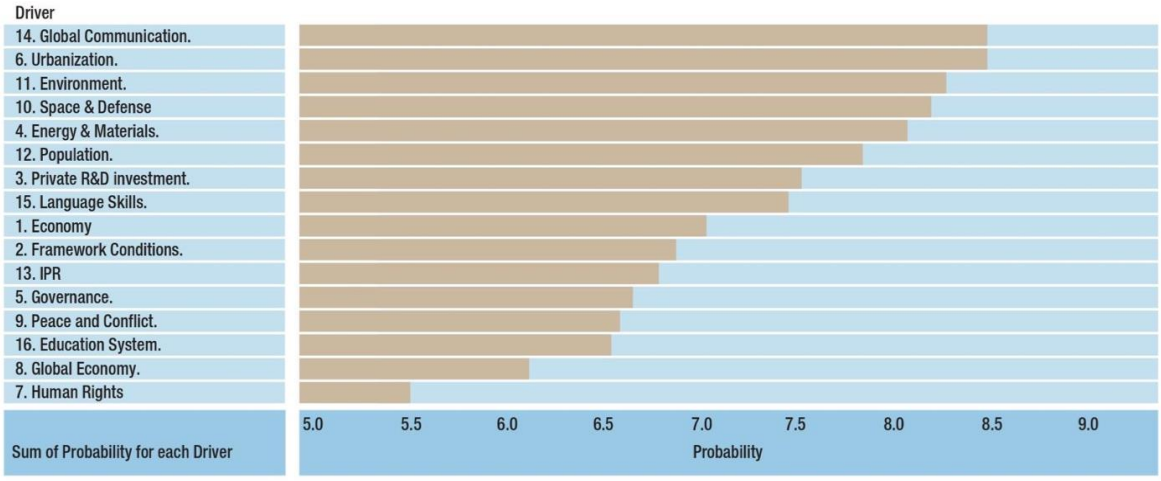


Figure 6.2: Trends Evaluation, Probability.

The evaluation results of the trends are summarized in *Figure 6.3*, and demonstrate the critical importance of Governance and of the National Economy, in shaping and catalyzing the research environment in China, followed by Energy & Materials, R&D framework conditions, the Education System, the Environmental situation, and the language skills.

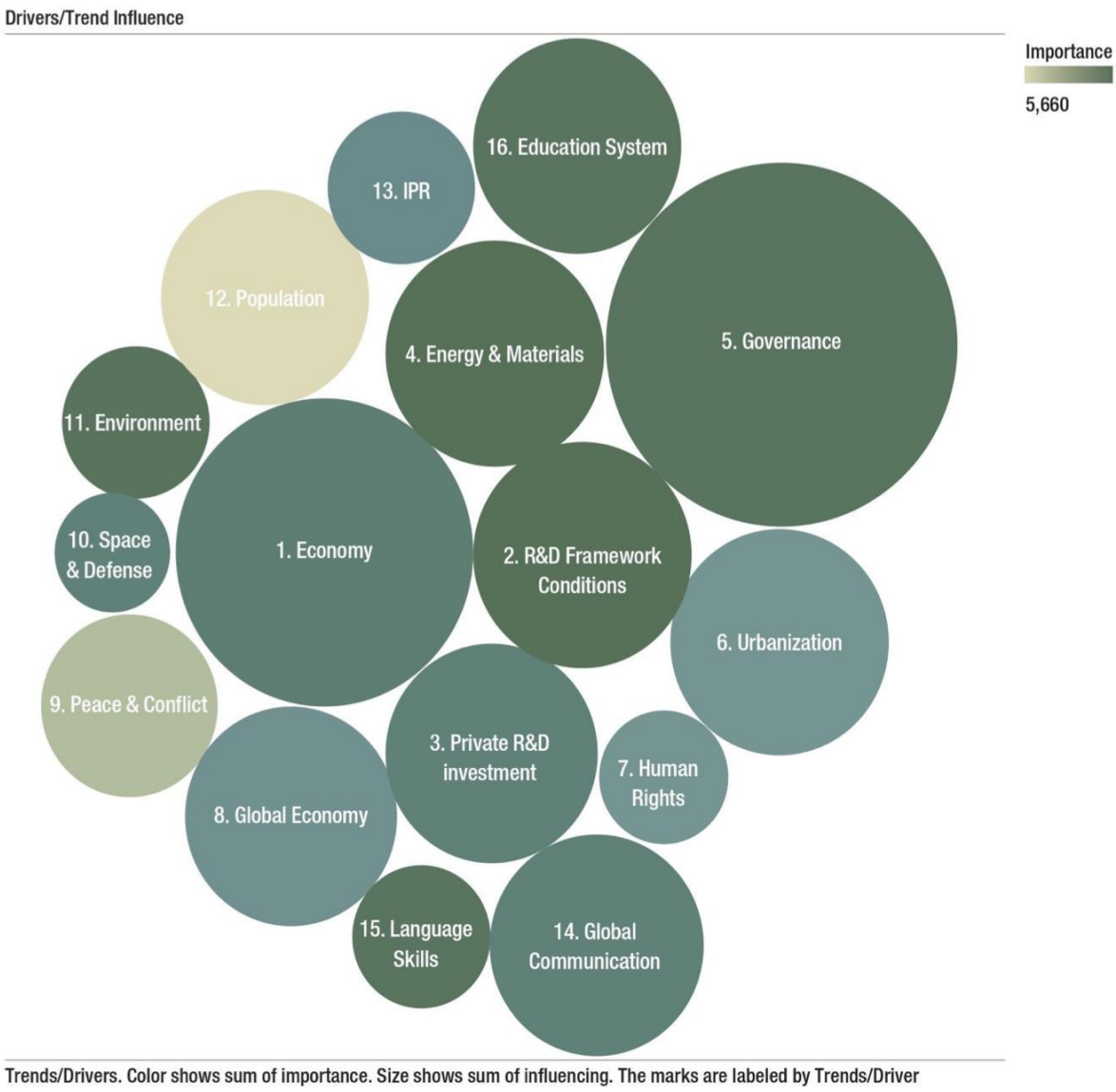


Figure 6.3 : Trends in China. Color shows sum of importance, size shows sum of influencing

Tackling the need to prioritize trends a Trend Impact Analysis (TIA) was performed to identify the most important trends, that will be central in the formulation of the scenarios. The following graph (Figure 6.4) sums the outcome of the evaluation

process, indicating specific drivers that are of high importance and high probability to occur.

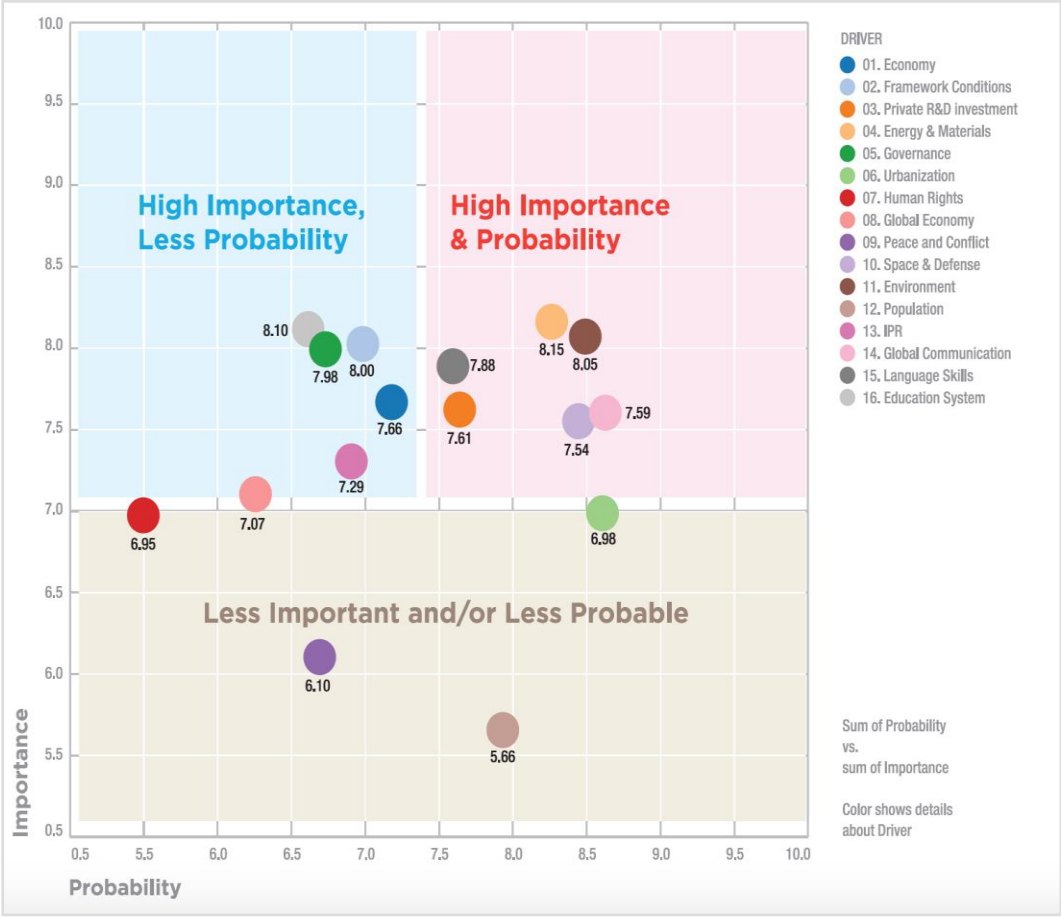


Figure 6.4: Trend Impact Analysis

Notes: The X axis represents the probability (ranking marks from 1 to 10), while the Y axis represents the importance of the same drivers on affecting the research environment (ranking marks from 1 to 10).

The trends in the upper right corner were evaluated by the experts as *certain* and *important.* The Trends in the top left corner were evaluated as uncertain (or less certain) but still highly important. These two sets of trends according to the scenario methodology are deemed of high importance and are studied in more detail, while are playing an important role in the formulation of the four scenarios.

6.2 Cross Impact Analysis (CIA)

The Cross-Impact Analysis (CIA) is an essential part of the scenario methodology that reveals how different trends affect each other, and help analyze the interrelationships between them. In the first step of the CIA analysis, the influence of every factor/trend upon the other factors was evaluated, highlighting several important findings like the

strong role of the National Economy and of the Private R&D investment in transforming the R&D environment, as will the overall strong role of Governance. The graphical visualization of the cross-impact analysis (see Figure 6.5), sheds light on a several other issues, such as the seriously interdependent role of IPR.

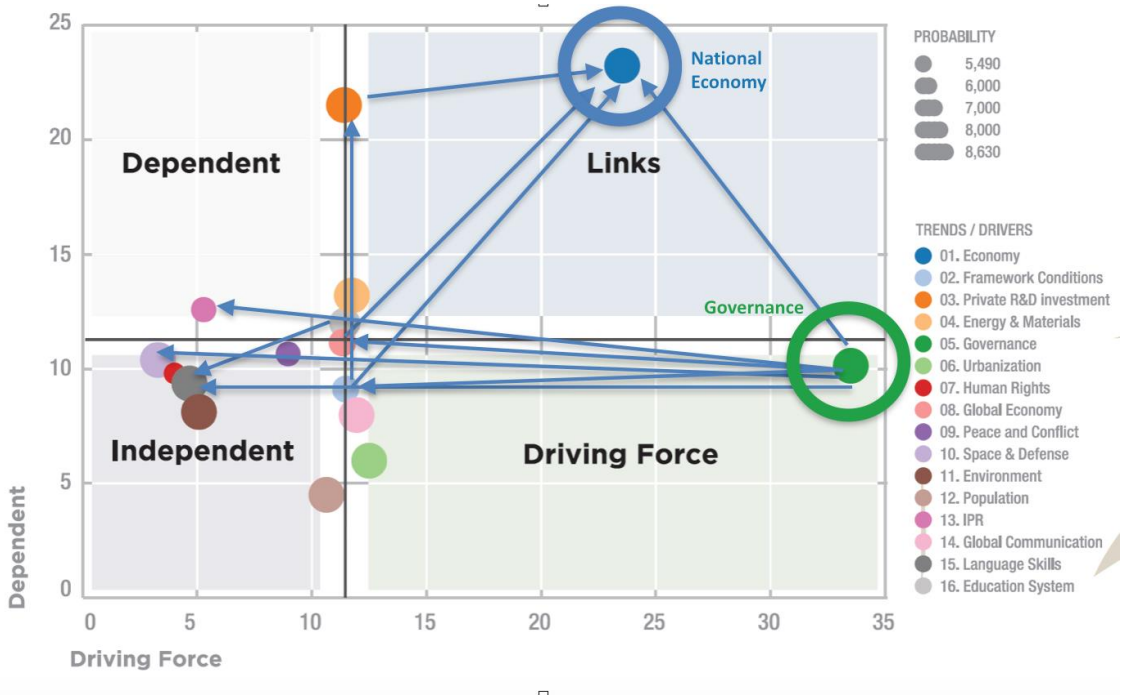


Figure 6.5: Cross Impact Analysis

The main outcomes of the CIA analysis (graphically presented above), are the following.

Governance is the major clear driving force and quite independent by other drivers. *Urbanization, Global Communications* and the *R&D Framework Conditions* are other important and quite independent driving forces. The *National Economy* is naturally a major driving as well, and has the strongest interconnections with other drivers. *Energy and Resources* is also an important driver high several interconnections (e.g. with the *Economy* and the *Environment*). The *Private R&D investment* and *IPR* are both highly dependent by other drivers.

Several factors with a strong effect on our focal question are strongly dependent by the *Governance*: *Human Rights*, *IPR* issues, *Education*, *Peace & Conflict*.

The *Environment* issues, the *Education system*, the *Language skills*, *Peace & Conflict*, and *Human Rights* are strongly dependent by other factors (*Governance* in most of the cases).

6.3 Wild Cards

The first phase of the work, also included the identification of wild cards. Wild cards are events that could cause a sudden and rapid radical change. These wild cards are very improbable,

because if they occur will change the world as we knew it. Such wild card events can substantially change the evolution of the future and should be taken into account in strategic planning (Mendonca et al., 2004).

During the analysis several wild cards appeared in the discussions, less or more probable, and some of them are included in the composed scenarios. Some of the most probable wild card events that will radically affect the research environment but also China itself, are listed below:

- *A brief military conflict in the South–East Chinese Sea will stop foreign investment, will shift research funding and focus on defence technologies and will stop bilateral cooperation.*
- *A nuclear accident might change the current governmental planning for several new nuclear plants in the years to come.*
- *A massive domino social unrest in the country fueled by poor economic performance, and poor civil rights will radically change the governance model.*
- *A collapse of the booming property market will cause financial crisis and anger between middle class.*

This non-extensive wild card list is indicative of the various diverse "rare" incidents that may occur altering suddenly the direction of the future. Few of the wild cards have been described in the scenario's narratives, while the rest are briefly described as factors that could dramatically change the linear development of the future.

6.4 Key Factors that Impact the Scenarios

The trend scoping process, was necessary to identify and study a large set of factors, but also set the basis for a discussion with a broader group of experts, that provided feedback throughout the study. After the finalization of the trend analysis, some initial assumptions for the Future of Research in China at 2025, have been made.

Firstly, a strong **Government Policy and Investment** will continue to guide the research, but will also limit it, unless important framework changes are going to take place (Sass, 2014; Orlik, 2013). In the case of social unrest, the research will also be affected. Moreover, the governmental policies in areas like Foreign Relations and the Space race, is expected to put some focus on defense/space related research.

Secondly, the expected **Growth of National and Global economy** will also support the research, however more financial risks are expected to affect and slow down the development of the research environment.

Thirdly, the **quest for resources and the environmental problems** (local and global) will continue to be an important driver, and we could safely expect new technologies on alternative materials, new-generation nuclear plants, as well as on renewable energy.

Moreover, the **Cross Impact Analysis** and **Causal Loop Analysis** of the **16 identified trends** have revealed that the Governance and the National Economy are the 2 key uncertain strategic trends that affect the development of the research environment. These two strategic trends were finally selected by the research team and were used as the basis for building our China's scenarios.

Governance and societal piece. During the last decades, the performance of the Chinese government has been considered successful taken into account the impressive development of the country (Fan et al., 2014; Hu, 2011; Naisbitt & Naisbitt, 2010, USPTO, 2014). There is however great uncertainty with regards the future prospects for greater transparency, fair justice and better protection of civil rights.

In the recent years, there are several cases of small scale social uprisings in the rural areas mainly due to pressure on ethnic minorities or due to cases of corrupted local governance (Hoyos, 2014; Board NYT, 2013). However, the main catalyst of change is expected to be the rising Chinese urban middle class.

In China the relationship between the middle class and the state corruption is underpinned by an implicit social contract based on prosperity and social stability. During the last decades, the Chinese Communist Party (CCP) has supported, in the context of the broader urbanization process, the development of a middle class to drive consumption and serve as a buffer against other relatively deprived groups [Yuwen, 2012]. Nevertheless, at the same time middle class citizens have higher rate of participation in "rights-upholding" activities and are more likely to pursue legal action to resolve disputes. Given also their superior resources, including personal connections, internet access and financial stability, the rising middle class is expected to become the catalyst of change in governing practices.

For the years to come the Chinese governance under president, Xi Jinping, will have to take decisions towards greater transparency and justice or will move backwards towards a more despotic state [Zhang, 2012; Johnson, 2013].

Each direction will affect dramatically the development of the Chinese society, economy, and education, and thus will shape the Chinese research in 2025.

National economy. Both Global and National economy are considered important factors on shaping the Chinese Research by 2025. However, it was decided to choose the national economy as the second strategic trend to build upon the scenarios, because there are many ongoing structural changes in the national system, and their success or failure will have dramatic effects in the growth of the Chinese economy and on research.

During the last years, the Chinese economy has appeared to be quite durable managing to deal successfully with the side effects of the global economic crisis.

The Chinese economy is undergoing a heavy transformation process in order to sustain growth, and to address worsening environmental and social problems [Gong, 2012; Orlik & Davis, 2013; Board NYT, 2014; Sass, 2014; Vltchek, 2012]. The transformation includes the creation of knowledge based economy, moving from "made in China" to "Designed in China"; move from an investment based economy to a consumption based, though supporting the creation of an urban middle class; supporting the development of the services sector Changes in the banking system and in the interest rates; Changes in the ownership rights of agricultural land [Cyranoski, 2014; Fu et al., 2013; Hansakul, 2013; Yang, 2013].

In 2012, the General Secretary of the CCP's Central Committee Hu Jintao stated in his report to the 18th National Congress, that by 2020, on the basis of making China's development more balanced coordinated and sustainable, the GDP income should be double that of 2010 (that means an annual GDP growth of 7,2%) [*Monan , Z. 2012*].

By encouraging cleaner industries and the service sector, the government hopes to generate relatively more jobs, as well as clearer skies and waterways. But this transition will require more bank loans, opportunities and policy support to SMEs, and less cheap loans to the State Owned Enterprises (SOEs). It will also need the creation of an innovative Chinese technologies, the successful implementation of the urbanization process and smooth cooperation with the international business partners [Orlik & Davis, 2013; Vltchek, 2012].

It should be also underlined that the expected emergence of the Chinese consumer could be the greatest global growth engine of this century, benefiting European manufacturing and service enterprises alike.

7.0 PRELIMINARY ANALYSIS & SCENARIOS: CHINA 2025

The scenarios are not predictions; it is simply not possible to predict the future with certainty. Scenarios are a powerful learning tool that helps us perceive futures today. The scenarios are challenging our mindsets and oblige us to think of uncomfortable futures. The four scenarios will help us suspend the disbelief in all the futures: to allow us to think that any of them might take place – and prepare for them.

Based on the strategic uncertainties described in the previous section, four different scenarios for the future of the Chinese research have been constructed. They are all set in 2025:

"Prediction is very difficult, especially for the Future" ***Mark Twain,*** *Author and Humorist*

The four produced scenarios aim to assist in suspending the disbelief in all plausible Chinese futures and to allow us to think that any of them might take place, and prepare for them. However, scenarios are not predictions; it is simply not possible to predict the future with certainty. Thus, we should consider them as powerful tools that can help us to perceive futures today, and prepare a successful strategy for the future.

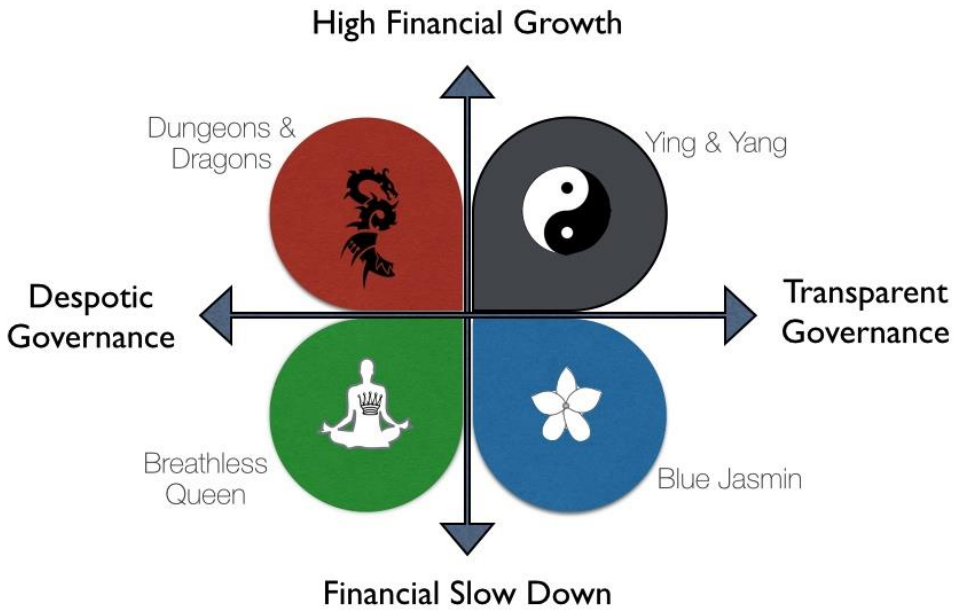


Figure 7.1: The 1st set of scenarios, China 2025

Yin & Yang – strong successful central governance combined with greater openness and a flourishing economy determines a cutting-edge research community in 2025.

Blue Jasmine– strong and open governance fights to revive the national economy that is hit by a global crisis and the relocation of foreign manufacturing industries, characterizes the situation in 2025.

Dungeons & Dragons – Less open governance, and an insufficient court system support a SOEs based development which seems to still to be successful in 2025.

The Breathless Queen – A broke toxic China, characterized by a collapsed national economy and a dismantled society, seems to be the greatest global disappointment in 2025.

Let's look deeper in every scenario, and check what the effects on the Chinese Research are in 2025.

7.1 Yin & Yang

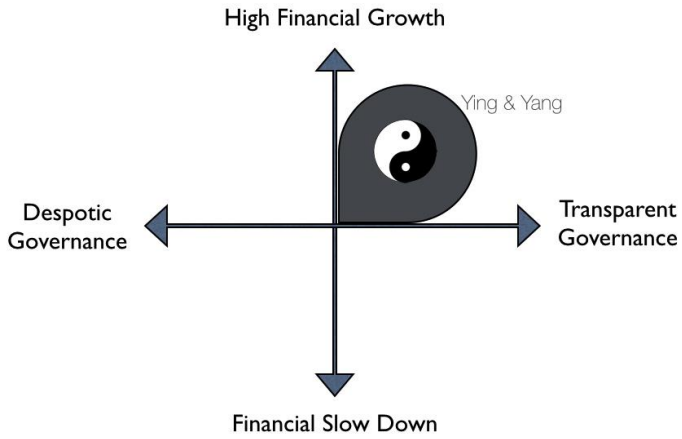


Figure 7.2: China 2025, the Ying & Yang scenario

Scenario at a Glance: The Chinese government under president, Xi Jinping has started in 2015 substantial reforms in the transparency of governance and the judicial system, involving greater participation of the public in local governance. The economy is flourishing and it is now based more on internal consumption, services and high tech exports. The Chinese research is a top global player, holding the first place in public and private R&D investment and demonstrating 2 Nobel Prize winners in Chemistry and Medicine.

Consider the best-case scenario of Yin & Yang China. A traveler to China in 2025 will witness a prosperous white-collar middle class interested in civil rights, and environmental conditions and spending their free time playing tennis, driving expensive European and Chinese cars and enjoying high tech products. Although, the one child policy has been loosened, most of the young couples are still having only one child, which is well educated and speaks fluently one foreign language (although automatic translation technologies have eliminated the need of learning languages). This new urban middle class is paying substantial taxes and in practice became a powerful political force that induced several government policies.

At 2016, a large government driven process has initiated an education and research reform, to prepare well-rounded students with creative and innovative thinking skills, and more self-motivated energetic researchers. The transformation of the education system has also changed the society and the economy, making China a true knowledge economy by 2025.

In 2018 Huawei has managed to reach the 1st place in global smart phone sales, due to novel energy efficiency and an ultra-light phone, while Lenovo is also between the top 5. At the other side, Chinese automakers have improved quality but due to intense market completion, have not managed to gain a substantial share in the European market.

The complete abolishment of the Hukou registration system in 2020, has radically improved the quality of life of migrant workers who are now slowly integrating in the urban communities and increase consumption. To serve the needs of the increased population, Chinese megacities heavily invested in novel health technologies and services, bringing Chinese companies on the top league of the sector.

In 2020, China's internal market became so important, that the country's prosperity is no longer dependent on exports and foreign investments. Thus, the country managed to deal successfully the new global economic crisis that busted in 2022.

In 2025, the CCP is still the only party but the increased transparency, the easy access to public information and the successfully reform Judicial system, has changed the relationship between the party and the people. The State, during the last decade has showed and increasing positive reaction addressing people's needs for cleaner environment, transparent land management and easier to global information.

A major driver for growth was also the transformation of the research framework in the country. Research integrity has been improved through a novel evaluation and auditing system promoting ethics and focusing on quality, rather on quantity. At the same greater openness is now playing a key role in collaboration, publication, peer review, criticism, replication, the evaluation of government projects and industry activities. As result China has enjoyed two Nobel Prize winners in Medicine and Chemistry.

Private R&D investment has steadily increased after the global financial crisis of 2008, initially driven by the SOEs and big private corporations, but the creation of several High Tech Funds has increasingly given to SMEs access to risk capital. The rise of global Chinese High tech brands was also fueled by the modernization of the IPR system that initiated in 2015, and allowed secure investments in technology sectors by local and foreign players.

In 2025, China is already a high-income country rivaling with EU and USA for access to natural resources, nevertheless is a global super power projecting confidence and prosperity to the rest of the world, and especially with bordering countries. China has started already in 2024 the construction of the Chinese space station and plans the first lunar base by 2040

The main topics of research interest are green energy; novel nuclear plants (Pebble bed reactors); alternative raw materials; IT (especially data processing and transmission); energy storage & distribution; seminconductor devices and electric solid state devices; sensors; micro organsims and enzymes; health (e-health, regenerative medicine, preventive care, etc) bioeconomy; treatment of water/waster water/sewage; defense and space technologies.

7.2 Dungeons & Dragons

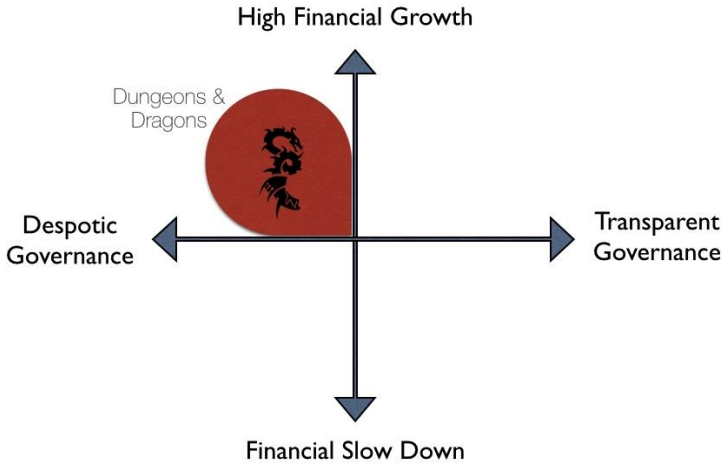


Figure 7.3: China 2025, the Dungeons & Dragons scenario

Scenario at a Glance: The Chinese government under president, Xi Jinping has started in 2015 substantial reforms towards greater transparency and social balance. However, it was proved impossible to overpass the hurdles set by a large group within the CCP and a new president was elected in 2018, driving the country to the opposite direction. The new authoritarian governance has managed to maintain high growth rates based both in cost innovations, but also on innovations in ICT, defense, space, and transport technologies.

Opposite to the previous scenario, China moves backwards in terms of transparency and openness, however the economy manages to maintain substantial growth rates.

Travelling to China in 2025, will require passing through a strict visa issuing process reflecting a strong policy to control the movement of people and ideas. All the western social media, including BOB (the successor of Facebook), are banned in the country, thus only the Chinese social platforms are available. WE (the successor of WeChat) is the main communication platform which is now widely spread globally.

The changes towards a more authoritarian governance and stricter censorship were initiated after a series of social and ethnic uprisings in Hong-Kong and other areas, and the failure of Xi Jinping to convince, key Communist Party officials, for the need to continue reforms. In 2018, and besides the successful financial strategies of the previous president, Dr Le Tsedung was elected as the new president of the PRC. Dr Tsedung has successfully created a dynamic Chinese economy based both to cost innovations, but also to more efficient management of the SOEs allowing them to gain competitive advantage in specific technological areas (ICT, defense, space, nuclear energy, transport, materials, etc). China has started already in 2023 to produce and sell competitive long-range passenger airplanes, while Chinese fast trains hold a big stake of the global market.

Besides the financial success for many years, the short term military conflicts in 2021 and 2022 with Japan and the financial embargo imposed by the EU and USA, have slowed the growth rates during the last 3 years and obliged China to strengthen the commercial and research relations with non-western emerging economies and with several African and South and Central Asian countries.

In 2024, an agreement has been finally concluded between the entire East and the South-East Asian countries, regarding the exclusive economic zones (EEZ) in the East and South-East Chinese Sea, flagging a new era of regional cooperation and peace.

Reforms in the Education system are modest resulting in hindering the knowledge economy direction of the country. At the same path, Research Framework conditions have been restructured towards global models, however authorities still favor specific groups and interests. Communication hurdles and cronyism have further hampered collaboration with international R&D partners, and decreased national outputs of disruptive technologies. Openness, innovative culture and creativity can be found in isolated "islands" with the state blessing, good financing and only on topics that are state's top priority like defense.

The country in order to keep up with its main role as a global growth engine and to maintain a steady growth in GDP, implement short term policies like easing credit controls, decreasing interest rates, and easing consumer credit. As growth and job creation is the priority, in many cases production neglects environmental implications and working conditions, and resulting to the serious industrial chemical of 2019 in Donguan.

The main topics of research interest are military technologies; Gen IV nuclear power plants; alternative raw materials; hydrocarbon fuel from bacteria, IT; transport and space; security; sensors; health technologies; water/sewage cleaning; GMOs.

7.3 Blue Jasmin

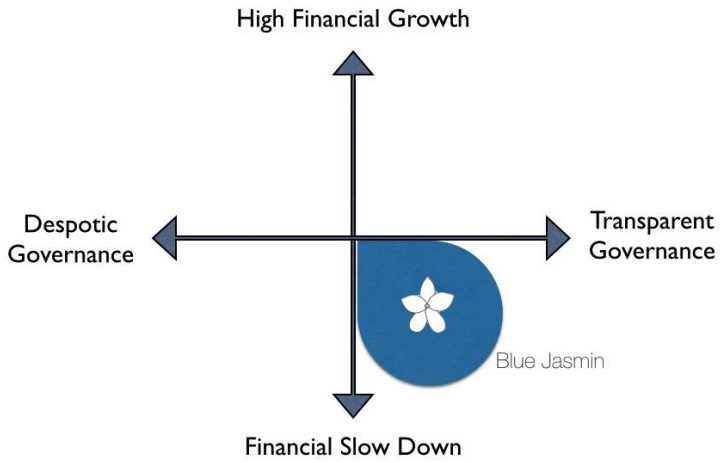


Figure 7.4: China 2025, the Blue Jasmin scenario

Scenario at a Glance: The Chinese government under president, Xi Jinping has started in 2015 substantial reforms in the transparency of governance and the judicial system, that were further enforced with the support of a dynamic urban middle class. Mr. Jinping has received a popular support by the CCP and the public and was re-elected in 2018, however the huge public debt (of central and regional governments) and the global "Rear Earth Metals crisis" of 2022, have stagnated the Chinese economy. Nevertheless, Chinese research is thriving driven by the substantial reforms in the

National research system that initiated in 2017 and by many international research cooperations, especially in the fields of alternative materials, biotechnology and health.

In 2025, Xi Jinping's dream for a Strong China (economically, politically, diplomatically, scientifically, militarily); Civilized China (equity and fairness, rich culture, high morals); Harmonious China (amity among social classes); Beautiful China (healthy environment, low pollution), is partly realized.

During the last 10 years, a steady decrease of air and water emissions, as well as local government environmental policies and Urban Middle Class efforts, have considerably improved environmental conditions. However still the problem of clean water scarcity remains top in the political and research agenda.

The Chinese education system has been radically modernized and upgraded, on the creativity and meritocracy aspect, providing momentum for an innovative knowledge economy. A number of critical structural changes at all levels has improves the education system outputs, and boosted open innovation and strengthened the position in the global R&D arena.

In 2018, the second term in power of president Xi Jinping, has started with strong reforms towards greater openness, transparency and more rights to ethnic and religious minorities.

At the same time the research reform that had been announced in 2014, and has started to be implemented in 2016, has rapidly transformed the Chinese research environment towards, greater transparency in the management of funds, greater flexibility, better strategic focus and stronger international links.

The Implementation of the Medium and Long Term S&T Development Plan (2006-2020) and the Five-Year-Plans for Science and Technology Development have led to an increase in SME's funding, and to a more transparent and efficient IPR law enforcement (seeing increasing numbers of foreigner filling patents in China). At the same time, private investments guide research both on high tech technologies and copy innovations, as state funding is now limited due to the economic slowdown.

Besides, the technological, and societal advances the country was hardly hit by the global "Rear Earth Metal Crisis" that boosted the prices of many rare earth metals, creating a domino effect in the global economy and seriously affecting the Chinese economy, that was also already bearing a great debt due the reforms in the Hukou system.

The main topics of research interest are alternative raw materials; energy storage and distribution; IT (5G, data management, internet of things, etc); preventive care; sustainable land use; environmental technologies (soil & water cleaning, emission control, etc); renewable energy (solar plants, biomass, etc); and biotechnology.

7.4 The Breathless Queen

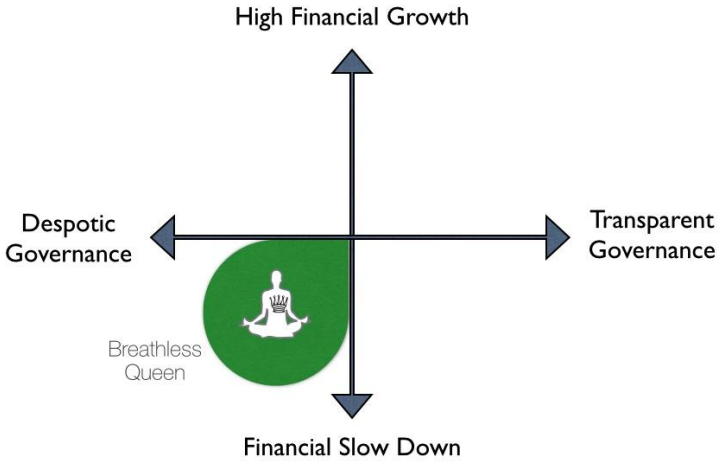


Figure 7.5: China 2025, the Breathless Queen scenario

Scenario at a Glance: China is still a global power but with feet of clay, reminding in many terms the Soviet Union of the 80s. The shortsighted and insufficient financial reforms have nailed the growth rate below 3%, fuelling several social side effects. Social unrests leaded by the middle-class and ethnic minorities are creating an explosive mixture in the Chinese society. The old-fashioned research system has limited funds and cannot follow the advances in space race, energy and biotechnology.

The first years of president Xi Jinping were quite successful, however was replaced in 2018 by the more hard liner Dr Le Tsedung, due to many objections of the CCP to the proposed massive Jinping reforms and the soft management of the social unrests in Hong Kong (2014) and in Xinjiag (2017) by the Uighurs. Under the new president, ACFTU[22] continues to hinder the operation of independent trade unions, and violent trade disputes is a common case.

Throughout *Breathless Queen* the operation of court system has moved backwards, and is again heavily influenced by local party officials, making impossible for the people to seek justice, and giving rise to more social unrest. In an attempt to control the situation, the new presidency has established a more authoritarian style of governance, applying stricter censorship, and transferring impressive powers to the cyber police and to the secret police.

Under this scenario, China has completely failed to transform from an export driven economy to one based on internal consumption. Gradually, foreign companies have lost interest investing and manufacturing products in China and moved to other areas in South Asia, Latin America and Africa. At the same time, the shortsighted and hesitant financial reforms imposed by the new government have limited the annual growth rate below 3%, fueling a domino of several side effects (unemployment, unrest, terrorism, rising public debt, etc). However, the financial embargos imposed in 2023 by the global

[22] All China Federations of Trade Unions

community, due to severe civil rights violations, seem to initiate a policy shift but still the final direction still remains to be seen.

Chinese education system is underfunded for several years and the important modernization reforms introduced in 2017 have now stopped, due to funding limitations and lack of political will. Naturally, the research environment was equally affected by the crisis, due to the reduced public and private R&D funding, the old-fashioned research framework, the global isolation, and the absence of a realistic long-term strategy. Instead of openness and meritocracy, we see the return of bureaucracy and nepotism. The main outcomes are less creativity, low innovation rates and many young minds moving to innovation hubs in S. Asia, the EU and the USA.

In this context, research is focused in specific priority areas (like defense, security, telecommunications) on which China is still competitive. Other topics of interest are nuclear energy, chemistry & materials, transport and space; security; GMOs.

*The production of the above described **4 generic scenarios** is the outcome of the **1st phase** of the research. These scenarios and all the research conducted in this phase, provided the basis for understanding the dynamics and complexity of the innovation system in China, that consists of many different stakeholders, and its affected by various global and national trends.*

*During the **2nd phase** of the work, a deeper analysis of the innovation stakeholders and of novel business models took place (section 8), while a more specific analysis of the main uncertainties that affect the innovation environment in China were taken into account. The outcome of this 2nd phase of the research, were **4 innovation focused scenarios** that provide plausible narratives for the innovation future of China.*

8.0 - THE INNOVATION LANDSCAPE TODAY

The initial scoping phase, as described in *Section 7.0*, allowed to better understand the overall dynamics of the innovation system in China, its main drivers, actors, and uncertainties. The first phase of the research included the analysis of the research environment in China, its drivers and trends, and a first set of scenarios for 2025, that included several aspects in relation with the economic and political situation in China.

The second phase of the research was focusing on analysing in more depth and detail the innovation environment and identify future opportunities and risks for Europe.

The methodology utilized during the phase 2 of the research is presented at section 5.3 and included participatory workshops, patent analysis, bibliometric analysis, interviews, Delphi, and SES.

During this phase of the study, the focus was drawn upon China's current innovation capabilities, and challenges that may drive innovation toward 2030, as well as on specific trends in business model innovation resulting in scenarios for Chinese innovation in 2030. In parallel, the western views towards China (current status and future cooperation potential) were also explored and analysed. In addition, specific technological areas presenting opportunities for research and technological cooperation, and emerging business models and markets are identified and discussed. Finally, scenarios for China 2030 were produced while policy actions for resilient bilateral cooperation were investigated.

The time horizon of the final scenarios for this second phase of this research was moved 5 years ahead (China 2030), as the current research phase was initiated almost three years after the conclusion of the first phase.

8.1 Innovation Developments in China

The brief, and admittedly somewhat oversimplified, story of China's innovation journey over the last decades is a tale of three regional innovation ecosystems. Shenzhen and its surrounding Pearl River Delta capture the evolution of the country's manufacturing sector and the Made in China label – from copycats to maker movements. Beijing, the centre of academic learning and government policy-making, cultivated a strong information technology ecosystem and became the birthplace of most of China's unicorn startups (i.e. startup companies valued at over $1 billion). Shanghai and the surrounding Yangtze River Delta, sitting at the pulse of China's consumer culture and making up the country's financial centre, spurned an e-commerce revolution and became a hotbed for consumer-driven innovation. The integration of these three innovation ecosystems is driving a new wave of innovation at the intersection between information technology and hardware. The result is a new breed of quality- and brand-oriented companies aiming for global markets.

8.1.1 The Evolution of "Made in China"

China's "opening up" was ushered in soon after the ascent of Deng Xiaoping in 1978. This coincided with financial deregulations and a move away from manufacturing in Western economies, accelerating the pace of globalisation and fragmentation of value chains. Capital and knowledge flowed into China's newly established Special Economic Zones, initially from Hong Kong and Taiwan. Meanwhile, loosened controls on movement meant that young Chinese lured by the opportunities in these new hubs could take up jobs there. Cheap, reliable and seemingly inexhaustible labour pools, combined with favourable regulations and infrastructure, served the country well as outsourcing became perceived as an inevitable trend in Western economies in the 1990s.

Gradually, Chinese manufacturers developed competitive advantages beyond cheap labour and large scale. Studies of China's wind turbine and solar photovoltaic industry[23], motorcycle industry[24]. and IT equipment industry[25] point to "architectural innovation", whereby Chinese manufacturers modularised the integral designs of Japanese and Western companies. This both lowered costs and increased interoperability. Such disentangling of complex processes led to new system-level configurations where a large number of manufacturers could focus on, and eventually commoditise, specific steps. It generated positive spillovers that further strengthened the ecosystem.

Over time, China came to master flexible mass production. Production lines were able to accommodate rapid changes in the products to be manufactured at mass scale. This became a hallmark of Chinese production, foremost exemplified by Foxconn, the manufacturer of household names such as iPhone, Kindle, PlayStation, and Wii. Scholars have made the argument that China needed Western companies to come up with new product innovations, but these western innovators simultaneously needed Chinese manufacturers to innovate in flexible mass production, enabling them to churn out new products quickly and efficiently[26]. This symbiosis resulted in a situation where China needed to keep moving fast enough to remain at the global technological forefront, but had no need to advance the frontier itself through breakthrough innovations.

In the early 2000s, knock-offs of well-known brands, especially in consumer electronics, began to proliferate. This phenomenon came to be known as Shanzhai, referring to the legends of bandits who opposed and evaded corrupt authorities. Nokia and Ericsson mobile phones were early targets of replication, later followed by Apple and Samsung. As demand for mobile phones rapidly grew in developing countries,

[23] Nahm & Steinfeld, 2013

[24] Ge, & Fujimoto, 2004

[25] Ernst & Naughton, 2008

[26] Breznitz & Murphree, 2013

Shanzhai phone came to occupy a growing share, peaking at roughly 20% of the globally 2G mobile phone market in 2010[27].

Initially, the key appeal of the Shanzhai products was the similarity to original products at a much lower price point. Later on, the selling point shifted to features not offered by the original products. Manufacturers began to target niche markets by adding unique features. For mobile phones this could mean Hello Kitty designs, better camera lenses, stronger battery packs or even integrated lighters or electrical shavers. These manufacturers achieved a temporary advantage through speed and customer-focus rather than through proprietary technology or branding.

Rapid speed was made possible by the wide distribution of complete design packages for working products as well as knowledge sharing with other manufactures within the ecosystem. Combining these factors allowed small teams of engineers to fork existing designs and focus on specific features. Mediatek, Rockchip, Arduino, and eventually Intel provided cheap or open source boards and chips. This allowed for rapid prototyping and production with low-entry-barriers. In a sense, Shanzhai represents an open source hardware approach where participants contribute and build applications on top of a shared knowledge base.

Recently, Shenzhen has become the chosen location for talented global makers and entrepreneurs to take advantage of this hardware ecosystem. They are drawn to incubators and accelerators such as Seeed Studio and HAX Accelerator for their ability to rapidly develop and launch products from start to finish. Their incubatees have successfully crowdfunded and launched products ranging from a low-cost robotic arm to a biometrics headset and from an air umbrella to a movement virtualisation sensor suit. The brain gain is further fuelled by positive media coverage in the West. European and North American media outlets have called Shenzhen "the Silicon Valley of Hardware" (Wired), "a hothouse of innovation" (The Economist), and "a gadget geek's paradise" (Financial Times).

At the individual level, manufacturers attempt to make money by building applications on the shared technology and design knowledge base or by rapidly spotting and copying new designs introduced by others. The system-level outcome of such individual-level behavior is a system that evolves along an emergent design and technology path. This conceptualisation shows both the strengths and limits to the Chinese manufacturing ecosystem. Two illustrative cases highlight the speed with which the ecosystem can turn ideas into products in some areas, but also its inability to take on some types of problems.

The first case is that of Stikbox, a smartphone case which unfolds into a selfie stick. After a year prototyping the product, its Israeli inventor attempted to raise funds through a crowdfunding campaign. Just one week into the campaign, an identical product was sold online by a Chinese manufacturer. Rapidly, a growing number of Chinese manufacturers started selling the product online, sometimes using the images created by the original inventor.

[27] Android market share rose to 20% (2014), Sandor (2011)

The second case is that of Hong-Kong based startup Native Union. Similar to Stikbox, it's initial consumer electronics product was quickly copied and sold cheap by Chinese manufacturers. In response, the company focused on developing a product that proved more difficult to replicate – smartphone cases made out of Italian marble.

The Stikbox design assimilated perfectly into the Chinese manufacturing ecosystem because it precisely matched its core capabilities. Sourcing and processing marble, on the other hand, required material expertise not amongst the competencies of Shanzhai manufacturers, making the product less likely to be copied. The evolution of the Chinese manufacturing ecosystem thus changes the logic of what ideas are, and are not, valuable.

As the dynamics and overcapacity of China's manufacturing ecosystem drives rapid commoditisation of components and products, Chinese OEMs are seeking increased value added along several dimensions:

1. ***Climbing the value-added ladder through design, R&D, and branding.*** Leading domestic brands in different industries, notably Haier and Lenovo, have inspired many Chinese low value-added manufacturers by showing them it is possible to operate on radically higher margins. Meanwhile, the government has put pressure on manufacturers to move up the value-chain. A wave of OEMs (who design and produce for other companies) are hence transitioning to ODMs (who design and produce for their own brands). The same companies that manufacture the flagship products for many leading international brands, ranging from kitchen utensils to diapers, have set up their own brands, primarily targeting the Chinese market and other developing markets. This has been a contributing factor to the soaring of Chinese trademark applications from 766,000 in 2006 to 3.691 in 2016.

   In the process, many of these Chinese companies started to build up their own intellectual property. Our analysis of Chinese invention patent shows that, in 2006, Chinese patenting started to undergo a relative shift toward lower-tier, manufacturing-oriented cities in China's eastern and southern provinces, such as Dongguan, Huizhou, and Zhongshan (Guangdong Province); Wuxi, Changzhou, and Zhenjiang (Jiangsu Province); and Bengbu, Hefei, and Wuhu (Anhui Province). On a macro level, this shift in R&D represents an effort by Chinese manufacturers to move from simply assembling products to owning a larger share of their value-added parts.

2. ***Rapid development.*** When speaking to executives in China, whether working for Chinese or foreign companies, a common theme tends to be the speed with which Chinese companies execute their R&D and product development. This appears to be a function of several factors: keeping a constant eye on competitors, suppliers, and customers to pick up new ideas and needs; an iterative approach to product development that involves prototyping, even in safety-oriented areas such as mining equipment, and constant feedback from customers; R&D and product development processes that are organised around speed; involvement from top management and strong leaders that provide clear goals and direction; a tendency of teams to self-organise around, and reach out through their social networks to solve, difficult tasks; and innovating in small steps by taking proven, sometimes reverse-

engineered, designs as the point of departure, exploring additional value-added along specific dimensions.

As Chinese OEMs increase their investment in R&D and develop novel products, they apply the same principles they have perfected in manufacturing – modularisation and flexible mass production. For example, Guangzhou Pearl River Piano Group applied "simultaneous engineering" – executing different steps in parallel – on product development in piano making by modularising the process and assigning a large number of people to each task. By doing so, they were able to launch 10 new piano models in five months at a cost of $1 million – a tenth of the comparable cost.

3. ***Maximising value-for-money by delivering on just the right level***. In many areas, Chinese goods have now reached a quality level of "better-than-good-enough", in the words of one interviewee. While incumbent companies have often felt confident that the complexity of their products makes them difficult to replicate in the medium term, the relative simplicity of Chinese products has in fact become an important selling point. In industries where downtime can be extremely costly, such as mining and construction equipment and industrial machinery, the ease of maintenance and abundance of standardised, low price spare parts make Chinese products attractive. Consequently, the premium segment, which has traditionally been the home tuft of multinational companies, is now shrinking in many industries. Chinese and other developing market customers are satisfied with the "better-than-good-enough" mid market products that are offered at a fraction of the price of premium alternatives. While the expectation was that Chinese companies were slowly marching up the value chain to eventually challenge incumbents in the premium segment, Chinese companies are instead taking the fight to the mid segment, threatening to undermine the premium segment as it looks today.

4. ***Service-based offerings.*** As hardware commoditises, manufacturers are increasingly competing with aftermarket service offerings. These are sometimes built around the information generated as the products become connected, as in the case of Xiaomi, or in more traditional ways.

5. ***Automation.*** Labour is not as abundant and cheap as it once was, and manufacturing has received competition from the burgeoning urban service sector. In line with international trends, Chinese manufacturers have taken to automation. This trend is underlined by electrical appliances manufacturer Midea's high-profile acquisition of Kuka (Figure 8.1), the German leader in industrial robotics. Haier, another electrical appliances leader, launched "the world's first intelligent and interconnected air conditioner manufacturing plant", to drive a transition from mass production to mass customisation.

Figure 8.1: A Kuka robot at the Shenzhen 2017 High Tech Fair (Photo: Epaminondas Christofilopoulos)

8.1.2 The Emergence of China's Internet Economy Innovators

Much like their manufacturing counterparts, China's internet companies started out replicating overseas ideas and adapting them to fit the needs of the domestic market. This tendency was reinforced by the difficulty for software development startups to secure venture capital for ideas that had not already proven successful in overseas markets. Copy-and-adjust projects were, in effect, favoured over novel ideas.

Barriers to Western giants such as Google and Facebook enabled Chinese counterparts to stake out their turfs with limited foreign competition. Thus the giants that now form the backbone of China's internet industry – Baidu, Alibaba, and Tencent – emerged. What was missing in competition from foreign companies was, however, more than compensated for by domestic firms.

In areas ranging from location-based dating to easy-to-use mobile wallets, live-streaming to in-app integration of an array of functions, companies like MOMO, Alibaba, YY, and Tencent preceded their Silicon Valley-based counterparts. It has been said that the best way to understand the roadmaps of Facebook and other Western social internet companies is to look at what has already taken place in China's internet economy. The feeling that "China, not Silicon Valley, is cutting edge in mobile tech" is increasingly echoed by Western industry leaders.

As hinted at above, however, the most important strength of Chinese internet companies compared to their Western counterparts does not lie in novel functionality, but in the

ability to monetise users. Their ability to reach this level of success stems from the business models they employ, whether in gaming, knowledge sharing, live streaming, grocery shopping, virtual gift giving, or travel booking.

Why have Chinese internet companies been so successful at monetizing users and popularising new features? Our interviewees have pointed out five key reasons:

1. ***Competition is fierce.*** It is said that almost 5,000 startups joined the fray in copying the Groupon group buying business model into China in 2010-2011. The last company standing, Meituan (now Meituan-Dianping), survived by perfecting its business model for the Chinese market. The company posted a revenue of USD 6.42 billion in 2016, to be compared to Groupon's revenue of USD 2.2 billion the same year (Shu, 2016).

   The same pattern is visible across applications: Chinese internet companies starting out as copycats but iteratively adjusting their business models under immense competitive pressure. As this is written, for example, at least 30 companies are competing for a share in the bike sharing market, which will eventually consolidate as has happened in other hot areas. When the dust settles, the winners tend to come out strong, which often involves having developed models for monetisation that are better than those of the Western idea originators. Over time, the strong competitive pressure forces market leaders to continuously improve their offerings and launch improved products.

2. ***The lack of advertising revenue has forced Chinese internet companies to develop other revenue streams***. The advertising industry is a much smaller in China than in many Western countries. While Facebook generates more than 90% of its revenue from advertising, WeChat-parent Tencent derives the same share from non-advertising sources, including mobile payments, e-commerce, and sales of virtual items (McKinsey, 2015).

3. ***The consumer class is large and open to try new things***. In a short time span, Chinese middle-class consumers have become among the most discerning in the world. They are mobile-centred, high-spending, experience-seeking, densely concentrated in urban centres, and rapidly growing in number. Their willingness to try new things makes "crossing the chasm" between the visionary early adopters and the pragmatic early majority (Moore, 2001) less of an issue than in other places. The presence of large markets even in narrow product categories, such as self-balancing one-wheels, supports niche players to iterate through generations of products until, in some cases, they eventually appeal to a wider audience.

4. ***The mobile payments infrastructure is mature.*** The willingness of consumers to shop using their mobile phones prompted mobile payments to take off in a big way in China in 2013 and 2014. In 2016 they were an astounding fifty times higher than those in the United States (Wildau & Hook 2017). The wide adoption of mobile wallets, and the ease of using them to pay even the smallest sums of money, has reduced payment barriers and therefore made it easier for internet startups to monetise users.

5. ***Companies are willing to leap into new areas outside their core competencies***, as Alibaba did when it transitioned from B2B to B2C commerce (Tse, 2015). On the individual company level, this often leads to failure. Once-mighty technology company LeECO, for example, is currently struggling as a result of too quickly reaching into too many new areas. But on the ecosystem level, such behavior translates into rapid exploration and exploitation of new areas.

These have resulted in a strong internet technology ecosystem, containing the strong "BAT" (Baidu, Alibaba, Tencent) backbone but also a "long tail" of entrepreneurial ventures.

The factors that have made Chinese internet companies strong domestically may also hinder them as they attempt to go global. The business models that have been adjusted to work so well in China have so far not helped Chinese companies to become successful in Europe and the United States. The main overseas market for Chinese mobile wallets, for example, are Chinese travellers.

8.1.3 The Integration of the Different Innovation Ecosystems

China is part of the global trend where sensors and wireless communication are increasingly embedded into physical products, enabling them to collect data and become connected. As this happens, a decreasing share of these products' value is related to the hardware itself, while a growing share is generated through the products' interactions with their users and surroundings. This "smartphoneification" of everything is driving the interest in emerging areas such as internet of things, smart homes, digital health, intelligent manufacturing, connected vehicles, and smart cities – all of them areas that China is well positioned to lead.

As hardware enters the information domain, entirely new business models become available to product makers who adopt an internet mindset. Rather than making the bulk of their money from selling hardware, they now have new aftermarket venues to develop additional revenue streams. Xiaomi, a consumer electronics brand known for its array of products spanning health wearables, smart home appliances, and mobility devices, is an example of this. The company defines itself as an internet company despite being a seller of hardware. Its former CTO has said that the company charges no margins on its mobile phones. Its TV, for example, sells at about CNY 3,000, just half the prices of Samsung's TV using the same panel (Smith, 2015). The difference is made up by showing advertising when the TV is being turned on.

Such razor-and-blade business models through zero margin hardware have been applied for a long time in some sectors, notably game consoles where profits instead come from selling games. But as China's huge hardware sector is now becoming "informatised", and ambitious Chinese companies tend to be hungry challengers in their industries, the scale is likely to become much larger and the implications likely to be felt in a number of sectors. Incumbents who define hardware as their business will have difficulties adjusting to a paradigm where hardware is given away for free to obtain other revenue streams.

Tellingly, the companies that have become successful in applying internet business logics to hardware are usually not the OEMs themselves. Such thinking instead comes from the country's internet ecosystem, with its strongest centre in Beijing's Zhongguancun cluster, an area which has more unicorn startups than anywhere else bar Silicon Valley[28]. Many new startups and concepts can be attributed to the connection between Zhongguancun and Huaqiangbei – or, more broadly, the merging of China's internet and manufacturing ecosystems. Examples given by our interviewees are discussed below.

1. *Xiaomi*, the consumer electronics company, is not developing most of the products it sells. In order to move fast and minimise the financial risk associated with failure of any one product, the company instead taps into China's vast manufacturing ecosystem, taking a minority share in selected OEMs. An interviewee told us that dozens of OEMs pass through Xiaomi's doors every day to make their pitch. Chosen products then undergo several design iterations to align with the Xiaomi touch and feel, and smart features are added to plug the devices into the company's online platform. From their mobile phones, users can seamlessly interact with a variety of devices, whether color-changing LED lights, connected scales, robot vacuum cleaners, air purifiers, or smart flower pots. This approach, combining the unique advantages of China's hardware sector with logics that stem from its internet economy, has made Xiaomi one of few companies globally with the lucrative claim of comprehensively furnishing the smart home – while clearly aiming beyond it.

2. *Mobike*, a bike-sharing platform, is another startup concept that emerged from the integration of the two ecosystems. Effectively consisting of GPS-enabled locks surrounded by cheap hardware, its bikes can be tracked and their position displayed to users through an app. The system enables users to pick up and leave bikes anywhere rather than being restricted to dedicated stations, a factor that has limited adoption in many Western cities. Bike-sharing has taken off in China, with hundreds of thousands of bikes in each of the major cities, because of the availability and flexibility that the business model provides. Barriers to use are low, as the standard charge for a bike-ride is one yuan, easily paid through one of the popular mobile payment platforms. Chinese companies are now taking the concept to cities around the world, including Silicon Valley and Singapore.

[28] Zhongguancun, cluster of unicorn companies. (2017, March 3).

Figure 8.2: *Mobikes parked in a Chinese city*

3. *DJI*, a Shenzhen-based drone maker, is a third example of innovation at the intersection of hardware manufacturing and internet thinking. At one point occupying 70% of the global market for civil drones, the quality-, design-, and brand-oriented company has primarily been known for technological and product innovation. There is, however, an important business model component to its success. By opening up its platform to third-party app developers, the drones quickly become useful for a number of applications such as mapping and surveying in forestry and agriculture. As a result, challengers need to compete not only with the company's technology, but with its entire ecosystem of apps. Such thinking has long been used by the likes of Apple and Google for mobile platforms, but Chinese companies now increasingly extend it to the world of hardware.

4. *Ehang*, a Guangzhou-based drone maker and competitor of DJI, has won a contract to supply Dubai with autonomous one-person drone-taxis to be taken in service during 2017. The company, "passionate about the union of hardware and software", uses artificial intelligence to enhance its flying and photography and has launched virtual reality goggles to give the user a 360° view.

While the most instructive examples are found in consumer electronics, the trend extends to many other industries as well, ranging from construction equipment (Sanyi) to medical equipment (Mindray). The Internet Plus concept, proposed by Li Keqiang in 2015, envisages the "information trend" to have a large impact in areas such as agriculture, government, manufacturing, medicine, and finance[29].

Beyond market share, the new breed of visionary, ambitious, quality-oriented brands working at the intersection of hardware and software have the potential to change the

[29] China unveils "Internet Plus" action plan to fuel growth. (2015, July 4).

image of the Made in China label. It is hard to come by a better example of this than *NIO*, a newly started brand of Shanghai-based, electrical vehicle start-up *NextEV*. Its electrical concept car, luxurious, record-fast, and autonomous, made waves as it was unveiled at the trendy Saatchi Gallery in London at the end of 2016. The company says it plans to eventually produce a range of electric cars for the mass market, with a strong emphasis on connected technologies and user experience.

8.2 The Changing Structure Of R&D And Academic Research

Scientific and technological research is sometimes been conceptualised and a network of topics, such as "automation", "gene editing", and "spacecraft". When a large number of researchers work on two different concepts, these two concepts can be said to be closely related. From this logic emerges a structure of topics. Over time, some topics become more central in the network, meaning that they connect to a growing number of other topics. At the same time, other topics become more peripheral over time, as their usefulness in different areas decreases. By studying concept change over time in the structure of topic networks, based on data mining of 7.6 million academic articles published by Chinese authors during the period 2012-2016 and 2.3 million invention patent applications filed by Chinese entities during the same period, we obtain an understanding of which topics in R&D and academic research are becoming increasingly central. It should be noted that high centrality does not equal large quantity of patents and articles. Rather, centrality is a measure of position.

Increasingly central R&D topics

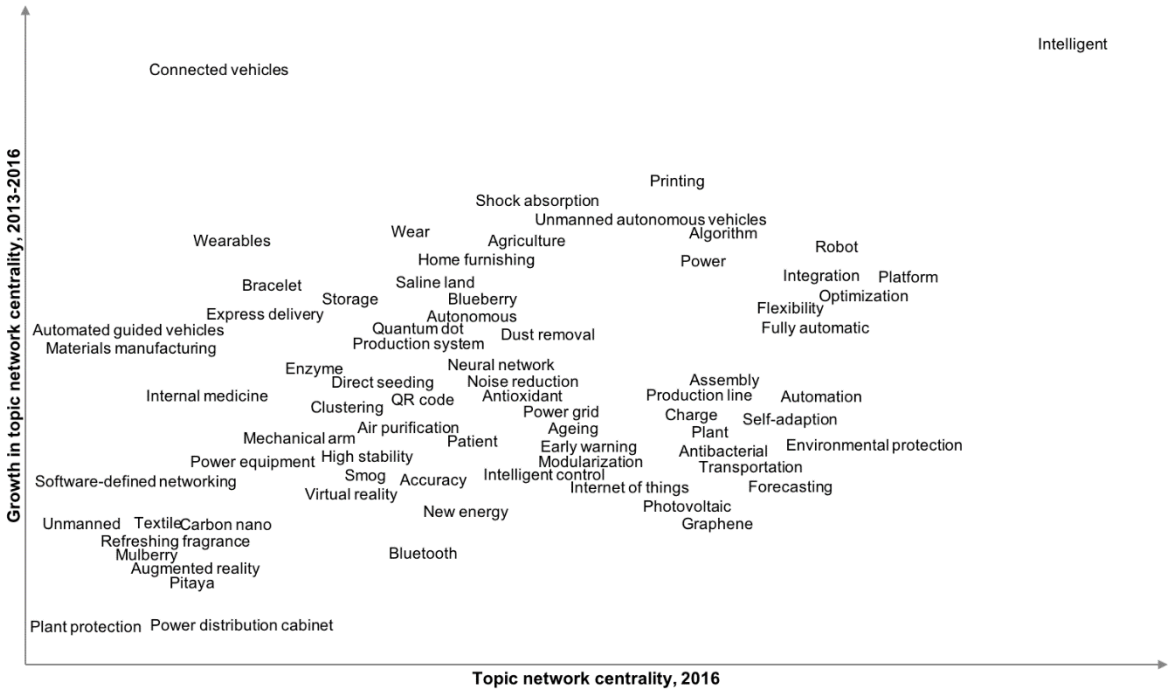


Figure 8.3: Network centrality and growth in network centrality of topics based on invention patenting.

- *Intelligent* or *smart* is the concept with both the highest and fastest growing centrality, as everything from healthcare to electronics to cities get the prefix *smart*. Related to this are several other fast-centralising topics: *internet of things*, *intelligent control*, *optimisation*, *clustering*, and *algorithm* – technologies enabling the rise of *smart*.
- *Automation* is becoming a priority in a growing number of areas, from production processes to home appliances to vehicles. A related area is *robotics*, another of the most central and continuously centralising topics.
- *Automotive* technology has moved to the intersection of several areas of technology, with concepts such as *connected vehicles*, *automated guided vehicles*, and *autonomous driving* making inroads.
- More broadly, *transportation* is a topic that increasingly integrate thinking from other areas.
- R&D in *drone*, or *unmanned autonomous vehicle*, technology combines hardware and software expertise in areas spanning photography, flying, control, and machine learning. This complexity is positioning drone R&D as an increasingly central node in the R&D topic network.
- *Energy* related R&D is also pulling ideas from a growing number of areas. This involves topics related to the *power grid* and *electricity distribution*, as well *energy generation*, with concepts such as *new energy* and *photovoltaics*.
- *Storage* is becoming a more central concept partly because it is related to both energy and information, two areas that individually are growing in importance.
- Several *nanotechnology* related topics are finding new applications, including *graphene* and other *carbon-based nanomaterials*, as well as *quantum dots*.
- *Environmental protection* is bridging different technological areas, with concepts such as *air purification*, *plant protection*, and *smog* related issues becoming more central.
- *Printing* is getting more of a bridging position as it is used in up-and-coming areas such as *3D and bio-printing*, which in turn have a growing number of applications.
- *Wearable* technologies are becoming more central as they become applicable in more different areas, including healthcare, consumer electronics, and even fashion. *Textiles* are getting more of a bridging position between concepts, highlighting their growing technology content.
- *Agricultural* technology is becoming a focus in several different areas, including biotechnology, genetics, drone technology, big data, and artificial intelligence. Related topics, primarily attracting a growing interest from biotechnology companies, include *direct seeding*, *plants*, *blueberries*, *pitayas*, and *mulberries*.
- Topics in medicine gaining importance include enzymes, internal medicine, antibacterial, aging, and antioxidants.
- Related to the internet economy, R&D on QR codes and express delivery are becoming increasingly central. Augmented reality is gaining inroads not only in gaming and entertainment but in industrial applications as well.
- In line with the idea of modernising China's manufacturing sector, a number of production related concepts – assembly, production line, production system, modularisation, and industrial automation – increasingly intersect with other R&D topics.

Increasingly central topics in academic research

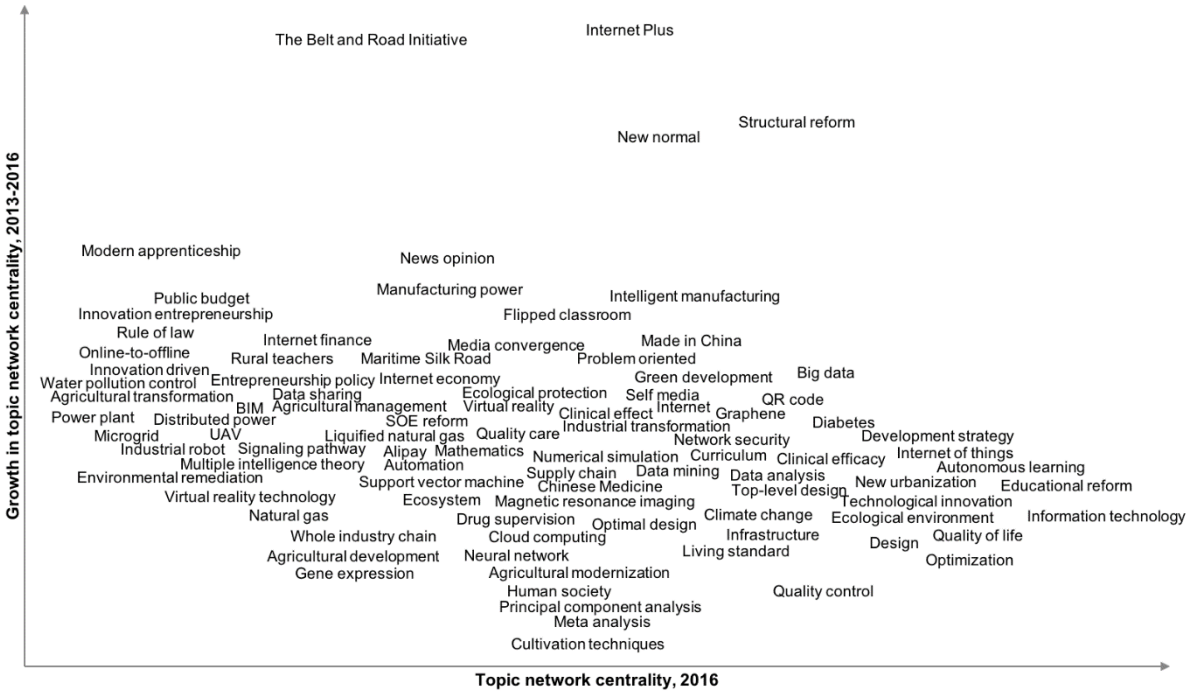


Figure 8.4: Network centrality and growth in network centrality of topics based on invention patenting.

- In academic publishing, many of the same areas and topics are becoming more central as in patenting, although they tend to be approached from a different angle. This includes *information technology* (with topics such as *big data*, *artificial intelligence*, *neural networks*, *support vector machine*, *cloud computing*, *online-to-offline*, and *internet finance*), the *internet economy* (*QR code*, *Alipay*, *self-media*), *environmental protection* (*green development*, *ecological protection*, *climate change*), *advanced manufacturing* (*intelligent manufacturing*, *industrial robots*, *manufacturing power*, *Made in China*, *industrial transformation*), *agricultural development* (*agricultural management*), *energy* (*distributed power*, *liquified natural gas*), *medicine and healthcare* (*clinical efficacy*, *diabetes*, *Chinese medicine*, *magnetic resonance imaging*, *quality care*), and *nanotechnology* (*graphene*).
- Some topics are becoming increasingly central in academic research, not seen in R&D. Examples include topics related to *living standard* and *quality of life*.
- A growing focus can be seen in topics related to *educational reform*: *curriculum*, *flipped classroom*, and *problem oriented learning*.
- Research related to political concepts is also becoming more central, including *New Normal*, *Internet Plus*, *New Urbanisation*, and *the Belt and Road Initiative*. Some of these relate to the environment for innovation, such as *structural reform*, *rule of law*, and *entrepreneurship policy*.
- Finally, *design* is gaining increased interest in various academic areas.

8.3 State's Influence on China's Innovation Trajectory

The most recent innovation agenda is a step away from policies under the Hu-Wen administration, when a coalition of industrial planning advocates exerted great influence over policy making and "indigenous innovation" was the buzzword. Current policies are less oriented around ambitious mega-projects and more focused on guiding the development of current capabilities in strategic directions. The aim is to comprehensively upgrade Chinese industry while simultaneously stimulating breakthroughs in key areas of basic research and technology.
Different levels of government have issued more than 100 national-level plans for innovation. By clustering the hundreds of goals in these plans, we reach a bottom-up understanding of China's policy ambitions. Note that the categorisation below is not explicit in these policy documents, but emerges from the analysis.

1. ***Transform China into a leading manufacturing power.*** This involves increasing Chinese companies' share of core components and materials used in manufacturing to 70% in 2025, forming 40 industrial technology research bases by the same year, gradually upgrading manufacturing processes to become more digitised and automated, and encouraging manufacturers to switch from production-oriented to service-oriented manufacturing and build strong brands.

2. ***Take the lead in the next generation of information-driven technologies.*** Information technologies are expected to enhance manufacturing, agriculture management and production, energy production and distribution, financial innovation, healthcare accessibility, logistics and warehousing, e-commerce reach, and environmental monitoring. Information technology is seen as a mitigator of the urban-rural divide, with policy documents targeting a broadband penetration rate of 82% in 2025, up from 50% in 2015. Data analysis, artificial intelligence, cloud computing, and quantum computing are strategic areas of development.

3. ***Feed China by transforming the agricultural and food technology sectors.*** The aim is a modern agricultural sector relying on biotechnology, intelligent production, and sustainable development. Policy documents contain specific targets for 2020 with regards to agricultural e-commerce value, information technology utilisation rate, mechanisation level, emission of agricultural waste (zero), and pilot demonstration bases. Special emphasis is given to seed technology, animal and plant breeding, high-end agricultural equipment, yield gain improvements, water-saving technologies, and bio-fertilisers. In the area of food technology, cold chain logistics and automated food processing are highlighted as important areas for innovation.

4. ***Achieve environmental sustainability without compromising economic growth.*** Policy documents set up goals in different areas of environmental sustainability, including new energy, green manufacturing, electromobility, smart cities, and new energy technologies. In manufacturing, low-carbon technologies will be utilised and the intensity of major pollutants in key industries will drop by 20% until 2020. In new energy vehicles and transportation, the electric vehicle production will reach a cumulative production and sales of 5 million units by 2020 and breakthroughs will be achieved in high-speed railway and Maglev technology. In the area of smart cities, standardisation, digitalisation, and intelligent technologies will lead the way

for more efficient transportation, power distribution, communication, and underground pipe networks. Green construction and prefabrication of buildings will reduce the environmental impact of the built environment. Breakthroughs will be sought in renewable energy, while the efficiency and use of conventional energy will be improved.

5. ***Increase the quality of life for all citizens***. In 2020, every citizen should be covered by basic medical and health services and the per capita life expectancy should be one year higher than in 2015. Eldercare is to become more home- and community-based. In medical research, policy documents mention novel drug discovery and development, Chinese medicine, high-end medical equipment, and the development of an "intelligent clinical ecosystem". By 2020, large pharmaceutical companies should invest at least 2% of their revenues in R&D and at least 100 pharmaceutical companies should reach "advanced international level". Prevention and treatment of major diseases will be strengthened. Breakthroughs will be stimulated in biotechnologies such as 3D bioprinting and immuno-, gene, and cell therapy.

6. ***Use innovation to support China's re-emergence as a great power.*** In the area of deep sea exploration and marine engineering, goals include the ability for deep sea exploration at depths of up to 11,000 metres; the extraction of oil, gas, and minerals at high depths; and the operation of large marine engineering equipment. In space exploration, infrastructure and spacecraft technology are to be enhanced, satellite communication and navigation to be improved, and a string of space science satellites to be launched. A lunar expedition will depart in 2018 and a Mars probe will be dispatched in 2020. Key technologies for polar region development are also on the agenda, involving resource exploration and polar environment observation. Informatisation of military equipment and the furthering of naval military technology are also high priorities.

7. ***Foster talent and creativity.*** This includes specific targets for the number and funding of R&D staff and researchers overall, with special emphasis on cultivating world class scientists, high-end engineers in high-tech fields, and innovative entrepreneurs in emerging technology areas; by 2020 setting up 1,200 training bases tasked with rapidly educating 10 million high-skilled professionals in areas of talent shortage; attracting thousands of high-level overseas Chinese to return home for innovation and entrepreneurship; providing special support to 10,000 high-end talents in prioritised areas; and developing infrastructure for mass creativity, such as co-working spaces and incubators.

8. ***Enable breakthroughs in basic science and technology***. Policy documents pinpoint 13 scientific fields in which breakthroughs will be promoted, spanning quantum control, protein machinery, gene editing, and fusion energy. They also outline 19 "important projects" to be realised in 2020 and 2030. Toward 2020, these include high-end chips, large-scale integrated circuit manufacturing equipment and processes, gas cooled nuclear reactors, major new drug discoveries, AIDS prevention, and a high-resolution earth observation system. Toward 2030, the plan is to realise aircraft engines and turbines, deep sea stations, quantum communication technology, and brain science breakthrough for artificial intelligence and treatment of diseases.

9. ***Bridge academic research and real-world applications.*** The government is encouraging technical cooperation between industry and academia and the establishment of innovation platforms co-founded by research institutes, universities and enterprises. More technology transfer and commercialisation centers are to be set up within academic institutions. A trading platform for science and technology research results will be created for faster technology transfer. Stronger ties between companies in universities will be cultivated to increase the flow of talent between them.

The tools and mechanisms for realising the multitude of goals can be categorised into the following seven types:

1. ***Direct economic funding*** **and investment in basic research, industrial technology innovation, and key projects** through structures such as the Natural Science Foundation, funds supporting to the National Science and Technology Major Projects, and funds related to the National Key R&D Plan.

2. ***Tax incentives*** (15% tax rate) for high-tech enterprises that meet certain requirements, as well as for incubators and angel investors.

3. ***Financial policies*** to encourage an expansion of investments in innovative ventures, cultivate capital markets that support innovation, and promote financial products and services that support innovation.

4. ***Talent attraction***, training and cultivation through educational reforms, talent investment plans, and programs to attract overseas Chinese and non-Chinese knowledge elites to China.

5. ***Improvement of science and technology infrastructure***, including optimising the scientific research base, constructing national laboratories in major innovation fields, and encouraging the establishment of platforms for sharing of equipment and data.

6. ***Strengthening of intellectual property*** **rights** and other innovation-related laws.

7. ***Strong authority*****, communication channels**, and channels of direct and indirect influence over personnel in different positions, ensuring that the priorities are well understood by all relevant stakeholders.

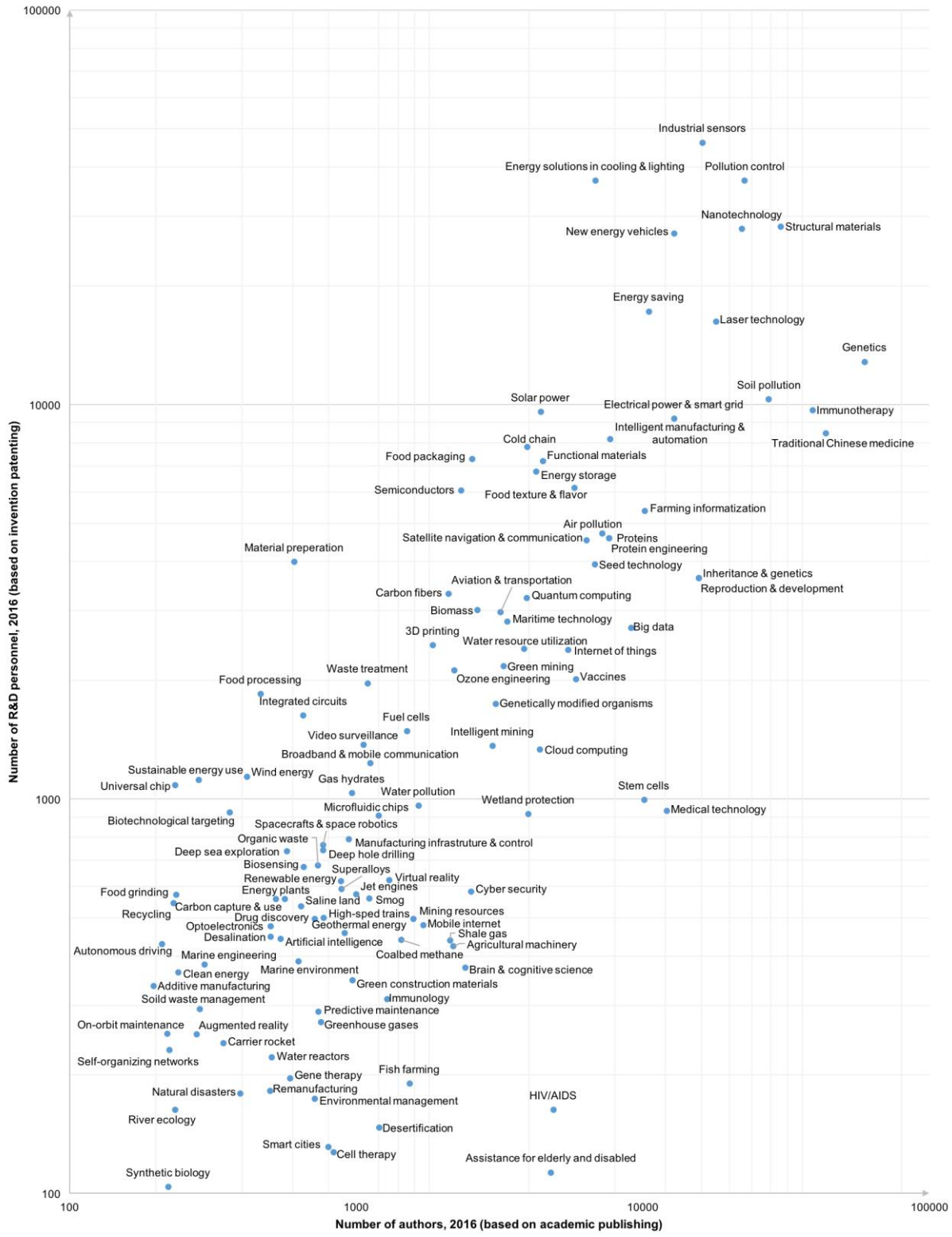


Figure 8.5: Volume of on-going work on policy priority areas: number of authors of academic articles (academic researchers) and inventors of invention patents (R&D personnel) in areas targeted by government policy *(Copyright: KAIROS Future).*

8.4 China's Talent Capacity

Human talent and creativity is a key driver for innovation, and it is one of the more disputed topics as regards China (Florida et al. 2008).

Millions of engineers graduate from Chinese universities every year, yet one of the most frequent complaints heard from European multinationals in China is about the shortage of talent. To explain this, some point to the educational system, saying it teaches learning facts by heart and "copying the master" rather than stimulating creativity. A political culture marked by censorship has also been seen as blocking the flow of ideas.

Things are changing fast, however, with a number of developments impacting the arena of talent and creativity in China.

1. ***Overseas returnees***. In 2016, 540,000 Chinese students went abroad to study, more than 13 times the amount in 2000. These numbers pushed the total of overseas students since China's economic reform to more than four million. According to the Education Ministry, only a third of overseas students returned home in 2006. Today, on the other hand, roughly 80% of students return to China to utilise their advanced foreign degrees. Many of these returnees perceive the opportunities for work as better in China than abroad (Chen, 2017).

2. ***Government incentives.*** The Chinese government has also deployed a variety of national programs to support the innovation economy. The National Science Fund for Distinguished Young Scholars offers research funding for projects while the Changjiang Scholars Program awards distinguished professors much needed research grants. The renowned Thousand Talents Plan specifically targets elite Chinese researchers overseas in efforts to bring them back to China. Major cities like Beijing also try to attract returning graduate students with incentives such as local residence permits.

3. ***Emergence of creative "tribes".*** China's thriving independent music scene in cities such as Wuhan, Changsha, and Beijing is a reflection of the strength in the its emerging creatives. From reggae to psychedelic, heavy metal and punk, China's youth is adding a variety of new sounds to its repertoire. If underground music sounds to niche, look no further than to the explosion of China's literary scene. Of the over 350 million Chinese who read literature online, 327 million use their mobile devices for this (Ouyang, 2017). A large number post their own literary pieces online for anyone to read. Art and design have similarly undergone a renaissance in China. In 2016, Beijing Design Week attracted more than one million visitors to more than 300 events across the city (Qin, 2017). The city boasts 119 design schools graduating 10,000 designers every year. Design brands such as Shangxia seek to create a uniquely Chinese yet modern style with international appeal.

4. ***The rise of the maker movement.*** Known for manufacturing 90% of the world's consumer electronics (Carter, 2016), Shenzhen has emerged as a hub for the maker community. Providing mature supply chains, strong manufacturing know-how, and a free flow of ideas, the city has proven ideal as a location to quickly realise product

ideas. The city is attracting creative designers, avant-garde architects, and entrepreneurial makers from all over the world.

Figure 8.6: The makers community exhibiting drone applications, at the Shenzhen High Tech Fair, November 2017 (Photos: Epaminondas Christofilopoulos)

5. ***An entrepreneurial ideal.*** Fuelled by the success of inspiring entrepreneurs such as Jack Ma (Alibaba), Lei Jun (Xiaomi), and Ma Huateng (Tencent), entrepreneurship has become an aspirational ideal to many young Chinese. The proliferation of incubators and co-working spaces – currently standing at around 8,000[30] and counting (at least 500 coworking spaces in Beijing and Shanghai alone[31]) – shows the preference among young Chinese for less rigid forms of working. The large number of startup and entrepreneurship events in the big cities suggest that the entrepreneurial culture is growing faster than the start-up scene itself.

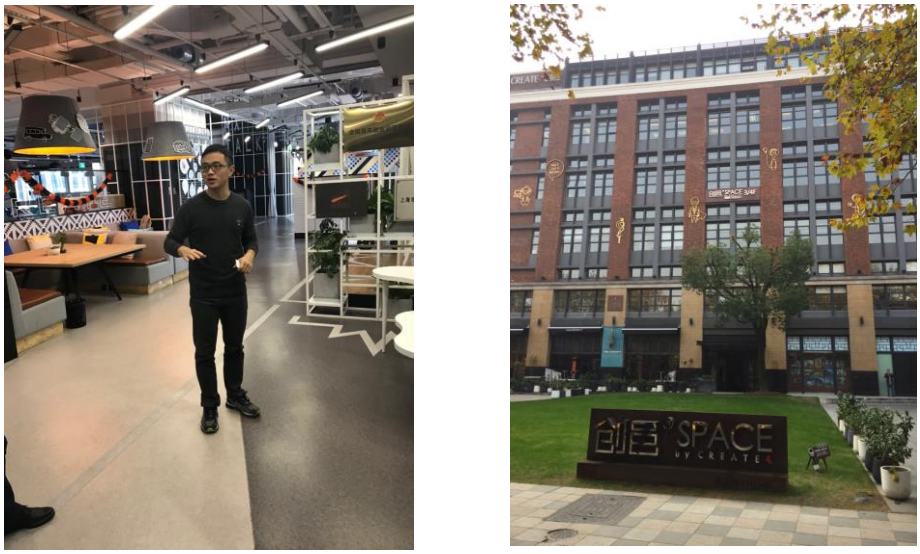


Figure 8.7: An Incubator (left) and the Space coworking space (right) in Shanghai (Photo: Epaminondas Christofilopoulos)

[30] Jie, 2017

[31] JLL, 2017

Despite these encouraging signs, the future development of creativity in China is a key uncertainty. The central question is whether it will be a small creative elite responsible for developing innovative ideas, or it will be broad creative class that will be drive the race and unleash innovation on a bigger scale.

9.0 INNOVATION SCENARIOS: CHINA 2030

Taking into account the main nine uncertainty dimensions identified, each with three options, generates a total of almost 20,000 scenarios. However, as not all of these dimensions, are independent of each other, only a fraction of these scenarios is possible. Global integration, for example, was seen by the experts as highly dependent on Government & regulation. Types of innovation, meanwhile, were seen as an outcome of several other drivers. Thus, the experts evaluated the correlation between dimensions (uncertainties), and a smaller number of overall dimensions was identified.

Further reduction of the possible scenarios was possible by asking the experts to rank the uncertainties by importance and removing the least important ones.

The uncertainty dimensions were ranked in the following way:

1. Global integration
2. Talent & culture
3. Government & regulation
4. Network effects
5. Manufacturing
6. Innovation drivers
7. Access to money
8. Innovation actors
9. Types of innovation

Two overarching uncertainty dimensions emerged from this exercise. The first is related to the Chinese government's approach toward innovation: on the one hand top-down management, on the other hand nourishing of framework conditions.

The second dimension is related to China's creative capabilities: on the one hand isolated knowledge silos and a small enlightened elite, on the other a free flow of knowledge and a broad creative class.

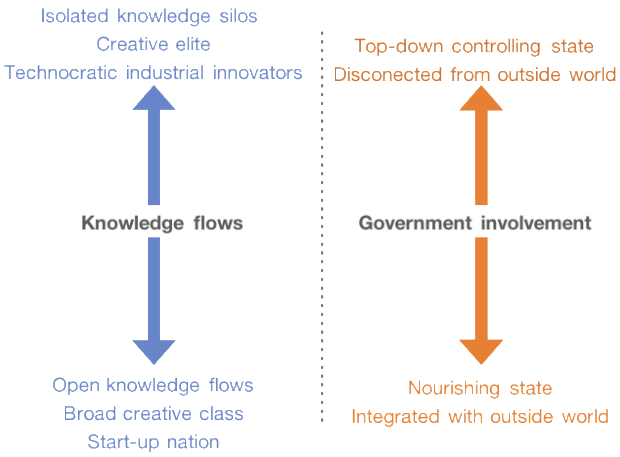


Figure 9.1: Two main uncertainty dimensions.

These two overarching dimensions were constructed the basis for building 4 alternatives scenario for the innovation future in China by 2030 (Graph 9.2), and are discussed in the following sections.

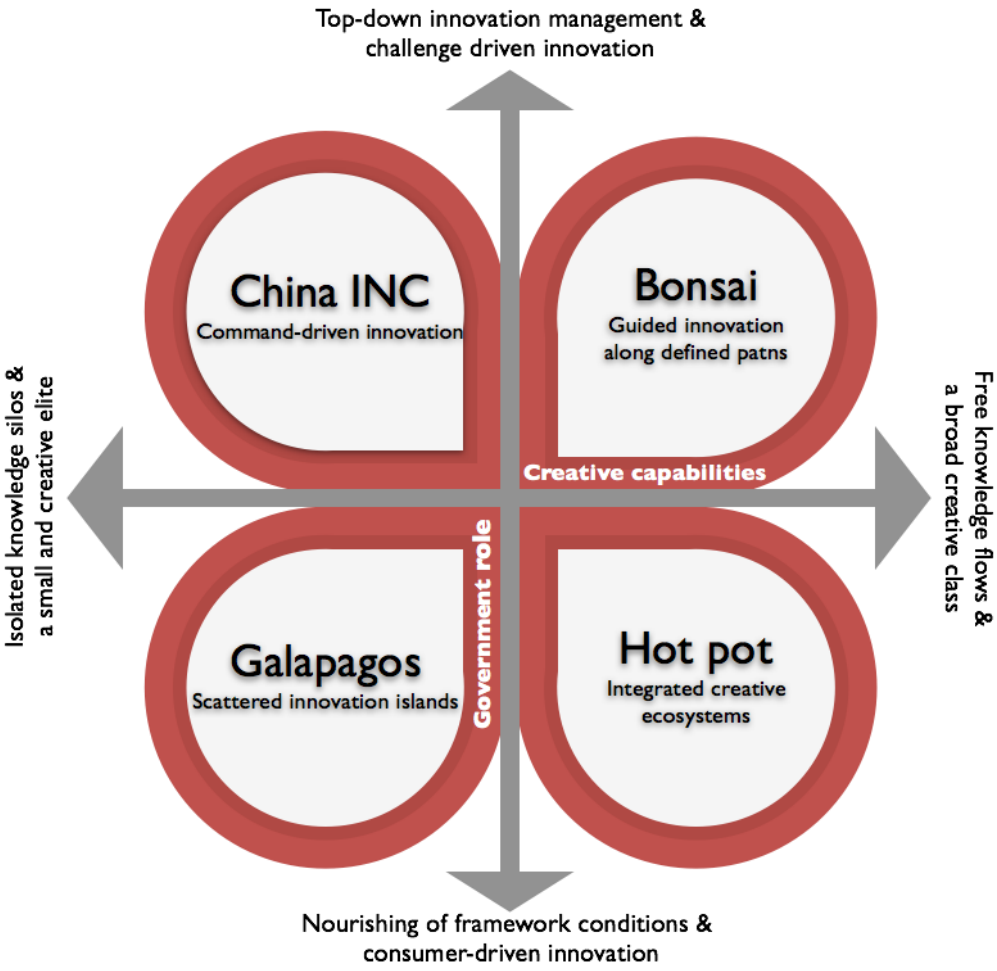


Figure 9.2: The 4 innovation scenarios for China in 2030

9.1 Scenario 1 - China INC: Command-Driven Innovation

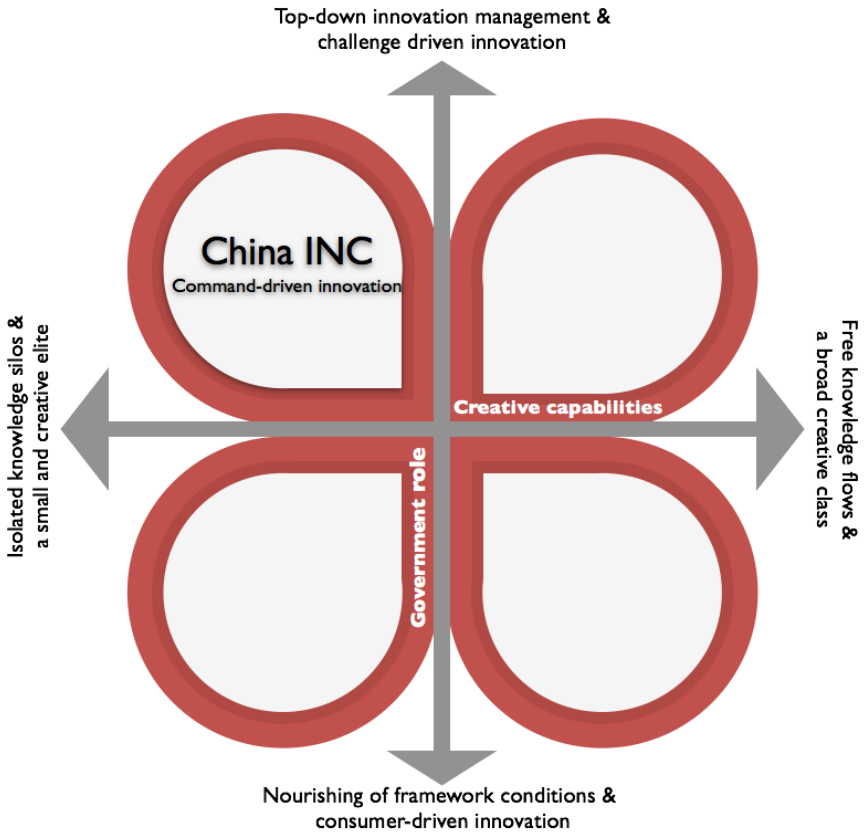


Figure 9.3: Scenario 1 – China INC: Command-driven innovation

In this scenario, the Chinese government is the main entrepreneur. It actively allocates resources to different innovation projects of strategic interest. The government draws special focus on mega-projects such as space and deep-sea exploration, quantum computing, supercomputers, while national technology standards are promoted (against western standards).

As a result, rather than developing broad creative capabilities nationwide, a small creative elite takes charge in driving innovation in China.

At the same time, foreign companies complain that the playing field is uneven, but the large Chinese market obliges to remain in the country and try to acquire a market share, by adapting products in their global portfolio for the Chinese market.

The development of this future towards 2030 is characterized by the following events in 5, 10, and 15 years:

…5 years

- The European companies are growing increasingly concerned about unfair treatment in China.
- In China for China is the dominant strategy among multinational companies (MNCs), seeing China as a market for their products but not as an arena for innovation.

- Chinese acquisitions of enterprises are increasingly blocked in the West, as Chinese activities in are seen through a national security lens.
- Environmental regulations are strictly enforced in the country, substantially easing the burden on the environment.
- High-tech and infrastructure deals with countries along the Belt and Road initiative, are facilitated through high-level political meetings.
- The Chinese state finances the global expansion of high-tech champions.
- China becomes a global leader in deep-sea exploration technology and establishes underwater bases (Chuanjiao & Lei, 2017)

Figure 9.4: China's new manned submersible "Shenhai Yongshi" returns to port in Sanya, Hainan Province on Tuesday, after completing deep sea testing in the South China Sea, Oct. 3, 2017. (Photo/Chinanews.com)

…10 years

- The mutual distrust between Europe and China is growing, accompanied with various barriers to trade and flows of people and ideas.
- China's innovation track record already contains spectacular successes but also failures, in areas where resources have been inefficiently allocated.
- The last years, low-cost manufacturing has largely migrated from China to countries in South and South-East Asia.
- Specific key technologies are developed and deployed in the service of national interests, including deep-sea resource exploration.
- Inside China, large, engineering-driven enterprises dominate innovation and control knowledge flows.

- Elite research institutes solve prioritised challenges in areas of strategic importance.
- China manufactures its own jet engine and rocket turbine engine.
- Large-scale clean-up projects of soil, water, and air pollution are drastically improving the environment.

…15 years

- China becomes the first country to send manned mission to Mars.
- China's strong geopolitical position is cemented by world-class technology in strategic areas.
- Innovation in China and the West are two entirely separate spheres, with very limited interaction; Chinese companies dominate in China but are weak overseas.
- Large investments to tackle environmental challenges lead to breakthroughs in new energy technology.
- China is a global technology leader in specific targeted areas.
- Overall, China lags in picking up new innovation opportunities and is not known for a source of new thinking and innovative ideas.

9.2 Scenario 2 - Galapagos: Scattered Innovation Islands

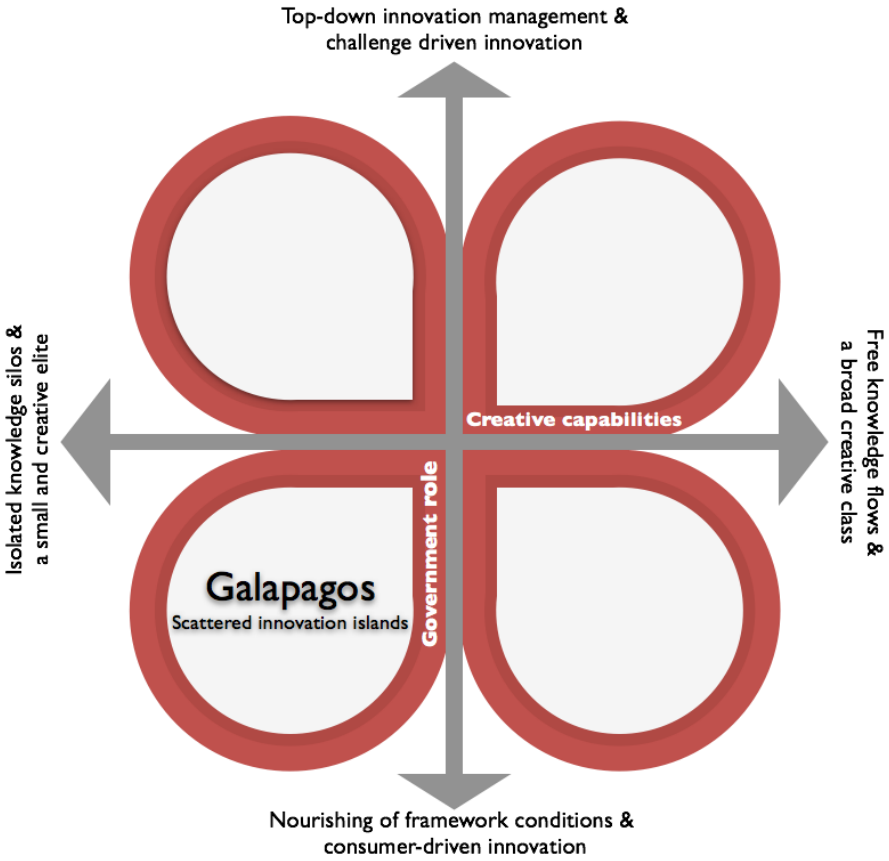


Figure 9.5: Scenario 2 – Galapagos: Scattered innovation islands

In this scenario, the Chinese government focuses on framework conditions for innovation rather than taking an active role in driving innovation.

The inability to develop a broad creative class and open knowledge flows leads to a situation where individuals and alliances of large industrial innovators and academic institutions dominate the innovation landscape. The innovation landscape in China is not characterized by strong ecosystems with crowd-driven bottom-up innovation, but in the contrary small cliques of innovation stakeholders, involving private companies, universities, and government agencies, are formed in different areas.

As a direct outcome, breakthroughs happen in areas where only a small number of researchers and engineers need to have novel ideas, while a large number of less-qualified engineers do testing and execution – for example in large-scale, labour-intensive biotech laboratories.

The development of this future towards 2030 is characterized by the following events in 5, 10, and 15 years:

…5 years

- Creative elite directs assembly line-style innovation with large numbers of low-level R&D personnel.
- Innovation comes from applying brute force, for example in large biotech labs.
- Innovative products are made in China, but they have limited diffusion outside China.
- Innovation is hampered by a lack of knowledge flows between innovation stakeholders; most innovation happen in isolated R&D centres rather than collaboratively with customers, suppliers, and partners.
- Universities become a relatively open environment and strong force in a situation where the industry is fragmented.
- European companies partner with individual companies and research institutions in China for implementing joint R&D activities.

…10 years

- Chinese companies manage to take a lead in specific areas of life sciences where systematic exploration is more important than development of novel ideas.
- Alliances between elite players rather than ecosystems drive innovation.
- New knowledge tends to have its source in universities, from where they usually become commercialized in university incubators.
- Products invented elsewhere in the world are adapted to fit the Chinese market peculiarities.
- The lack of vision and strong coordination make the large shifts and transformation needed for environmental sustainability impossible to achieve, thus several critical environmental problems remain.
- China looks to Europe as partner for revitalising innovation.

…15 years

- Chinese researchers today lead in brain science (China Brain Project[32]) and gene editing (Rosenbush, 2018).
- Small number of Chinese innovation giants are present among global leaders.
- Hopes of innovation-driven growth remain mostly unrealised.
- A high degree of mutual trust between Europe and China has been established.
- Besides the weak system-level integration, EU-China links are strong on the level of individual companies and universities.
- Many of the large challenges, including environmental problems and caring for China's ageing population, remain unsolved.

[32] Stix (2016), CAS (2016)

9.3 Scenario 3 - Bonsai: Guided Innovation Along Defined Paths

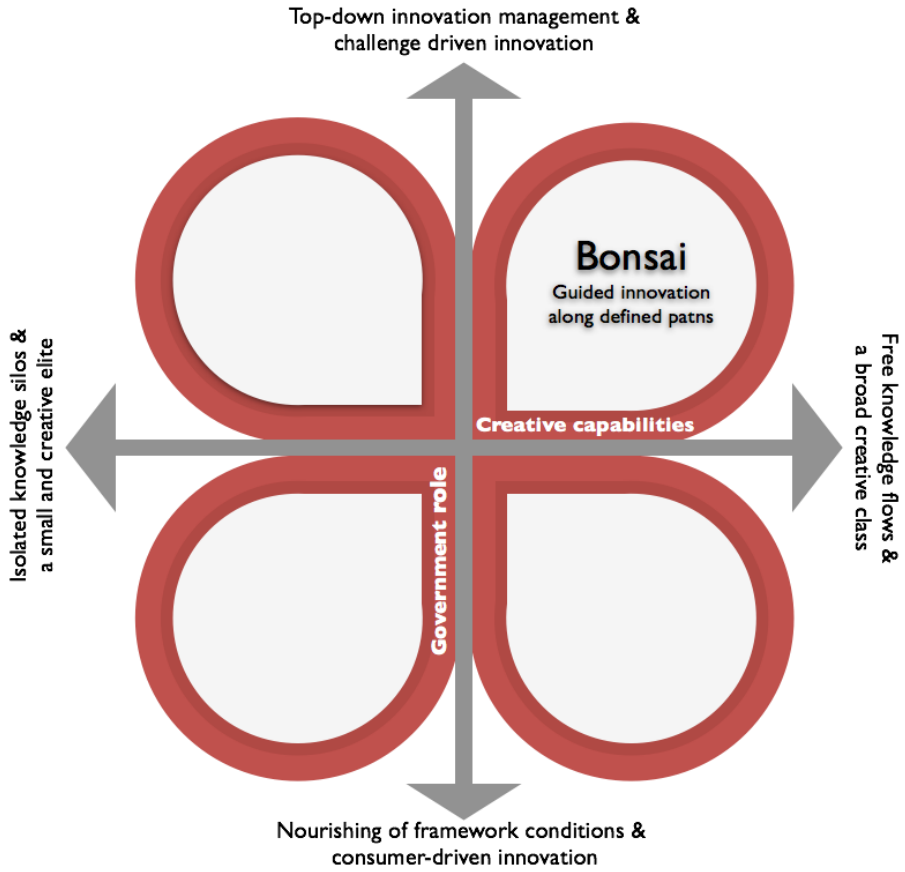


Figure 9.6: Scenario 3 – Bonsai: Guided innovation along defined paths.

In this scenario, the government takes an active role, while at the same time a large creative class and free flows of knowledge and ideas emerge. Rather than allocating resources to specific mega-projects, the state directs the industry and academia in certain directions by using other incentives such as tax cuts and funding mechanisms.

China is strong in strategic areas such as artificial intelligence and semiconductors, while Chinese companies incrementally climb the value-added ladder but without becoming known as disruptive innovators.

The development of this future towards 2030 is characterized by the following events in 5, 10, and 15 years:

…5 years

- Innovation in the country is stimulated by allocation of resources to key areas, which are carefully selected to improve the position of Chinese industry globally.
- China excels in incremental innovation, which occasionally creates tipping points for more disruptive change.

- Autonomous electrical cars dominate in all major cities, as the Chinese government has rolled out the infrastructure needed while a new generation of connected vehicle companies provide word-class cars.
- Unexpected innovation appears in the shadows of state policy, where a long tail of small, unknown, but entrepreneurial companies are connecting to emerging market needs.
- European companies grumble about unequal treatment but are easily swayed by the large Chinese market and the vibrant environment for new ideas.
- Chinese entities exert a growing influence over foreign popular culture production, but the domestic cultural industry still has little appeal outside China.
- Foreign companies are reluctant to locate core R&D activities to China, but instead prefer to set up listening stations to pick up the latest innovations and ideas.
- Industry 4.0 decreases the reliance on Chinese manufacturing, with many western countries providing incentives for setting up manufacturing there.
- The domestic content value of core components in domestically manufactured goods reaches 40% (Hsu, 2017).

…10 years

- Almost every industry sector has one or a few Chinese companies among its best performers.
- China is leading in artificial intelligence applications, both for commercial and military applications.
- China is respected but at the same time distrusted among European populations.
- The domestic content value of core components in domestically manufactured goods reaches 70% (Hsu, 2017).
- Chinese brands become better-known than western brands in developing nations, in Asia, Africa and Latin America.
- Environmental sustainability is mostly driven by a state-guided strategy that combines strict regulations and technology breakthroughs, notably in smart grid and energy efficiency.
- Few cities in China have managed to become strong magnets for global talent in specific sectors.
- Bureaucratic rule limits outside-the-box thinking.

…15 years

- A flagship milestone is achieved as China overtakes U.S. in the number of top-ranked universities.
- Through determined efforts, China becomes the top global technology player in key areas of national security and strength.
- In non-key areas, China is known as a fast-follower, rapidly adapting for domestic markets, ideas that emerge outside China.

- The domestic semiconductor capabilities reduce reliance on foreign technology, as now more than 50% of the integrated circuits are produced in China (Thomas, 2015, Lapedus, 2017).
- By 2030, two parallel innovation systems operate independently: one that is led or supported by the state, and one that operates silently without state support.
- Large consumer spending power, further enforced by urbanization, enables rapid consumer-driven innovation.
- Chinese brands have difficulties appealing to Western audiences.

9.4 Scenario 4 - Hot Pot : Integrated Creative Ecosystems

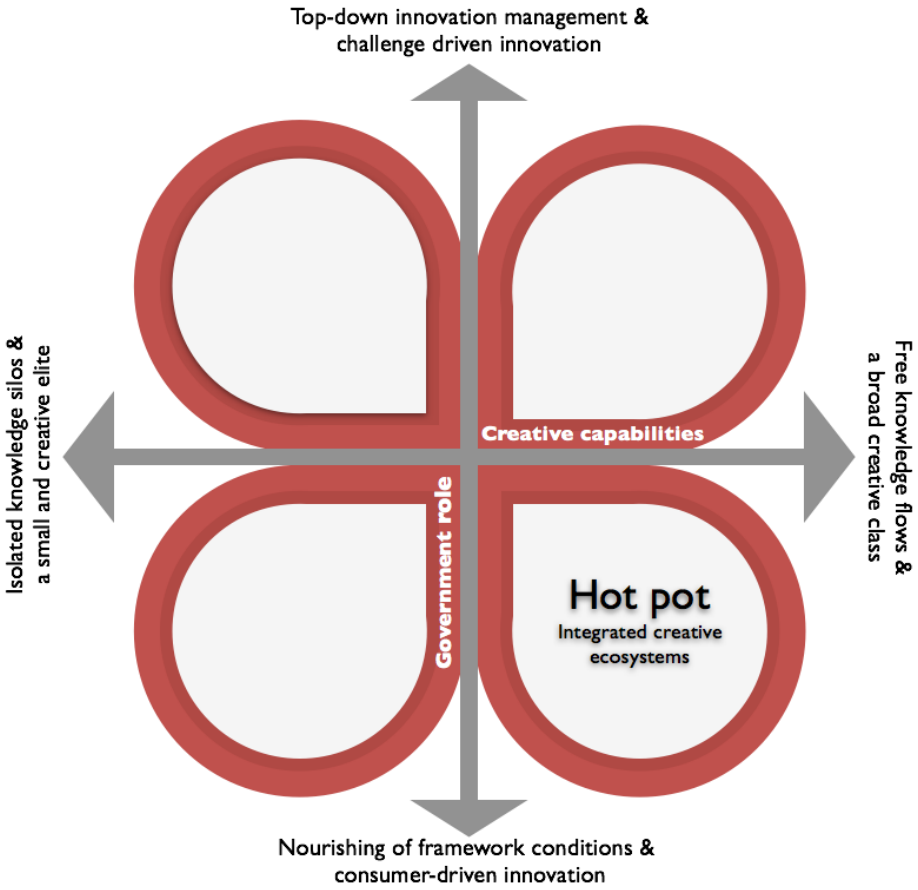


Figure 9.7: Scenario 4 – Hot pot: Integrated creative ecosystems

In this scenario, open knowledge flows have been established in China, which combine a strong creative class, and a government that focuses on establishing nourishing framework conditions for innovation without actively channel resources into prioritized areas.

This dynamic combination results in a vibrant start-up ecosystem, a stronger appeal of Chinese brands on the international stage, and new types of thinking that lead to disruptive innovation.

However, the lack of a strong top-down coordination makes it more difficult to overcome large barriers, such as infrastructure for electromobility and to coordinate efforts to achieve environmental sustainability.

The development of this future towards 2030 is characterized by the following events in 5, 10, and 15 years:

…5 years

- China's vibrant startup ecosystem attracts talents from all over the world.
- The ongoing educational reform focuses on enhancing creativity.
- Economic reform stresses on market mechanisms.

- The home-grown popular culture wins global appeal.
- A large consumer class and several customer-focused, fast-moving companies give China an edge in consumer goods, rapidly developing new generations of products.
- Strong innovation ecosystems emerge around new opportunities.
- A substantial creative shift takes place as the post-00s generation enters labour force.

…10 years

- China becomes a leading global talent magnet.
- Chinese art and design flourish globally, with a unique Chinese style that blends tradition and novelty.
- China has become an inseparable part of global knowledge ecosystems and Chinese are seen as indispensable to innovation in companies and universities in Europe and the North America.
- Automation (Industry 4.0) cements China's role in global manufacturing and ensures that value networks stay within the country's borders.
- Chinese electronics and appliances brands dominate in European homes.
- A mix of industry and research entities collaboratively push innovation, engaging crowds for ideation and user-driven innovation.

…15 years

- An important landmark is achieved, as China becomes the world's leading Nobel Prize nation.
- New ideas and thinking give rise to new industries and business concepts.
- China is admired and studied as an innovation role model.
- Chinese luxury brands take on legacy brands globally.
- Creative new approaches to artificial intelligence and 3D printing emerge, giving rise to entirely new services and product types.
- Chinese researchers are the most cited in quantum communication, with functioning quantum computers operating in specific areas.
- The passive role of the state leads to a slow transition to autonomous driving and electromobility due to lack of suitable infrastructure.

9.5 SES China

As described in section 4.3, an engagement platform (SES China) has been developed (more details in Annex 6), in the form of a serious role-playing game. The engagement platform was developed in cooperation with the Policy Lab of the JRC in Brussels.

SES provided to the Chinese and European policy makers a role-playing opportunity to experience the 4 alternative innovation scenarios, presented above, and to test different policy actions for achieving their different objectives. The SES China version was used in a participatory workshop organized in Shanghai (16/05/2017), with the participation of over 40 Chinese and European stakeholders (Annex 5).

Figure 9.8: The SES China session in Shanghai (May 2017)

Over the course of the session, four explorers at each table, representing two Governmental Policy Makers (one from Europe and one from China), an Industry and a Research or Technological Organisation **(**RTO), act over three rounds to reach their visions in a 15-year time horizon.

The main purpose for developing SES China, was to offer an alternative tool to policy makers for engaging with future scenarios, and for developing and testing strategic actions. The utilization of SES China in the Shanghai workshop was accompanied with a very positive feedback from the participants (EU and Chinese government policy

makers, academics, enterpizes). After the end of the exercise, all participants were given a questionnaire to evaluate the methodology, and China SES was considered a deeply learning (87%), surprising and fun experience (70%) by the vast majority of the participants (Annex 5).

In addition, SES China was highly valued among participants (by the 77% of the participants) for its capacity to serve as a tool for helping understanding the scenarios, while 78% of the participants declared that SES China helped them to establish a future oriented perspective and to develop a strategic perspective.

9.5.1 Strategic Recommendations

In the context of the SES workshop in Shanghai there were five (5) tables hosting five (5) main roles on each: Chines Government, European Commission, Industry, Academia and Public Voice. There were also game masters on each table guiding the process. Thus, totally there were:

- 5 Chinese Government representatives
- 5 European Commission representatives
- 5 Industry representatives
- 5 Academia representatives
- 5 Public Voice representatives and
- 6 game masters

After three (3) hours of interacting and "playing" the roles the following points were gathered and identified as important Strategic Recommendations for each one of the 4 future scenarios:

China INC Scenario

1. Chinese government should Invest more on STI, and focus on Improving STI personnel
2. Access to Chinese research for international researchers must be one of the important goals, and an increase to reciprocal funding should support that.
3. Bring in (China) international experience to support excellence in STI in strategic areas must be a priority.
4. Major stakeholders should constantly develop foresight studies to secure best results
5. EU should develop a permanent mechanism in place to understand the local (Chinese) circumstances in terms of what is going on in the market, STI, possibilities for collaboration with Chinese, and organize more STI events, and better Coordinate its Resources
6. Industry (both local and global) must work together with the Chinese government to increase efficiency. But at the same time industry should be more innovative in developing new business models for the Chinese and global markets.
7. More emphasis should be given on promoting and showcasing actions focusing Chinese STI knowledge & strengths.

8. European commission must constantly communicate with Chinese government in order to make sure about fair legislation
9. European commission must constantly communicate with Chinese government in order to work together and fully cooperate on tackling global inequality
10. Chinese Government should take more leadership type actions in coordinating STI on international level, invest resources on long term STI projects and challenges and support – work closer with United Nations on human future needs.
11. Academia when working in China should be able to constantly raise funds, build Alliances and change models to adapt to new rules.
12. Chinese Academia must build Alliances and connected to international knowledge and business actors in order to be world leaders. Building trust thus is essential.
13. Public voice, recommends that Chinese government should change its legislation to provide support to the whole STI ecosystem needs (transparent, IPR protection, banking rules, etc) and allow build alliances and have more private companies (small) participate in it.

Galapagos Scenario

1. EU Industry must invest both in STI and general Business facilities to get as much as possible out from the Chinese big market and should cover an extra mile, to accomplish that. Support from both EU and local groups and cooperation with governmental Chinese bodies will ensure long term success.
2. Chinese government should be focusing on bringing together EU and Chinese triple helix entities to overcome the trust gap.
3. Chinese government should invest on local capabilities for global excellence with a long term perspective and on the parallel works towards a more friendly innovation ecosystem through flexible taxation, better communication, cofounding mechanisms simplification and efficient legislative context, to improve international collaboration.
4. Chinese academia should heavily invest to be global leaders in many areas, and One Belt One Road initiative is seen as a platform of extroversion and entrance to more markets.
5. EU must push for more open communication channels, campaigning a lot to make sure its voice is heard and pushing hard for more fair legislation i.e. taxation for startups, standardization, and constant cooperation with Chinese stakeholders
6. EU should invest in STI projects, fund basic co-research projects based on excellence.
7. EU should tighten its links and build the missing infrastructure between Chinese and European researchers and create a balanced collaboration network of excellence in basic research. In order to overcome the scattered innovation landscape EU should launch a joint long-term call, built up infrastructures and finally invested in joint consortia engaged in sustainable development.
8. Chinese government should explore international collaboration on STI results and business models to valorize them
9. EU and China should support industrial research collaboration focusing on a lot on industrial private partners.

10. Scattered innovation and knowledge islands seemed to be overcome by creating a balanced collaboration framework and nurturing trust relationships.

Bonzai Scenario

1. EU industry must invest in STI and other business activities, but make alliances with local partners
2. Chinese government must invest heavily in local STI competences, but at the same time will try to make the ecosystem as friendly as possible mainly for local entities through incentives like taxation, and legislation.
3. Chinese Academia must invest a lot in STI infrastructure and personnel, and collaborate with stakeholders to become global power.
4. European Commission will try to persuade Chinese government to open up ecosystem by more transparent legislation, standardization, will invest in STI infrastructure to ensure EU interests in the power game and will promote its interests through campaigns and summits.
5. EU and China must built new programs based on alliances in the whole STI value chain.
6. EU and China must focus more in building infrastructures that are covering all research fields, both in China and EU, by co-defining common challenges and goals.
7. EU and China must cooperate more on building together stronger global brands and promote them in the global markets, now that the Technology transfer phase has finished.
8. Chinese government must promote its global role as an STI leader focusing on strategic alliances and co-investments and that must.
9. China's global role will inevitably force its government in taking more emphasis on STI policies regarding global challenges and that collaboration is an important strategy to tackle them in the long run.

Hot Pot Scenario

1. Academia in China should expand and develop alliances in a number of different areas to experiment and see what works. It should also invest in talent and securing it won't leave. Lastly Academia should campaign more to promote activism and highlight international tech links importance.

2. European Union must invest in STI but mainly coordinate better its actions and focus on huge global challenges like water scarcity.

3. Public Voice feels strong on all stakeholders expanding alliances, better coordinate actions on sustainability, and invest in creativity.

4. Public voice also feels strong on EU and China promoting their common values societal good, by co-investing a lot on STI (infrastructures, HR, etc)

5. Chinese government should focus more on actions that will ease entrepreneurship barrier, and strengthening networking with European innovation partners

6. Industry (Chinese) should form global partnerships, raise capital, develop products, licensing globally and be in global stores as a goal.

7. Chinese government should quickly change/reform its education system to adapt to a very dynamic global consumer environment, focusing a lot on Creativity.
8. Chinese government should immediately make economic reforms in all activity parameters (tax, cooperation incentives, etc), to be able to be a viable leader in the global markets.
9. EU and China should form rules and participate in ethical, social impact funds

General Recommendations

Besides the scenario specific recommendations several overall conclusions can be extracted.

Figure 9.9: Word frequency analysis, strategic actions of Chinese policy makers

In most of the cases Chinese policy makers seems to prefer invest resources on R&D, and for enhancing global R&D collaboration. Other actions include legislation changes and tax cuts to further improve R&D investment.

Figure 9.10: Word frequency analysis, strategic actions of EU policy makers

European policy makers wish to support collaboration with China in R&D, but prefer to rather focus on specific priority topics, and invest on joint infrastructures towards addressing common challenges. In addition, funding programs for joint research projects are always in the agenda.

Figure 9.11: Word frequency analysis, strategic actions of Chinese RTOs

Chinese RTOs (Research & Technology organisations) are having as a top priority to raise more funds for research, to build international alliances, to attract best talents, to lobby with government, and to change their business model towards a more modern and efficient form.

Figure 9.12: Word frequency analysis, strategic actions of European RTOs

As regards European RTOs, the main effort is to enforce their competitiveness by establishing alliances with Chinese institutions.

Figure 9.13: Word frequency analysis, strategic actions of Chinese companies

Chinese companies aim on increasing R&D investment, raise capital, and change modernize their business models to address future needs.

Figure 9.14: Word frequency analysis, strategic actions of European Chinese companies

On the other hand, European companies focus strongly on R&D investments to offer new products and remain globally competitive.

In addition, several other conclusions have been reached by studying the strategy actions tested through the SES China workshop, and the outcomes of these actions:

- In the top-down command scenario, it was very difficult to collaborate even when some environmental crisis variable drivers came up. This indicates that it is in everybody's interest to strive for engagement, cooperation, and mutual benefits.
- Actions/strategies to integrate the innovation ecosystems of China and Europe came up in various ways. It is important not only to think about the giants, but also about the startup scene and the smaller companies. Having infrastructure (such as incubators, co-working spaces, mentorship programs, etc) to support these small companies from Europe to "test the waters" in China and vice versa are very important.
- Environmental topics are important for collaboration. Some actions/strategies revolved around smart cities and electrical vehicle technologies.
- Policies should support European companies to tap into and benefit from the speed of China's hardware manufacturing ecosystem.
- It is important to gather all the stakeholders and make sure policies translate into benefits for the various stakeholders, so that it is not on a too abstract level.
- Chinese government generally keener on cooperation on a policy-making level (with EC), than on a private level, with European industry.
- We should highlight the strategic action of the academia to invest resources in the cooperation with the EC and Chinese government. This was done in order to ensure personnel (excellence) will be attracted. Also, it seems that it is in the

interest of both the Chinese government and the EC, to facilitate programs like students exchanges between EU and Chinese universities (to guarantee a balanced mix of Chinese and EU students in universities both in Europe and China). Of course, investing resources and funding in establishing these relations and giving a guarantee of more stable future for students, was surely the most appreciated action by the public voice.

- The Chinese government (role) was consistently (both scenarios) very keen on cooperation with the EU at a policy level, taking a long view.
- Academia was obsessed with raising funds, both from public sources and from industry, and engaged in some lobbying to that end. Its objective was to become one of the world's best.
- The EU was mostly aligned with the Chinese interests in developing long-term cooperation.
- Chinese Government is always keen to collaborate, and even coordinate global cooperation in STI. Actions towards improving innovation framework conditions like (IPR framework) are always on table.
- EC seems to have a traditional approach towards funding of STI addressing solutions to global problems, etc. It seems that a natural tool is the continuation of Framework Programs, and maybe create another global funding scheme for global problems with the participation of China.
- EU University seems to heavily invest in cooperation, building global networks including China, and seeking to attract Chinese talents. A Chinese physical establishment seems to be a natural choice.
- Unite nations should step in and claim a more dynamic position on decisions on the future of human being.
- EU and China should use press (journalists) in their favor to push for more cooperation actions.

Section 9 included the detailed presentation the main outcome of the research, the four scenarios (Hot Pot, Galapagos, China INC, Bonzai) developed for the innovation future of China. It also includes the feedback received through testing SES China, and the specific strategic recommendations received as an input by the workshop participants.

Next, Section 10, presents the scientific discoveries achieved through out this research, and the overall conclusions.

10.0 Conclusions

The final formulation of the 4 alternative scenarios for the innovation future of China, as presented in section 9, and the long list of uncertainties that have been identified during the process, have provided proof that any projection based on a linear extrapolation of the present situation in China, has little possibilities to be successful.

The economic environment in China is complex and the changes are rapid, and for organisations to be able to address this increasing uncertainty and establish a resilient long-term strategy, it is necessary to use novel tools. This was the main purpose for producing scenarios for China's complex financial environment, which in our case were mostly focused on the innovation effect on China's economy.

At the same time, within the framework of the current research, several scientific discoveries have been achieved as regards as novel research methodologies, and the development of gamification tools, that are briefly presented in the next paragraphs.

10.1 Scientific Discoveries

The peculiarities of the Chinese economic and innovation environment and the increased difficulty for performing the research (language barriers, cultural differences, lack of reliable data, dynamic environment with many weak signals, etc), required a research approach that combined several different foresight methodologies that were used in various steps of the research. In addition, it required a flexible design that allowed to adapt to the various resource constraints, and to the limited access to Chinese media.

These special requirements have however produced several scientific advances as presented analytically bellow.

vii. **Novel Scenario Development Approach**. The research was structured upon a novel two-stage scenario making approach (*see section 5.1*), that included the production of two sets of scenarios. This approach was deemed necessary to address the complexity of the China.

The first phase was the scoping phase for understanding the overall system, while the second stage allowed a deeper analysis. In this context, the first set of scenarios provided information of the basic system/actors/trends/drivers in China.

The second phase allowed a deeper analysis, and concluded to the production of the 2nd set of scenarios that specifically focused on the Chinese economic and innovation environment. This two-stage scenario formulation, has proved useful and can be applicable in similar complex systems, as long as there the available resources and time.

viii. **Trends/Drivers Template.** Communication of research results is always a challenging task, as requires to effectively transfer scientific knowledge to a broader non-expert target group.
In this context, a specific format to present Trends/Drivers has been proposed (*table 3.1, section 3.2*) that includes a basic description of the trend/driver, some examples to demonstrate the development and impact of the trend/driver, any counter trends, the driving forces behind the trend, the actors related with the trend/driver, estimations for the expected future development of the trend, and its main impacts.

All the information is presented in concise, simple form to be communicated easily to both experts and non-experts, but at the same time to provide convincing evidence of the trend's importance and expected development.

ix. **Multidimensional Scenarios**. Usually scenarios have a specific focus and address issues political, economic, technological, etc. The dynamics of the economic and innovation environment in China, requested a multidimensional approach to address not only technological and socioeconomic aspects, but also integrate business model innovations, environmental challenges, etc, and offer an integrated approach.

This approach is necessary for any complex system that requires systems thinking, in order to provide a sound future scenario. The development of both the 1st set of scenarios (section 7), and of the final 2nd set of scenarios (section 9) had this multidimensional approach that proved essential for such a complex system as China is.

x. **SES China – Exploring Future**. As already discussed, it is very difficult to engage non-experts in a long-term future discussion. It is even more difficult to communicate these plausible future changes, when are they are opposite to the current status quo. The difficulty level rises even higher when you need to initiate long-term discussions with a large group of non-experts.

A unique platform in the form of a serious game (SES China) has been developed (*Annex 6*), with the support of the JRC/Policy Lab, as a tool to engage policy makers in long-term scenario thinking. This is the first serious game focusing China, and its primary purpose is to have participants experience and act through plausible alternative futures, by thinking and conversing systemically outside of their usual frame of reference. SES uses two contrasting scenarios to challenge the assumptions of the participants and offer them space to respond to alternative and changing framework conditions.

xi. **SES China – Strategy & Vision tool**. SES China besides being a tool for exploring the future and engaging with scenarios, at the same time it is a unique tool for drafting and testing long-term policies, especially as the game is fully-adaptable to serve specific needs of policy makers in businesses, academic institutions or government.

At the special test session organized in Shanghai (*Annex 5*) with policy makers from Europe and China, several strategic actions have been developed and

tested by the participants against contrasting future scenarios. The value of the tool has been proved by the high evaluation received by the participants (*Annex 5*).

xii. **Serious Game – Gamification in China.**

Gamification, that is the application of game-design elements and game principles in non-game contexts, is a rather new concept with potentially large applications in every aspect of our lives (marketing, recruitment of human resources, health, professional trainings, crowdsourcing, education, etc).

Gamification strategies use rewards or competition to engage players, or make existing tasks feel more like a game, and a combination of these techniques is incorporated in SES China. The main question here was the application of the SES platform to a non-western group of people, to a mixed group of Chinese and western high-level officials and entrepreneurs in the field of research and innovation.

Other versions of SES had been tested by JRC with western participants, but was never tested in Asia, and the effect of Hofstede's (Hofstede, n.d.) Six (6) Cultural Dimensions[33] on SES was unknown.

The Shanghai test event offered the unique opportunity to test in a cross-cultural environment a serious game, and provided input whether SES works cross-culturally, and more importantly about how the game rules are interpreted cross-culturally.

Thus, it was the first time a serious game was tested with Chinese high-level officials, proving that the SES China platform is also suitable for use by non-western policy makers, beyond any cultural differences.

10.2 Conclusions

The main overall objective of this research was to prove that in the complex and rapidly changing (ramplex) environments like in the case of China, the utilization of foresight methodologies and scenarios offer a sound tool for understanding the system and build a successful long-term strategy that successfully addresses business, financial and other uncertainties.

It is a commonplace of organization theory that organized systems (companies, countries, organisations, etc) must adapt to their environment in order to survive. But how organisations can form a long-term strategy, that will allow them to adapt and make them able to address the complexity and uncertainty of the future?

Current thinking (Boisot & McKelvey, 2011) holds that organisations can invest in adaptation in two ways: (1) simplify the complexity of incoming stimuli so as to economize on the resources that need to be expended in responding; (2) invest more

[33] The six cultural dimensions: Individualism, Power Distance, Masculinity, Uncertainty Avoidance, Long-term orientation, Indulgence.

resources in the response than they judge to be strictly necessary so as to ensure some degree of adaptation. The first approach holds the risk of oversimplification, and the second the risk of resources depletion before achieving adaptation.

Nevertheless, adaption alone is not enough to ensure success. In today's fast changing environment, adaptation needs also to be fast. In fast moving worlds, individuals, public bodies and companies have to run just for their existence, and run even faster achieve success. Thus, critical to success in fast-moving and complex business environments are both adaptation but also speed (Lindgren & Bandhold, 2003).

The other important aspect of adaption (besides speed) is the ability to understand and address complexity (variety). According to *Ashby's Law of Requisite Variety* (Ashby, 1956), the larger the complexity of a system, the greater the variety that is needed to address it.

This is exactly the case of the innovation environment in China, a highly complex and fast changing system requiring strategic flexibility, that combines speed and adaptiveness[34] (Lengnick-Hall, & Wolff, 1999). This strategic flexibility to address complex systems, can be achieved by improving the organisation's "strategic response capability" (Bettis, & Hitt, 1995), to combine responsiveness and robustness. This is exactly what foresight and the development of scenarios can offer. Scenarios can be used in the strategic planning process to test a strategy's robustness against various futures, and also help organisations to develop their responsiveness capability.

During the first exploratory phases of this research, the complexity of the Chinese innovation environment has been demonstrated, as several interconnected drivers and trends appear to influence the structure of the system and its future developments. The development of the final set of the 4 future innovation scenarios offered an ideal tool, as described above, to test the robustness of long term strategies for China and to help develop responsiveness capability.

The usefulness of the scenarios to test strategy robustness and to increase future responsiveness was confirmed in the workshop in Shanghai (May 2017). Over 30 Chinese and European experts from various organizations, business, academic institutions and governmental agencies, used the China SES platform to explore alternative future scenarios of China, and to test strategies against these scenarios. After the completion of that special session, 87% of the participants declared that it was a learning experience, 65% that it was useful to understand scenarios for the future, 78% that helped them to establish a future oriented perspective, and 87% that helped them to developed strategic perspectives.

The combination of performing economic foresight through developing scenarios, and the use of gamification techniques (SES China) has indeed been proven to be an efficient and robust planning tool for addressing China's urban Economic Foresight & Scenario Thinking as a Planning Tool for Addressing China's uncertain environment.

[34] Also called the "*guerilla logic school*".

The same methodology could be replicated in various situations offering a useful tool for developing long-term strategies in ramplex[35] environments, especially in cases where managers need to establish robust and responsive strategies. Various strategies can be tested against alternative plausible scenarios, become fine-tuned, and finally refined to become more robust and more responsive to future needs.

[35] Complex and rapidly changing

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ANNEX 1: Glossary

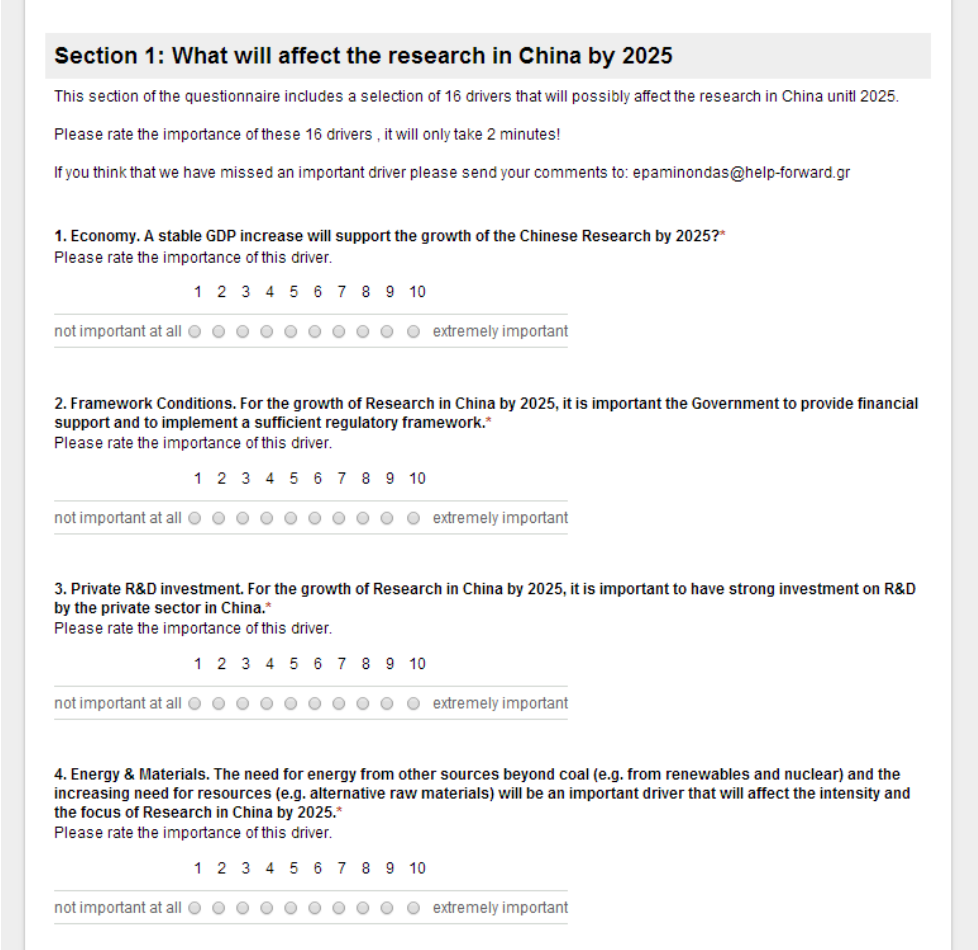
BAT	The term BAT refers to the three big leaders of the Chinese Internet industry: Baidu, Alibaba, and Tencent,
Counter Trend	A contradictory trend is called counter trend. For example healthy leaving is one trend, while junk food is a contradictory trend. A trend and a countertrend may exist at the same time.
Guanxi	Guanxi describes the basic dynamic in personalized networks of influence (which can be best described as the relationships individuals cultivate with other individuals) and is a central idea in Chinese society. (Goh & Sullivan, 2011, Mak, 2012)
Hukou	A household registration record that officially identifies a person as a resident of an area, and allows free access to local services like hospital, schools, etc.
Megatrend	The concept of megatrend was first introduced by John Naisbit, in the book Megatrends (Naisbitt, 1982), describing a long-term, transformational process with global reach, broad scope, and a fundamental and dramatic impact.
Ramplex	Complex and fast-changing environments (Lindgren & Bandhold, 2003).
Saoing	It is the popular practice, following most social interactions in China with people scanning each other's WeChat QR codes .
Shanzhai	The term shanzhai is often used pejoratively to refer to Chinese copycat producers of mobile phones and other electronic devices, based on copied designs and knock-off brand names.
Trend	A trend is a measurable or observable transformation in a given system.
Wild card	Unlikely future events that would have great impact if they occurred are usually called wild cards.

ANNEX 2: First Delphi Study

The first Delphi study was focusing on evaluating the importance and the probability to occur of 16 drivers and trends, that were identified through the preliminary desk-study, and author's first-hand observation.

The main characteristics of the Delphi study are presented below:

- **The Delphi consisted of 33 questions. 32** specific questions on the importance and probability of 16 Drivers. Answers were provided in a Scale 1-10 against importance and probability. One (1) additional open question for any further suggestions on important missing trends or drivers.
- The Delphi questionnaire was on-line (google-forms) and was distributed to selected experts in the fields of research, technology and innovation. (See figure 1 bellow)
- **41 replies were received in total from expert around the world** (global participation – 50% from China). The answers were provided anonymously.



Section 1: What will affect the research in China by 2025

This section of the questionnaire includes a selection of 16 drivers that will possibly affect the research in China unitl 2025.

Please rate the importance of these 16 drivers , it will only take 2 minutes!

If you think that we have missed an important driver please send your comments to: epaminondas@help-forward.gr

1. Economy. A stable GDP increase will support the growth of the Chinese Research by 2025?*
Please rate the importance of this driver.

1 2 3 4 5 6 7 8 9 10

not important at all ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ extremely important

2. Framework Conditions. For the growth of Research in China by 2025, it is important the Government to provide financial support and to implement a sufficient regulatory framework.*
Please rate the importance of this driver.

1 2 3 4 5 6 7 8 9 10

not important at all ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ extremely important

3. Private R&D investment. For the growth of Research in China by 2025, it is important to have strong investment on R&D by the private sector in China.*
Please rate the importance of this driver.

1 2 3 4 5 6 7 8 9 10

not important at all ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ extremely important

4. Energy & Materials. The need for energy from other sources beyond coal (e.g. from renewables and nuclear) and the increasing need for resources (e.g. alternative raw materials) will be an important driver that will affect the intensity and the focus of Research in China by 2025.*
Please rate the importance of this driver.

1 2 3 4 5 6 7 8 9 10

not important at all ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ extremely important

Figure 1: Screenshot of the first Delphi questionnaire.

The 32 specific questions were the following:

1. Economy. A stable GDP increase will support the growth of the Chinese Research by 2025?
Rate importance (1-10)
Rate probability to occur (1-10)

2. Framework Conditions. For the growth of Research in China by 2025, it is important the Government to provide financial support and to implement a sufficient regulatory framework.
Rate importance (1-10)
Rate probability to occur (1-10)

3. Private R&D investment. For the growth of Research in China by 2025, it is important to have strong investment on R&D by the private sector in China.
Rate importance (1-10)
Rate probability to occur (1-10)

4. Energy & Materials. The need for energy from other sources beyond coal (e.g. from renewables and nuclear) and the increasing need for resources (e.g. alternative raw materials) will be an important driver that will affect the intensity and the focus of Research in China by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

5. Governance. For the growth of Research in China by 2025, it is important to have a stable governance in the country and peaceful society.
Rate importance (1-10)
Rate probability to occur (1-10)

6. Urbanization. The urbanization process and the related governmental policy will affect the research in China by 2025
Rate importance (1-10)
Rate probability to occur (1-10)

7. Human Rights. A greater openess of the state and the improvement of human rights will have a positive effect on the research environment in China by 2025?
Rate importance (1-10)
Rate probability to occur (1-10)

8. Global Economy. A flourishing global economy means more exports for the Chinese companies and more investment by the western multinational corporations in China. A stable global economy will facilitate the growth of the Chinese Research by 2025?
Rate importance (1-10)
Rate probability to occur (1-10)

9. Peace and Conflict. There are expected regional conflicts with China's neighboring countries by 2025.
Rate importance (1-10)

Rate probability to occur (1-10)

10. Space & Defense. The space exploration and the further development of defense technologies are going to be important drivers for the Chinese research by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

11. Environment. Local environmental problems (e.g. atmospheric pollution, contaminated water) and global environmental implications (e.g. climate change) will affect the research in China by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

12. Population. The recent partial abolishement of the one-child policy and the continuous population growth, will affect the research areas in China by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

13. IPR. The modernization of the IPR regulations and the effective enforcement of IPR rights in the country, will affect the growth of public and private research in China by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

14. Global Communication. The increasing global interconnection, and the continuous upgrade of the communication technologies will allow the stronger interaction and cooperation of the Chinese researchers with their global counterparts. This will have a positive effect on the growth of the Chinese research by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

15. Language Skills. The improvement of the language skills of the Chinese researchers will have a positive effect on the growth of the Chinese research by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

16. Education System. The modernization of the education system (primary/secondary/higher) could support the growth of the Chinese research by 2025.
Rate importance (1-10)
Rate probability to occur (1-10)

The main feedback received by the experts is presented in the following figures and analysed in section 6.1 of the current document.

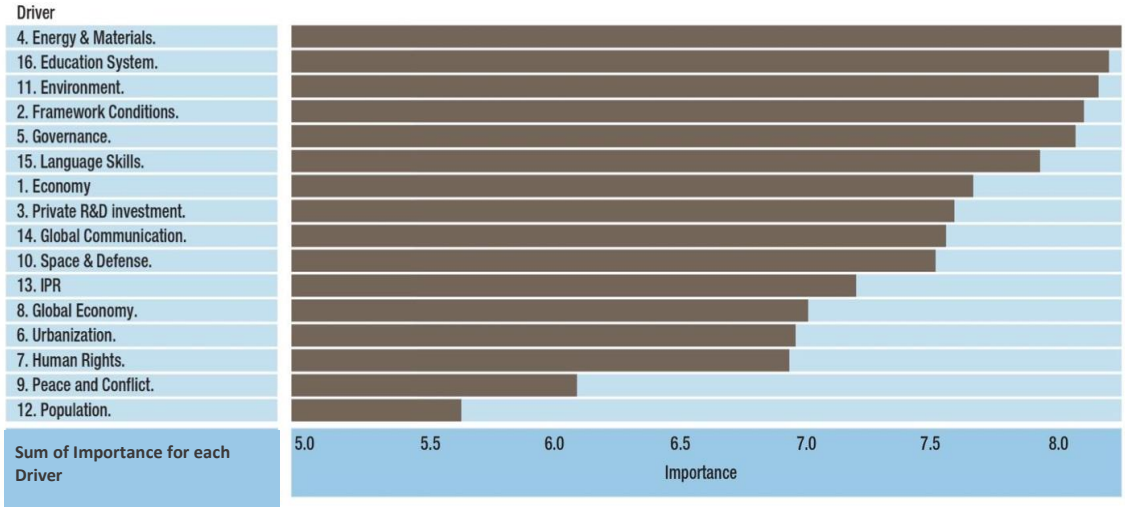


Figure 2: Trends evaluation, Importance in terms of affecting research and innovation in China.

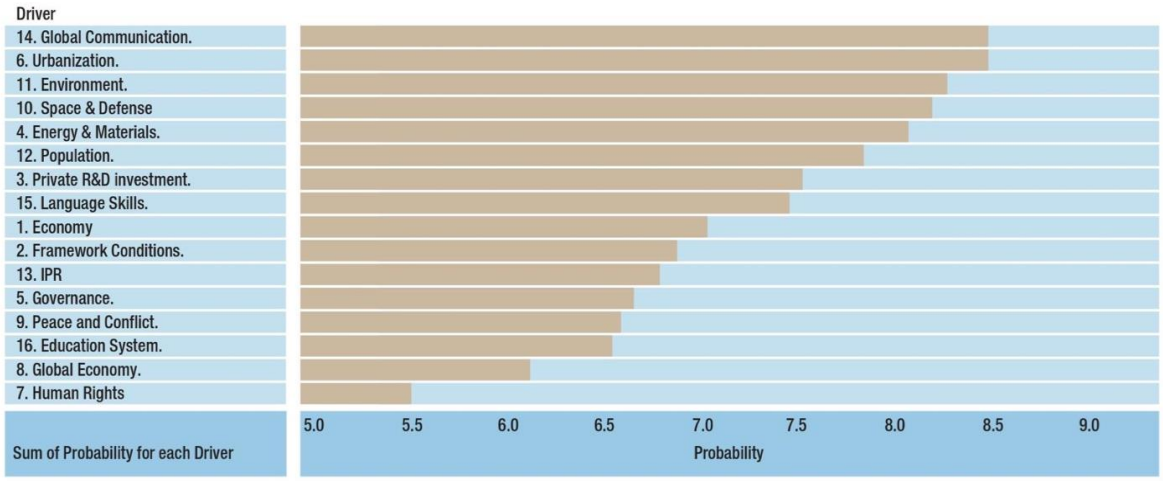


Figure 3: Trends evaluation, Probability to occur.

ANNEX 3: Second Delphi Study

The second Delphi questionnaire, was implemented during the 2nd phase of the research work (check the research phases at Section 5.1 of the current document). The main objective of the work was to investigate the technological and business model developments both in Europe and China, and identify specific bilateral cooperation opportunities.

The questionnaire was build and distributed on-line using the **google forms** platform, and was sent by email to specific experts and expert networks (e.g. the Millennium Project, and the Europe Foresight Network). In total, **77 experts**, from **29 different countries** and diverse technical and professional backgrounds, have provided feedback to the Delphi questionnaire. It should be also underlined that 40% of the experts had a strong foresight background. The main characteristics of the sample are presented in the following graphs.

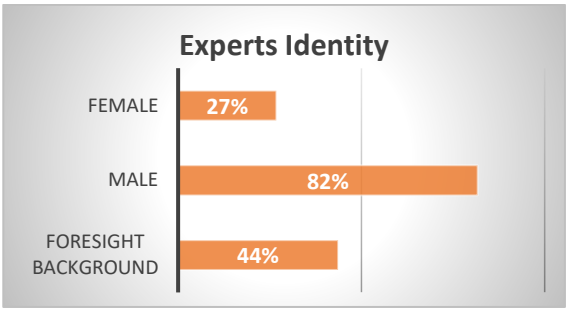


Figure 4: The sex and foresight experience of the Delphi experts

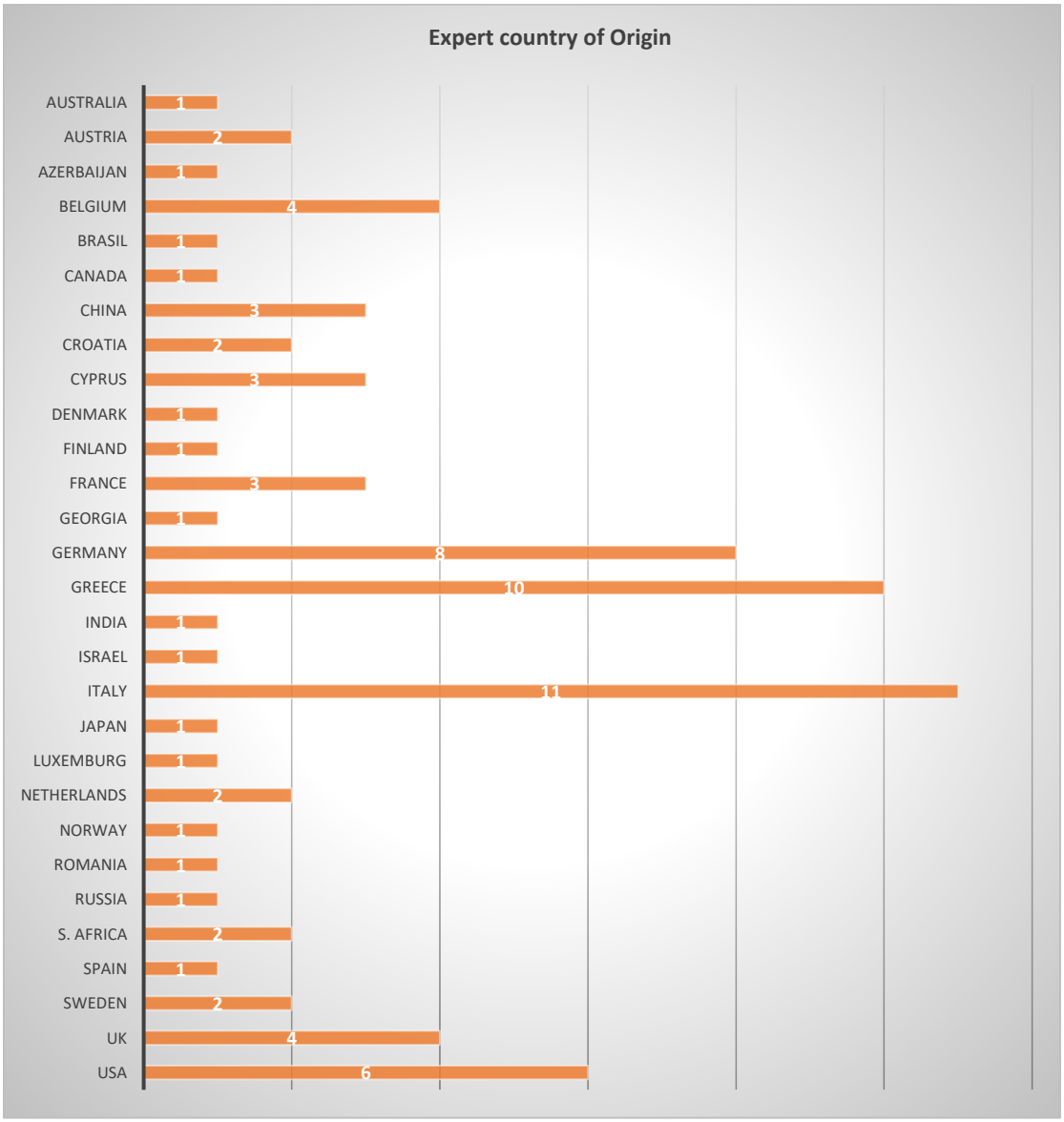


Figure 5: The country of origin of the Delphi experts.

The Delphi questionnaire consisted of 55 questions distributed in 4 parts :

- **Part 1** - Megatrends: *for evaluating the identified megatrends and investigating other important driving forces.*
- **Part2** - Disruptive Technologies: focusing on Europe's technological future.
- **Part 3** - Disruptive business models: focusing on identifying new disruptive business models and markets.
- **Part 4** - China: for investigating future opportunities for collaboration with China.

The questionnaire is analytically presented below:

Part 1 - Megatrends: *for evaluating the identified megatrends and investigating other*

important driving forces.

Rate the importance of these Megatrends to transform the global innovation landscape. (scale 1 to 10)
How probable is for this Megatrends to continue until 2030. (scale 1 to 10)

Which are the main Megatrends that will transform the global innovation landscape by 2030?

- Megatrend 1: Changing Demographics are going to affect the innovation landscape by 2030

Human race is growing older and richer with a growing middle class and widening inequalities across societies. The global middle class is expected to grow by 66% (mainly due to China and other emerging economies), to a total of about 3 billion more consumers with increased purchasing power. Changing demographics will have a profound impact on geopolitical and economic trends worldwide affecting global trade, services, and business models.

- Megatrend 2: Globalization 2.0

Globalization 2.0 is fundamentally different from Globalization 1.0, with the East playing a far more important role than being the workplace of the West. Western companies will still operate in the East, but under different circumstances; goods, people and capital will flow in multiple directions (not just from West to East, but also from East to West). As economic power gradually shifts eastward (with China playing a central role), trade between emerging markets will flourish, raising new risks and opportunities for the European companies, as the East will rely less on the West for goods and services.

- Megatrend 3: Technologies and the Information Revolution

The next decades will be shaped by the process of converging (and even merging) technologies through interdisciplinary developments across scientific fields. Nanotechnology, biotechnology, IT, cognitive science, and robotics will drive innovations in several fields like health, nutrition, and logistics and will rapidly change our lives. The importance of technology will dramatically increase within the next twenty years as new technologies are being adopted faster and innovation cycles become shorter. This trend will continue by 2030 as product life cycles become even shorter, obliging companies to be always alerted and invest more heavily on R&D.

- Megatrend 4: Climate Change

Nature's capacity to absorb human activity is diminishing, and global warming is increasingly causing extreme weather events around the world, leading to death, displacement and serious economic damage. Global energy consumption is raising, GHC and global waste are increasing, and ecosystems are collapsing. Climate change will mostly affect the most fragile areas and populations in the world that depend on agriculture and fisheries, and may have serious consequences in terms of migration and economic prospects and performance. Climate change effects are expected to bring focus upon new technologies like electric cars, saltwater agriculture, carbon capture and reuse, solar power satellites, maglev trains, urban systems ecology, cultivated meat, and to the establishment of global climate change collective intelligence systems to support better decisions and keep track.

- Megatrend 5: Scarcity of Resources

As global population increases, and climate change effects are worsening, the problem of food and water resources management will be central in governmental policies. At the same time, the continuous exploitation and the growing demand of other natural resources like metals and fossil fuels, will increase geopolitical tensions and further raise the issue of resource management. At the same time, even in a best-case scenario, the effects of the present rising energy consumption will be lasting and even become a major problem in the future.

Part2 - Disruptive Technologies: focusing on Europe's technological future.

Please rate the specific technological areas that you believe are going to be strong in Europe in 2030. (scale 1 - very weak to 5 – extremely strong)

[Internet of Things (IoT)]	[Cultivated meat]
[Gaming]	[Saltwater agriculture]
[3D/4D printing]	[Synthetic Biology]
[High density data storage]	[Brain science]
[Virtual Reality & Augmented reality]	[Wearable health devices]
[Information protection]	[Pathogen measurement]
[Digital imaging technology]	[Cancer diagnosis and treatment]
[Artificial Intelligence]	[Artificial organ]
[Robot]	[Functional alloy material]
[Optoelectronics]	[Nano-sensor]
[Superconductors]	[High-energy density materials]
[Space & exploration]	[Energy storage]
[Aircraft]	[Medical material]
[Unmanned aerial vehicle]	[Nuclear energy]
[Crop production]	[Solar energy]
[Customized food]	[Nuclear fusion]
[Fish farming]	[Carbon capture and storage]

What are the main areas of science, technology and business that are going be strong in Europe by 2030? Please share your views on specific technologies, and platforms, that will thrive in Europe by 2030.

- What are the main areas in Information and Communication Technology, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in Food Agriculture and Biotechnology, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in Clothing, textiles, leather and footwear, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in Transport and Space Systems, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in Medicine and Health Care, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in New Materials and Nanotechnologies, that are going to be strong in Europe by 2030? [open answers]
- What are the main areas in Creative Industries (Craft, film, television, music, games, etc), that are going to be strong in Europe by 2030? [open answers]

- What are the main areas in Energy Efficiency and Energy Saving, that are going to be strong in Europe by 2030? [open answers]

- What are the main areas in Environmental Management, that are going to be strong in Europe by 2030? [open answers]

Part 3 - Disruptive business models: focusing on identifying new disruptive business models and markets.

As traditional industries grow and mature, their core technologies often become commodities and thus their differentiating competencies are increasingly coming from their service components, switching the innovation paradigm from product innovation to service innovation. In parallel, the avalanche of technological innovations is continuously creating new markets and risks for corporations and countries not able to follow the speed of changes.

The term disruptive business model is exactly used to describe these new markets created by new technological innovations or by old technologies that are used in new ways.

Rate the importance of this business models by 2030, and the performance of the European corporations on a global level. (scale 1 to 10)

Business model	Description & examples
1. Sharing Economy – The on-demand model	This model grants customers the use of the product without buying it. "Everything is a service". These access-over-ownership companies generate revenue by using the power of the sharing economy, by facilitating the actions between people thus making it needless for these companies to invest in products or people. Examples: Uber, Airbnb, Zipcar, ParkCirca, Peerby, Operator
2. Glocalizing on growth regions	As many of the developed countries face a shrinking population, companies in those countries have limited potential to grow by acquiring new customers. Therefore, companies need to focus on countries with both a growing population and a growing income per capita In this international competitive environment, Glocalization is the concept that in a global market, a product or service is more likely to succeed when it is customized for the locality or culture in which it is sold Examples: McDonalds, Gillette Guard
3. The silver economy - the 60+ market	Due to rising life expectancy, rising infertility rates and declining birth rates, global median age is rising. In many developed countries, people aged 60 and over will become the largest segment. In 2030, 29% of people in the developed countries will be older than 60, compared to 22% today. In addition, an increased segment of the over 60s population in 2030 will be still dynamically working, due to the increase of life expectancy, the increase of the retirement age, and the regenerative medicine developments. This demographic change will oblige companies to draw focus on people in this segment and work towards understanding and addressing their special needs. This special group is heavily consumption-driven, enjoy quality service and appreciate easy-to-use products. The 60-year-old in 2030, will look younger and be fitter than

	the one today, and will look of different products, and certainly not products for the elderly of today. Examples • Nestlé had arthritic hands in mind when it redesigned the jar for its Nescafe Gold instant coffee in Australia. • Danone has developed Souvenaid aiming at early Alzheimer's
4. The rise of the services: Big Data & Micromanufacturing	In near the future, the internet will be drastically fused by the physical world (refrigerators, air quality, sleeping patterns, sex behaviour, etc) and the great data science companies of the future sensor-packed world will sell intelligent information, and provide tailor-made services to the connected citizens. In parallel, virtualization is rapidly creating new business models, disrupting the powerful relationships between corporations and customers, allowing the latter to directly communicate, interact, buy & sell, and check the reputation. At the same time 3D printing is expanding fast, and has just started to tap its potential Examples: Many cloud printing services, like Shapeways, Kraftwurux, iMaterialise or Cubigy offer today templates that let you design or customize objects online.
5. Crypto-currencies & blockchain	The main innovation related with crypto-currencies, is the ability to carry out transactions without the need for a trusted third party; i.e. a move towards trust-less transactions. This mechanism could work to eliminate the role of many intermediaries, thereby reducing radically transaction costs. According to backers of the open source digital currencies (like bitcoin), these systems will become the basis for a future low-cost standards-based financial system independent of the traditional banking system. Although the focus is naturally drawn on financial services, there are dozens of potential applications for blockchain (the technology behind the crypto-currencies), and several investments and new concepts are appearing in several major industries. Examples: DocuSign, a provider of electronic-signature and digital transaction-management technology, created an app for Visa's "connected car" proof of concept; the app integrates with the bitcoin blockchain and can record contracts. It is intended to simplify the car buying and leasing processes and enable auto-based secure payments.
6. The circular economy	A circular economy is a global economic model that aims to decouple economic growth and development from the consumption of finite resources. Unlike a linear economy, it is about optimizing systems rather than components. This includes careful management of materials flowing in both biological and technical cycles. In technical cycles, materials are maintained, reused, refurbished and (as a last resort) recycled. In biological cycles, non-toxic materials are cascaded and eventually returned to the soil, thus restoring natural capital. The tighter the cycle the more economic value is retained. Examples •Vodafone's Red-Hot plan: you can rent the latest phone for a year and keep on exchanging it for a newer version. •FLOOW2 facilitates the sharing of overcapacity of business equipment, but even the skills & knowledge of personnel that are under-utilised.
7. The subscription model	The subscription model is a business model where a customer pays a returning subscription price to have access to the product service. The constant revenue stream from subscribers reduces uncertainty & often provides payment in advance, while allowing customers to become

	greatly attached to using the service and, therefore, more likely to extend the subscription. The revenue stream from recurring subscriptions often is greater than the revenue from the simple one-time purchases. Examples: Netflix, HelloFresh, Dollar, Shave Club, Kindle, One
8. The freemium model	The freemium model is a business model where a customer has free access to the basic service but is charged for additional features. The freemium model is used to build a large consumer base when the marginal cost of producing extra units is low. Giving the service away for free results in acquiring a lot of prospects very efficiently. The non-paying costumers results in input of data, feedback, notoriety, advertising opportunities, etc Examples: spotify, dropboc, linkedin, the New York Times, Farmville
9. The free model	The free model is business model integrated by companies that don't charge the end users (directly). The data and the attention of the users is the currency. By offering the product or service for free it is easy to gain a lot of users. The more people interact with the product, the more data that can be extracted from the users. Revenue is produced by selling user data or user's attention, offering huge possibilities for targeting advertising. Examples: Google, Facebook, Snapchat
10. The market place	The market place is a business model used by a company that only facilitates a platform where parties economically interact with each other. The market place is a business model that defines a company as a big supplier of a service without the company having the good or the service. It only facilitates the platform where people interact with each other in any (economical) way. The market place generates revenue by taking a percentage of any transaction between people on their platform. Examples: eBay, Alibaba, Friendsurance, priceline.com, The Lending Club, Beatport, Upwork etc
11. The experience model	The experience model is a business model used by company that provides the customers with an unseen (user) experience. Customers of experience model companies are willing to pay more just because of the special (user) experience they get when interacting with the company or the product. Experience companies are often situated in or penetrating competitive markets. In these markets you can either offer the lowest price or provide consumers with the best experience. Examples: Tesla, Disney World, Tomorrowland
12. The ecosystem	One of the most powerful, disrupting business models. Companies build an entire universe of products and services. The ecosystem business model only exists when companies can offer enough services and or products that cause high level of dependence of the customer. Once the customer is dragged too far in the ecosystem, he can hardly get back out. If your iphone breaks you must buy a new one… and a macbook and an apple watch Examples: Google, Apple

What other business models and markets will be important by 2030? [open answers]

Part 4 - China: for investigating future opportunities for collaboration with China.

You agree or disagree with the following statements?

- By 2030, 15 Chinese companies will be on the list of world's 50 most innovative. (Agree/Disagree)
- By 2030, domestic private entrepreneurs, rather than the Chinese government or foreign corporations, will be the main driving force of the Chinese economy. (Agree/Disagree)
- By 2030, China will have globally famous pop stars and actors who are as famous in the West as the biggest Hollywood stars. (Agree/Disagree)

- By 2030, China will be the leading country in terms of exports of "green tech". (Agree/Disagree)
- By 2030, inland China will be regarded as a necessary place to have the presence of international corporations. (Agree/Disagree)
- By 2030, China has become a dominant Nobel Prize nation.(Agree/Disagree)
- By 2030, all major international technology companies have research centers in China. (Agree/Disagree)
- By 2030, at least one university in China competes with Harvard and Oxford of the world's best students. (Agree/Disagree)

In what of the following areas do you see the highest potential pay-off for collaboration between Europe and China in science, technology, and business? (scale 1 to 5)

[Environmental management]	[Telecommunication Technologies]
[Space exploration]	[Food biotechnologies]
[Aeronautics]	[Agricultural biotechnologies]
[Synthetic biology]	[Drugs]
[IoT]	[Molecular diagnostics]
[Robotics]	[Human genome]
[Computer Architecture and Systems]	[Functional materials]
[Data processing and analysis]	[Hybrid and bio-mimetic materials]
[Safe nuclear engineering]	[Efficient use of Renewable energy sources]
[Efficient storage of electric and thermal energy]	[Hydrogen power]
[Smart energy systems of the future]	[Nuclear Fusion]

- **Please suggest other priorities areas for collaboration between Europe and China** (open answers)

Delphi Analysis

The analysis of the input received by the experts is presented in the following pages. The analysis of the answers in the questions with specific answers took place using Excel. The open text answers were analysed using the NVivo text analysis software.

Part 1 - Megatrends: *for evaluating the identified megatrends and investigating other important driving forces.*

The 5 global MegaTrends identified during the desktop analysis were evaluated by the experts toward their ability to transform the global innovation landscape by 2030.

As it was expected the Delphi analysis validated the importance and high probability of the five pre-selected Megatrends, in shaping the innovation environment by 2030

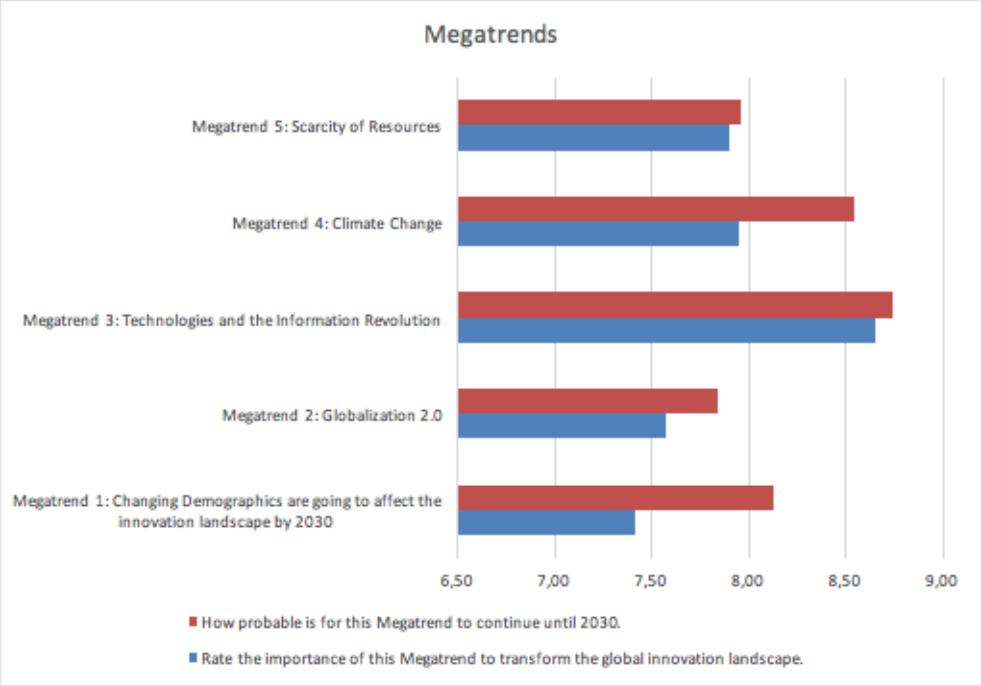


Figure 6: Re-evaluation of the key megatrends by experts, for their importance and probability to occur.

Megatrend 3, describing the explosion of the new industrial revolution, and the explosion of information technologies, is evaluated as the most probable and most important in shaping the global innovation environment.

The main technological fields particularly highlighted by the experts are:

- ***Energy independence:*** people will generate energy at home through renewable energy.

- ***IoT and Big Data:*** to bring services to traditional hardware-based industries, and allow customization of those services by the client, not the company.

- ***Gamification*** of many traditional products to make people save energy, water etc.

- ***Mass customization:*** 3D printing and supporting platforms will let people make products on demand. Lots of industry alliances will occur to allow

customization of products to the point that functions and product barriers are blurred.

- ***A.I. and machine learning:*** to increase productivity and unemployment.
- ***Biotech developments:*** CRISPR[36], bio-ecomimicry, personalised medicine and healthcare systems.

In addition, an open text question allowed the experts to suggest additional important trends and driving forces, and the results are summarized in the following graph. The main issues are related to the five indicated megatrends, while additional driving forces appear to be:

- Increasing fragility of the global financial system and the rising public debts worldwide.
- New forms of public policies and governance, and enhanced citizen participation (taking advantage of new technologies), in order to respond to rapid changes, low public income and low public expenses, and rising social inequalities.
- Rising immigration levels (climate, and economic).
- Shift in global economic (and political) power from the "Western world" to emerging countries.
- Value shifts: sustainability, atomization, etc
- Work 4.0: Different labour options,new roles and values in the work market.
- Changes in IPR management and technology transfer.

Figure 7: Word frequency analysis, Driving Forces

[36] Gene editing method.

Part2 - Disruptive Technologies: focusing on Europe's technological future.

A second objective of the Delphi, was to identify specific technology areas that are going to be strong in Europe 2030. The experts evaluated 34 technological areas in various fields. The selection of the technological areas was based on a desktop analysis of previous similar studies (e.g.Russia 2030) and the on-going scanning of the Millennium Project.

The overall results are summarized in the following graph, while the strongest and the weakest technological areas in Europe by 2030 are summarized in the following table.

Table 1: Technologies in Europe 2030

Strongest Technological Areas	Weakest Technological Areas
Energy storage	Nuclear energy
IoT	Saltwater agriculture
Nano-sensor	Nuclear fusion
Brain science	Cultivated meat
Medical materials	Fish farming
Cancer diagnosis and treatment	Space exploration
Solar energy	Carbon capture and storage
3D/4D printing	Crop production
High-energy density materials	Unmanned aerial vehicle
Wearable health devices	Virtual Reality & Augmented reality
Artificial Intelligence	Customized food
Artificial organs	Aircrafts
Information protection	High density data storage

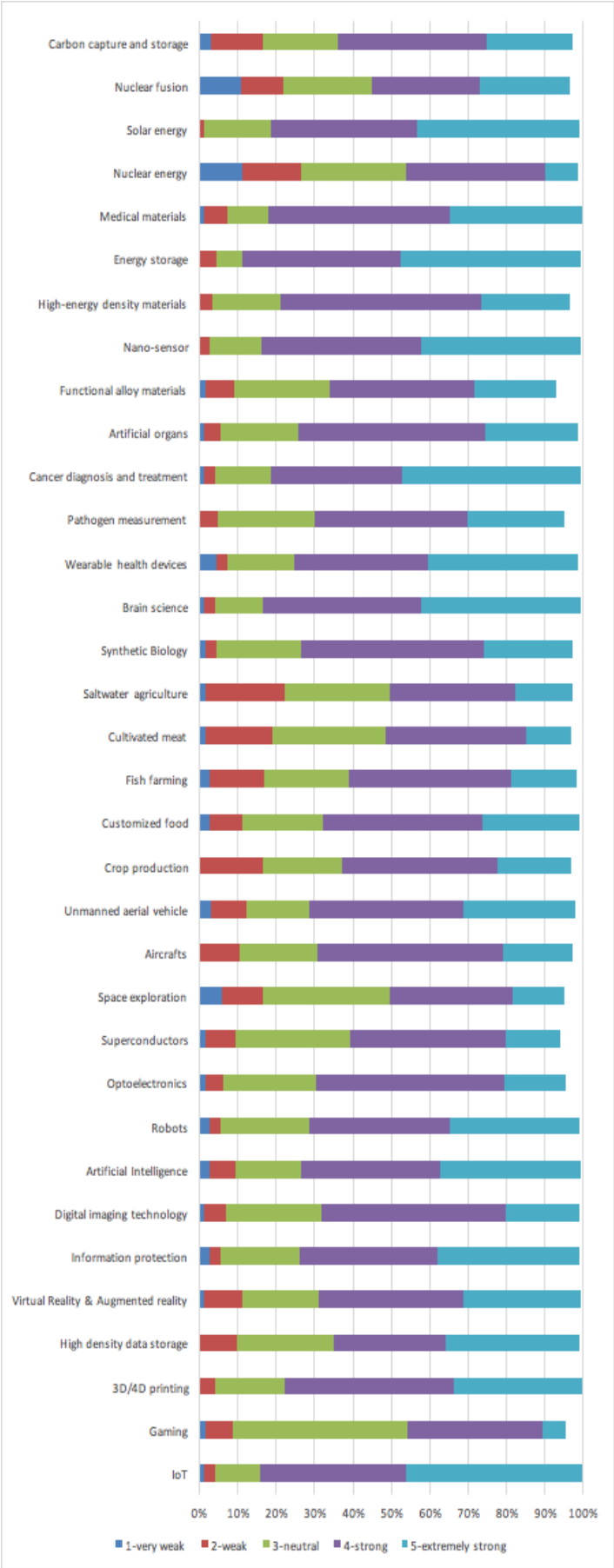


Figure 8: Strongest and Weakest technological areas in Europe by 2030.

Beside the evaluation of the 34 preselected technological areas, the experts were also invited to suggest specific technology topics that are expected **to be strong in Europe by 2030** in the broader areas of ICT, FAB, Clothing & Textiles, Transport & Space, Medicine & Health, Material & Nanotechnologies, Environmental Management, Energy, and Creative Industries[37]:

Information and Communication Technologies

- Data safety/analysis/management/storage
- Artificial Intelligence and machine learning.
- Internet of Things (IoT)
- Virtual Reality
- Smart cities, smart transportation, smart everything.

Figure 9: ICT technologies, word frequency analysis

Food, Agriculture and Biotechnology

- Food Safety
- Sustainable food production
- Specialized food products
- Organic food
- Urban agriculture
- Precision agriculture
- Reduction in animal food products

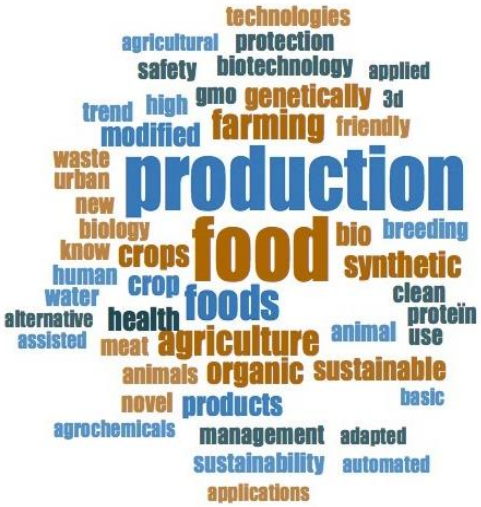


Figure 10: FAB technologies, word frequency analysis

[37] The word frequency analysis was performed with the NVIVO software.

Clothing, textiles, leather, and footwear

- Wearables
- Sensor technologies
- 3D printed clothes/textiles/footwear
- Smart textiles
- Eco-Friendly clothing, sustainable materials, fair-trade textiles.
- Medical clothes/ senior's fashion

Figure 11: Textile & clothing technologies, word frequency analysis

Transport and Space systems

- Clean transport systems and infrastructure
- Electric vehicles
- autonomous self-driving vehicles
- Space research and exploration, space probes (launchers), micro satellites
- Asteroid mining & space tourism
- Drones

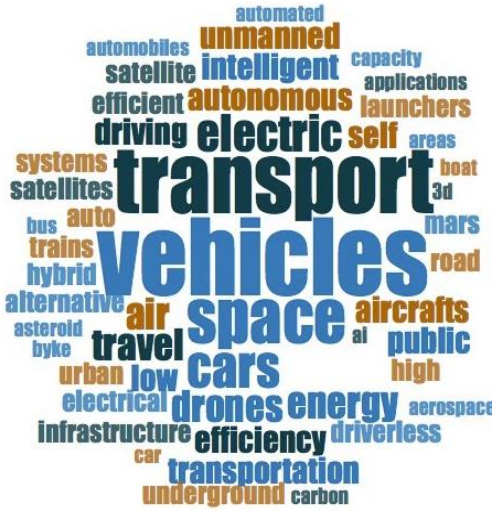


Figure 12: Transport & Space technologies, word frequency analysis

Medicine and Health Care

- Addressing cancer (diagnosis, treatment, etc)
- Age related diseases (e.g. Alzheimer)
- HIV treatment and vaccine development
- Personalized medicine, and health care
- Gene therapy
- Artificial organs and 3D/4D printing
- Wearable devices

Figure 13: Health technologies, word frequency analysis

Creative Industries (craft, film, television, music, games, etc)

- Augmented and Virtual reality productions
- Virtual reality holidays, films, games, sports
- Gamification, serious games, extended reality games
- 3D imaging/films
- User generated content, self-made stars

Figure 14: Creative industry technologies, word frequency analysis

Energy efficiency and Energy saving

- Home energy generation systems
- Energy storage systems (new batteries) and saving systems
- Solar & wind energy systems
- New generation nuclear reactors
- IT solutions for energy management
- Nuclear fusion
- Carbon capture technologies

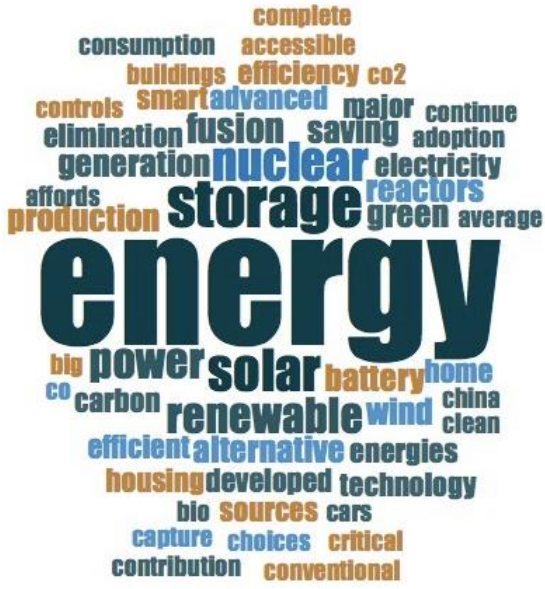


Figure 15: Energy technologies, word frequency analysis

Environmental Management

- Better Integration of environmental management: circular economy concept
- Water management, and water purification technologies
- Flood protection and water pumps
- Carbon storage
- Water & energy efficient production
- Sustainable cities

Figure 16: Environmental technologies, word frequency analysis

Part 3 - Disruptive business models: focusing on identifying new disruptive

business models and markets.

As traditional industries grow and mature, their core technologies often become commodities and thus their differentiating competencies are increasingly coming from their service components, switching the innovation paradigm from product innovation to service innovation. In parallel, the avalanche of technological innovations is continuously creating new markets and risks for corporations and countries not able to follow the speed of changes. The term disruptive business model is exactly used to describe these new markets created by new technological innovations or by old technologies that are used in new ways.

Under this section the experts were requested to evaluate (from 1 to 10) the importance of 12 business models and markets towards 2030.

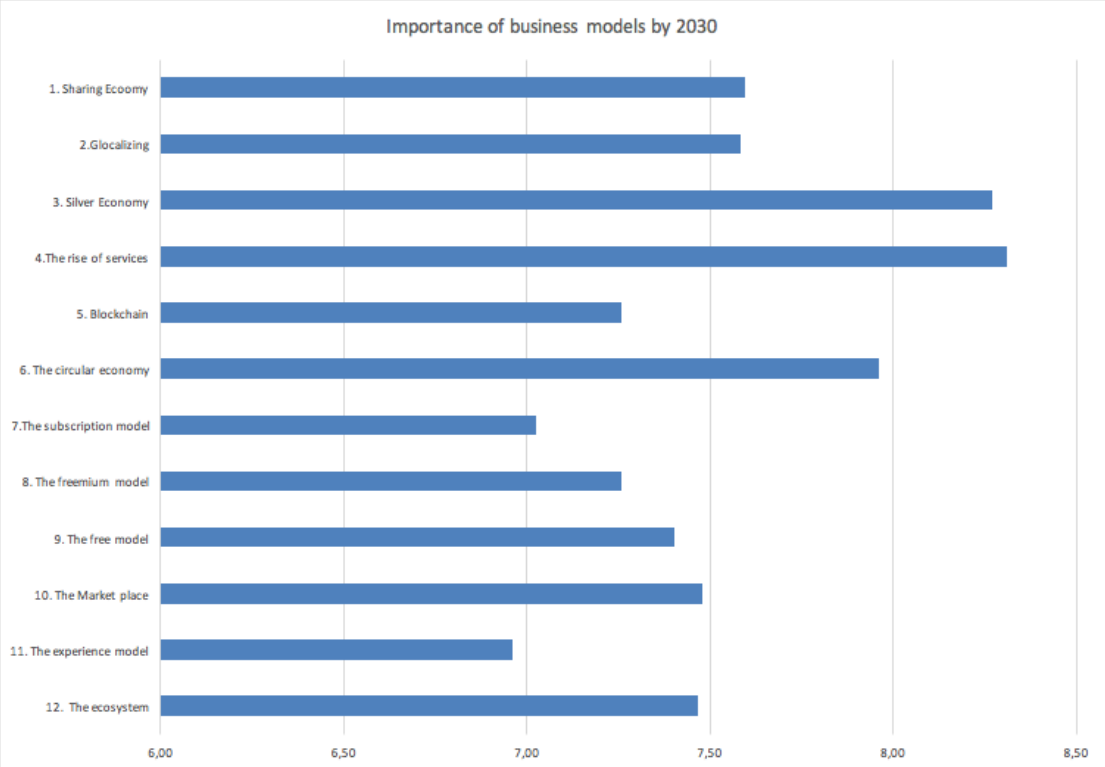


Figure 17: Evaluation by experts of novel business models towards 2030.

The "rise of services" and the "silver economy" are rated as the most important towards 2030, followed by the business models of "circular economy model", "sharing economy", and "glocalizing" , underlying specific opportunities and challenges for traditional European and Chinese industries.

Part 4 - China: for investigating future opportunities for collaboration with China.

The last section of the Delphi was focusing on the future of China, and the prospective for cooperation with Europe. Initially the experts were asked to answer a set of questions, for understanding the general views of the group on China's progress toward China 2030[38].

	Delphi		Shanghai workshop	
Question	Agree	Disagree	Agree	Disagree
By 2030. 15 Chinese companies will be on the list of world's 50 most innovative.	79%	21%	69%	31%
By 2030, domestic private entrepreneurs, rather than the Chinese government or foreign corporations, will be the main driving force of the Chinese economy.	62%	38%	77%	23%
By 2030, China will have globally famous pop stars and actors who are as famous in the west as the biggest Hollywood stars.	32%	68%	35%	65%
By 2030, China will be the leading country in terms of exports of "green tech".	38%	62%	47%	53%
By 2030, inland China will be regarded as a necessary place to have the presence of international corporations.	82%	18%	100%	0
By 2030, China has become a dominant Nobel Prize nation.	14%	86%	12%	88%
By 2030, all major international technology transfer companies have research centers in China.	66%	34%	88%	12%
By 2030, at least one university in China competes with Harvard and Oxford of the world's best students.	60%	40%	41%	59%

The answers received by the international experts and the Chinese based experts are quite similar, showing a similar division between the experts as regards the future progress of China. Most of the experts have a rather optimistic view for the future of China in terms of technology and innovation, however there is a clear negative view towards the "cultural exports".

[38]The same set of questions was asked in the Scenario workshop in Shanghai (May 2015).

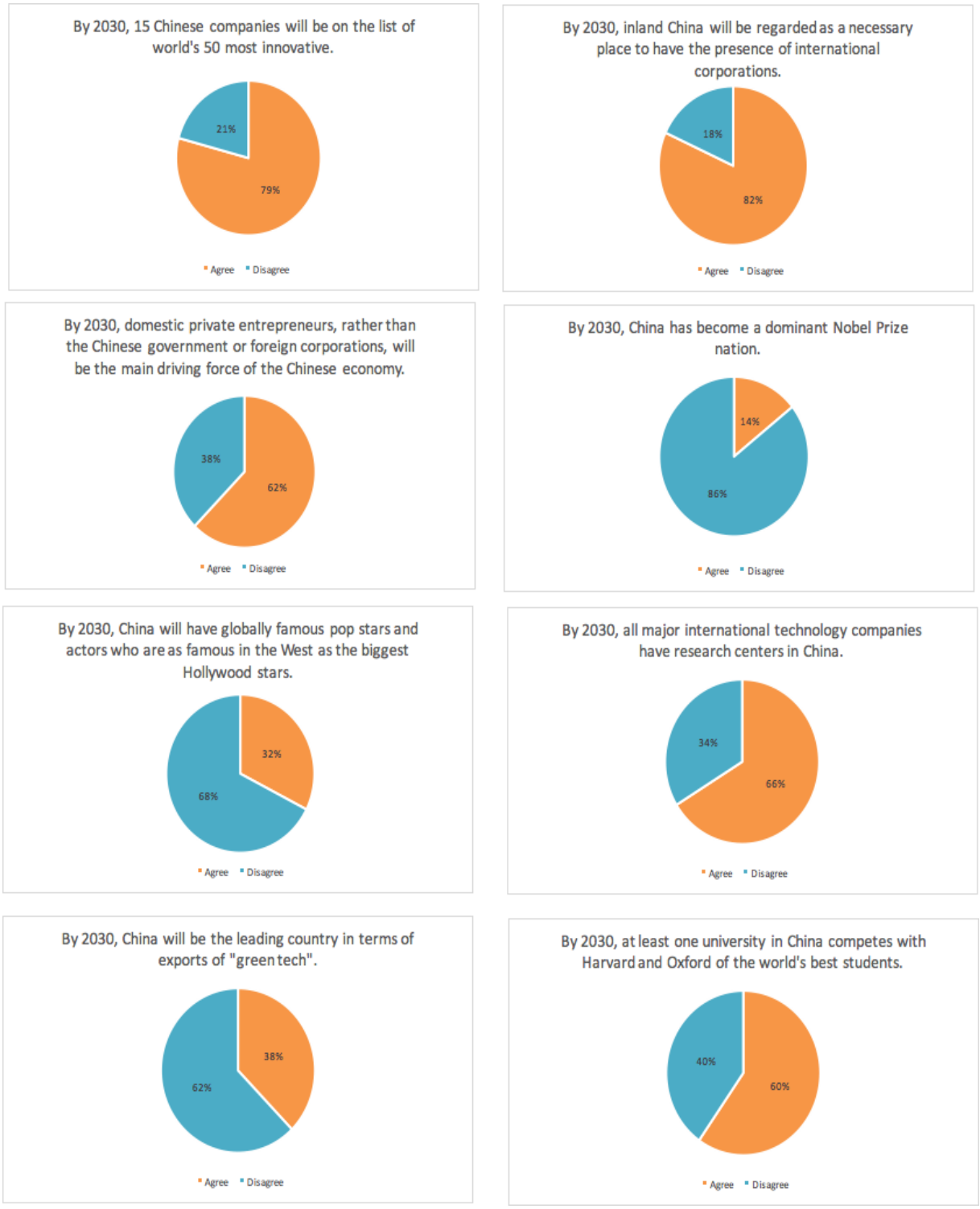


Figure 18: Expected developments in China by 2030.

The last set of questions was focusing on the collaboration areas with highest pay-off potential. The 77 experts were requested to evaluate the future potential of 22 technological areas.

The areas deemed with the highest cooperation potential between EU and China are:

- Environmental Management
- Robotics
- Telecommunications
- Renewable energy
- Smart energy systems of the Future
- Agricultural biotechnologies

The areas deemed with the lowest cooperation potential between Europe and China are:

- Nuclear fusion
- Safe nuclear engineering
- Space exploration
- Drugs
- Hydrogen power

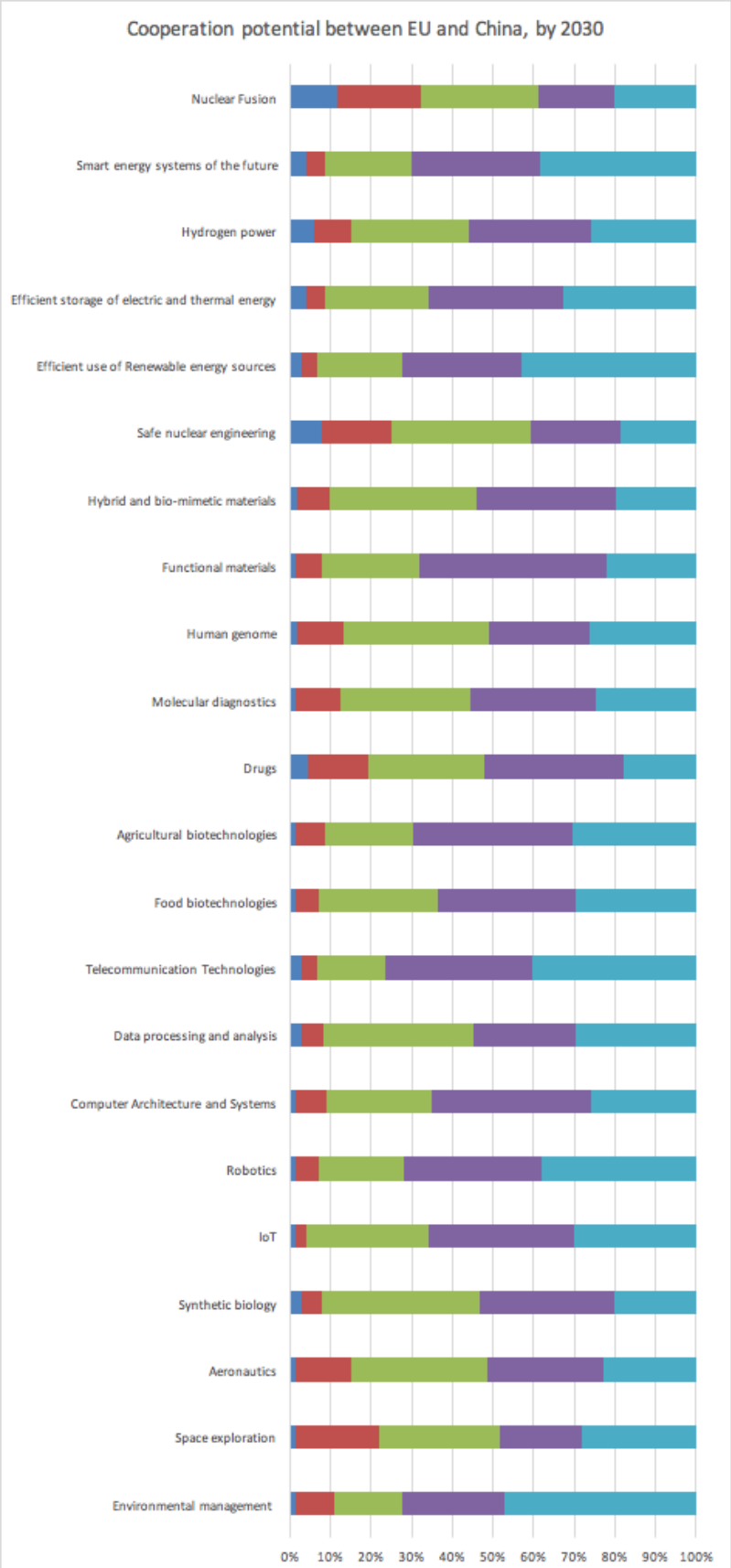


Figure 19: Topics with higher/lower potential for cooperation between EU and China

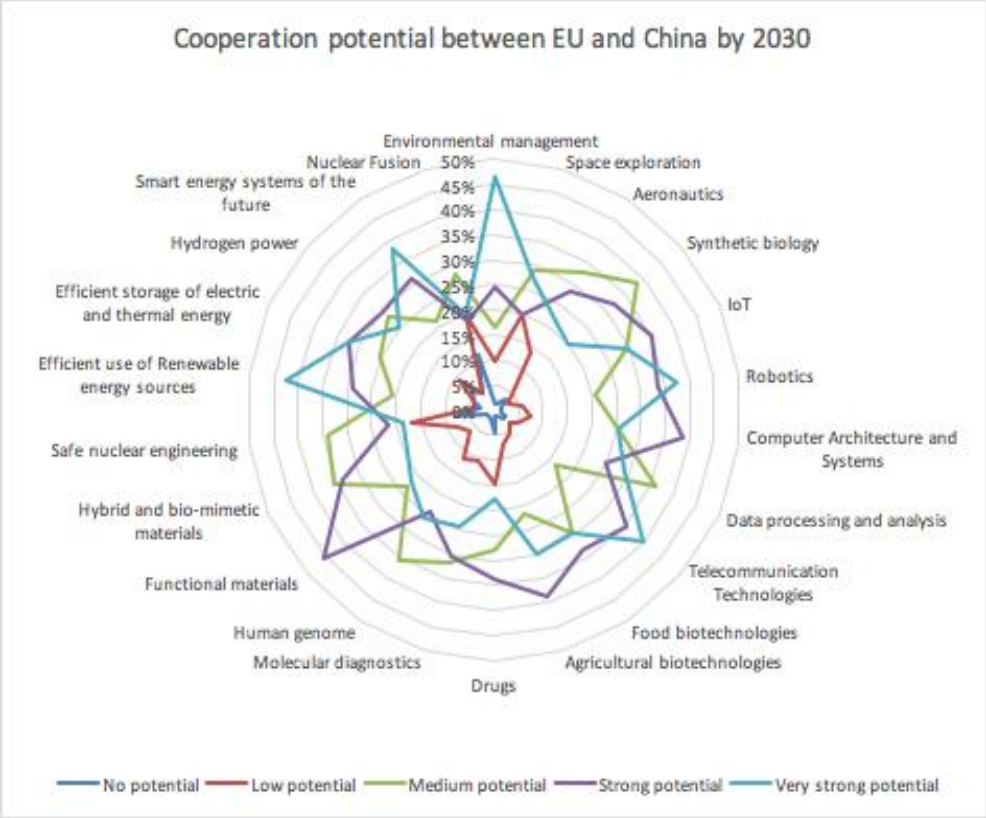


Figure 20: Topics with higher/lower potential for cooperation between EU and China

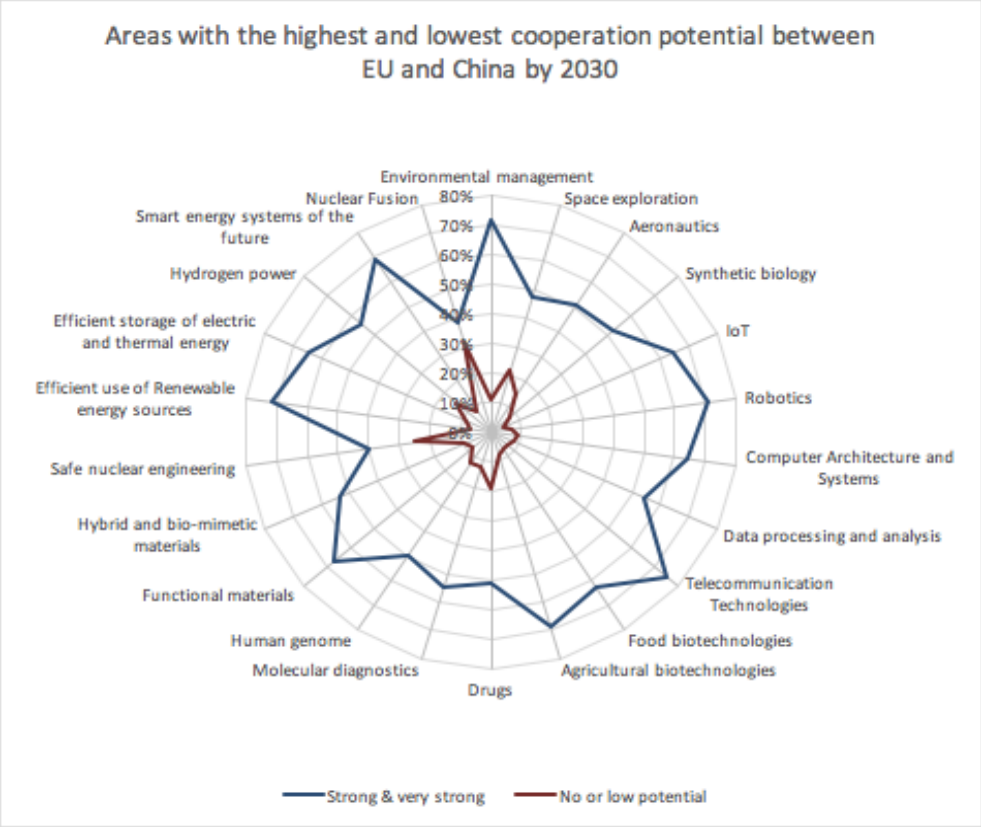


Figure 21: Topics with higher/lower potential for cooperation between EU and China

ANNEX 4: 1st Participatory Workshop, Shanghai (22 May 2015)

This report is a summary of a full-day workshop held on May 22nd 2015 in Shanghai to explore different possible futures for innovation in China toward 2030 using the scenario approach. The 21 participants represented European multinationals, start-ups, academia, and European national science and innovation agencies. The workshop was held within the Dragon Star Plus Project. It was financed by the European Commission and supported by the European Union Chamber of Commerce in Shanghai.

The workshop was divided into two parts. In the morning, the participants discussed China's current innovation capabilities, challenges that may drive innovation toward 2030, and trends in business model innovation. In the afternoon, drivers, options, and scenarios were discussed and analyzed, resulting in a scenario map for Chinese innovation in 2030.

Predictions About 2030

At the start of the workshop the participants were asked to answer a set of questions about innovation in China 2030. The results, displayed at the table bellow, show division within the group on China's progress toward 2030, with a majority on the more optimistic side. The same set of questions was also asked in the Delphi[39], to the experts based outside China.

2030 predictions	Delphi	Shanghai workshop
By 2030, 15 Chinese companies will be on the list of world's 50 most innovative.	79%	69%
By 2030, domestic private entrepreneurs, rather than the Chinese government or foreign corporations, will be the main driving force of the Chinese economy.	62%	77%
By 2030, China will have globally famous pop stars and actors who are as famous in the West as the biggest Hollywood stars.	32%	35%
By 2030, China will be the leading country in terms of exports of "green tech".	38%	47%
By 2030, inland China will be regarded as a necessary place to have the presence of international corporations.	82%	100%
By 2030, China has become a dominant Nobel Prize nation.	14%	12%
By 2030, all major international technology companies have research centers in China.	66%	88%
By 2030, at least one university in China competes with Harvard and Oxford of the world's best students.	60%	41%

[39] ANNEX 3

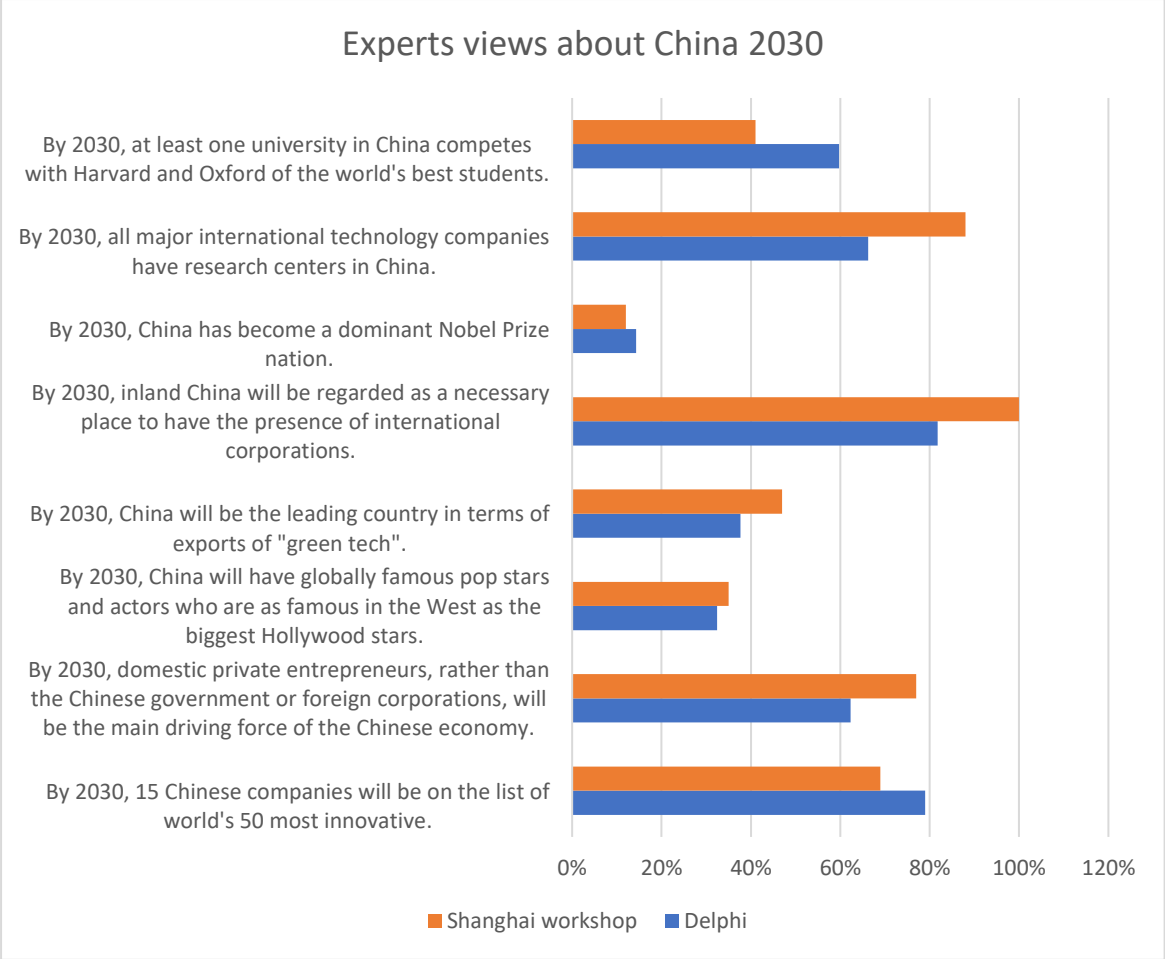


Figure 22: Views about China 2030.

Business Model Discussion

General Discussion

43 Chinese business model cases provided as input were divided into three categories by the participants: specialized, generic, and traditionalist. *Specialization* means finding a new way to break into an area and carving out a niche in that area. *Generic* business models typically involve building a platform or creating a space for an ecosystem. *Traditionalist* models often entail cost-focused innovation, modularization, and process-based innovation in manufacturing.

As characterized by the participants, specialists are interested in finding gold nuggets; the generalists create the conditions for the gold nuggets to exist; and traditionalists focus on what is good enough. Innovation can be found in all three categories, but traditionalist models were believed by the participants to be an increasingly exhausted mine with less importance in the future.

In relation to business model innovation, the following trends were discussed:

- The increasingly common practice of cutting out intermediaries and creating

market places.

• The merging of producers and consumers ("prosumers").

• Market data will increasingly be collected in non-traditional ways.

The notions of abundance and scarcity, both of which can drive innovation, were also discussed. Traditionalists tend to be abundance-focused, for example by utilizing large pools of cheap labor or by large-scale production. Scarcity-driven innovators, meanwhile, create solutions in an environment of limited resources, such as improving the flow, allocation and use of resources.

The *figure 23* shows how the group placed business cases on scales from uncommon to very common today and from less common and more common in the future.

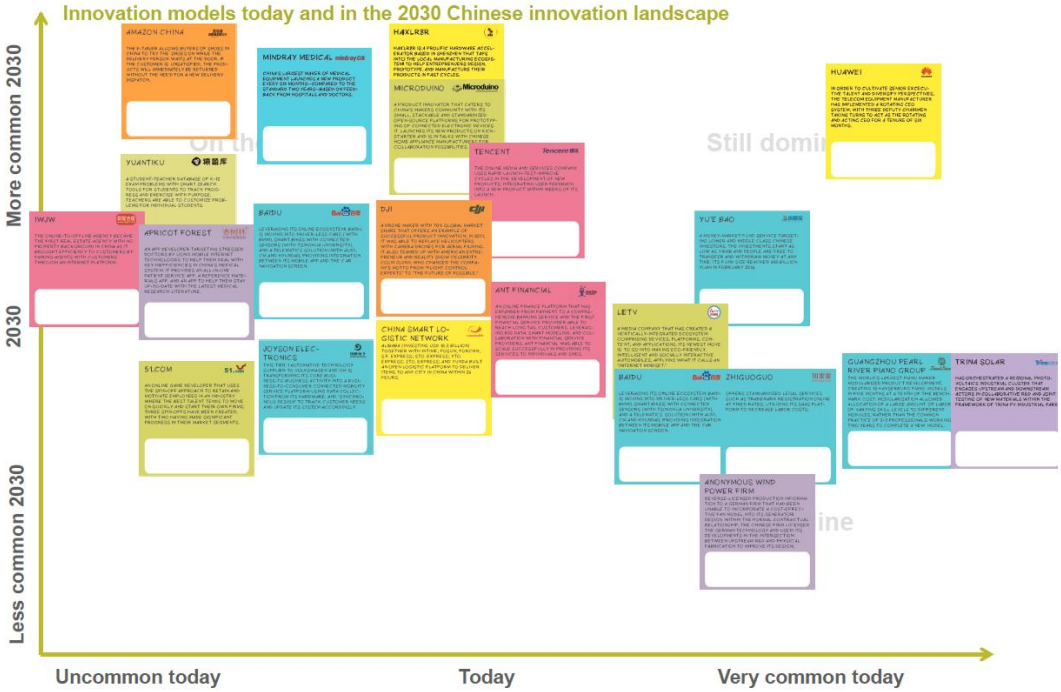


Figure 23: Innovation models in China.

Declining Business Models

Broadly speaking, business models that are important now but are expected to decline in value include:

- Those focusing on bringing affordable products to market in record time – the *"good-enough for China"* models.
- *Accelerated, simultaneous, and assembly-line style innovation*, where the innovation process is managed using systems and thinking from product lines,

large numbers of labor are assigned to each step, and modules carried out in parallel.
- *Design architecture innovation*, where a product's sub components and their interaction are redesigned to decrease cost, improve interoperability, etc, but not alter the features and function of the product.

Traditionalist business models oriented around *cost-cutting* and *modularization* were especially singled out. A representative case of this type is **Guangzhou Pearl River Piano Group**. The company applied simultaneous engineering on product development in piano making by modularizing the process of product development and assigning a large number of people to each task. In this way they managed to launch 10 new Kayserburg piano models in 5 months at a cost of $1 million, a tenth of the benchmark cost. With shifting economic realities, in 2030 Chinese manufacturers will need to do more than innovate around cost-cutting and modularization.

Other models that were considered common but of declining importance by the participants were those centered around *fast-following*, where imitation and minor adjustments are the key components. Companies placed in this category include **LeTV, Baidu**, and a wind power company that reverse-engineered, improved, and reverse-licensed German technology. Baidu, however, was also considered to offer a generalist approach that we will see more of in the future, described under Growing business models below.

Increasingly Important Business Models

The participants expected business models centered around the *makers community* to grow in importance. Two representative cases are Haxlr8r and Microduino. **Haxlr8r** is a prolific hardware incubator based in Shenzhen that taps into the local manufacturing ecosystem to help entrepreneurs design, prototype, and manufacture their products in fast cycles. **Microduino** is a product innovator that caters to the makers' community with its small, stackable and standardized open-source platforms for prototyping of connected electronic devices. It launches new products on Kick-starter and is in talks with Chinese home appliance manufacturers for collaboration possibilities. More broadly, business models focusing on a specific tribe were considered promising.

Representing the generalist model, cases involving *building or orchestrating an ecosystem* were considered important and expected to be even more so in the future. A case selected to represent this type was **Baidu** leveraging its online ecosystem to move into driverless cars (with BMW), "smart" bikes with connected sensors (with Tsinghua University), and telematics solutions (with Audi, GM, and Hyundai) providing integration between its mobile app and the car navigation screen. Another example was **China Smart Logistics Network**, the result of a partnership between Alibaba and several logistics companies that together are building an open logistics platform to enable delivery of items to any city in China within 24 hours.

Data-enabled platform building was also discussed in the context of high-potential

business models. An example of this is **Joyson Electronics**, an automotive technology supplier that is transforming its core business-to-business activity into a business-to-

consumer connected mobility service platform using data collected from its hardware, and "synchronous design" to track customer needs and update its system accordingly.

Carving out *niches in areas with growing needs* is another category where the participants expected to see more innovation. Current examples include **IWJW**, an online-to-offline real estate agency without property background, and **Yuantiku**, a student-teachers database of K-12 exam problems that helps teachers customize problems for individual students. Of special promise are models based on identification and *exploitation of excess capacity*, using IT to bridge supply and demand and distribute resources in a more effective way.

51.com was selected for *human resource-related innovation*, using the spin-off approach to retain talents in an industry (game development) where talents tend to start their own companies as soon as they have accumulated the required skills and capital.

There was as interest in cases that *combine product innovation with accelerated innovation, rapid incorporation of user feedback, and rapid test-launch-improve cycles*. Such cases include **DJI,** a civilian-use drone maker with 70% global market share, as well as **Mindray Medical**, China's largest maker of medical equipment that launches a new product every six month, compared to the standard two years, based on feedback from hospitals and doctors.

Other business models of interest were those that offer *localized solutions* in innovative ways, such as **Amazon** allowing buyers of shoes in China to try the shoes on while the delivery person waits at the door. If the customer is unsatisfied, the products will immediately be returned without the need for a new delivery dispatch. The case also presents a solution to the problem of logistics costs associated with people buying multiple items, keeping the best fit and sending back the rest.

Capabilities Discussion

The participants discussed China’s innovation capabilities based on the country’s performance along a number of dimensions in the 2014 study Global Innovation Index as well as the size and growth more than 600 major patent categories. *Graph 19* shows the capabilities that the participants considered weak and strong, as well as more and less critical.

Key strengths to build on include:

• Strong manufacturing capabilities with fast execution, large scale, and a large domestic market;

• Strong industrial learning and knowledge absorption capabilities;

• An entrepreneurial mindset among the Chinese people.

Capabilities that need improvement include:

• Academic learning, where basic research, teaching, and language capabilities lag behind;

• Institutions, which need to become more supportive of innovations;

• Access to resources, where shortages of food, water, and natural resources are expected to be an important driver of innovation.

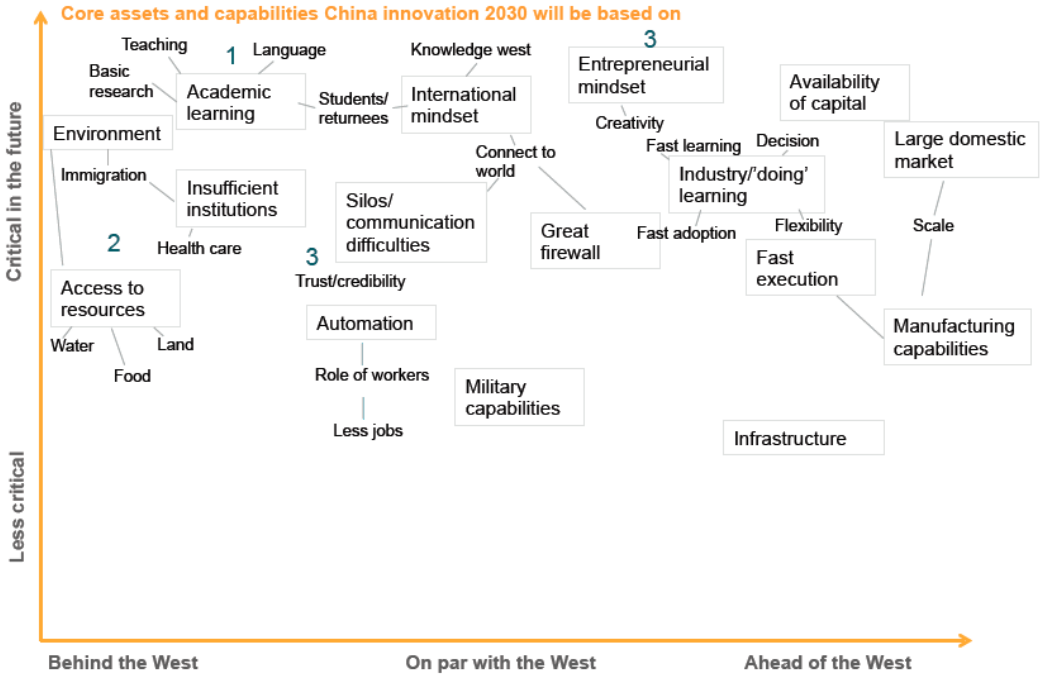


Figure 24: China's core capabilities

Related to the discussion about innovation capabilities, the tables below show obstacles and drivers to innovation in China found in the literature during research leading up to the workshop.

Drivers of innovation in China based on literature review:

Type	Obstacle
Macro drivers	• Global fragmentation provides Chinese companies with competitive advantages within specific phases of production– skills and innovation from specialization; • Supportive government policy; • Deregulation, simplification of procedures and increasing role of market forces; • Government funding and tax breaks for innovative companies; • Accelerated development of high-tech parks, clusters and incubators;

Industry drivers	• Large private sector; • Conditions for cost-based innovation rapidly eroding, need for changed mindset; • Innovation strategies focusing on consumer needs becoming increasingly common; • Capability upgrading and reverse learning – from customers, competitors, partners; • Accelerated innovation focusing on speed of problem solving and development; • Networked approach to accessing and building global innovation capabilities; • Knowledge acquisition from overseas; • Large domestic market, enabling critical mass, rapid feedback and fast cycles; • IP protection core part of innovation culture by compartmentalizing knowledge;
Education and talent drivers	• Relatively strong global position for top Chinese universities, high knowledge creation ranking; • Universities becoming increasingly integrated in innovation ecosystems; • Entrepreneurial mentality, growing talent base, overseas returnees;

Obstacles to innovation in China based on literature review:

Type	Obstacle
Political and economic environment	• Lack of institutional framework conductive to innovation, including weak IP protection; • Schools, universities, and businesses operating in a politicized environment; • Indigenous innovation policies favoring local firms in unfair and non- transparent ways; • Competition often limited due to regulations and focusing on national champions; • Harsh local environment for SMEs, as governments prefers larger firms; • National security concerns limits market competition in some industries; • Local government reliance on large-scale projects that bring growth and employment;
Education	• Weak educational system with too much focus on memorization; • Insufficient flow of knowledge and resources between industry and academia;
Talent access and retention	• Talent shortage and high turnover rates among skilled labor; • Difficulty to attract talent due to heavy pollution and

internet censorship;

Culture	• Risk-averse culture;
Traditional mindset in firms	• Traditional manufacturing-based focus, relying on cheap labor and large scale of production and lacking a deep customer understanding; • Still plenty of low-hanging fruit based on copy-cat model and local adjustment;
Financing	• Banks favor SOEs; • VC firms favors models with proven success and come in later than in West;

Future Challenges Discussion

Figure 25 shows the result of the discussion on trends that will push innovation in China toward 2030. Areas of important were believed to include the development of smart cities, health care and e-health, ageing infrastructure, values and lifestyles of new generations, and the quest for credibility among Chinese brands.

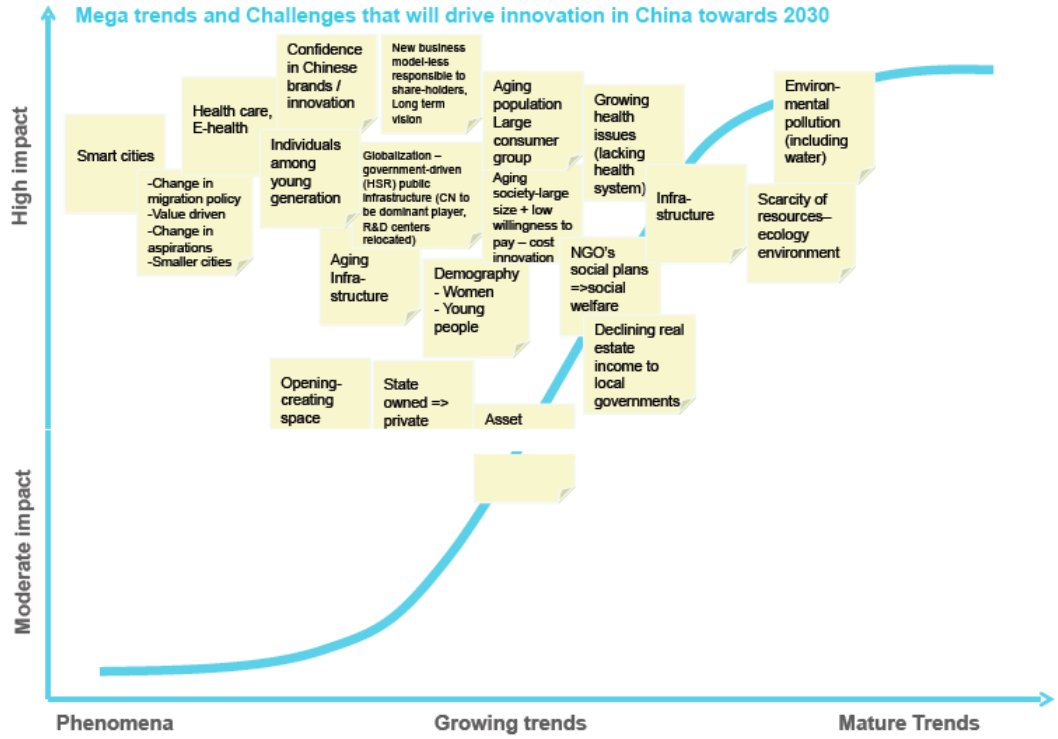


Figure 25: Trends and Challenges for China towards 2030.

The expert groups placed each option on a low impact-high impact as well as a low probability- high probability scale. *Figure 26* on the next page shows the result of one group's discussion. The values were used as input for the scenario analysis.

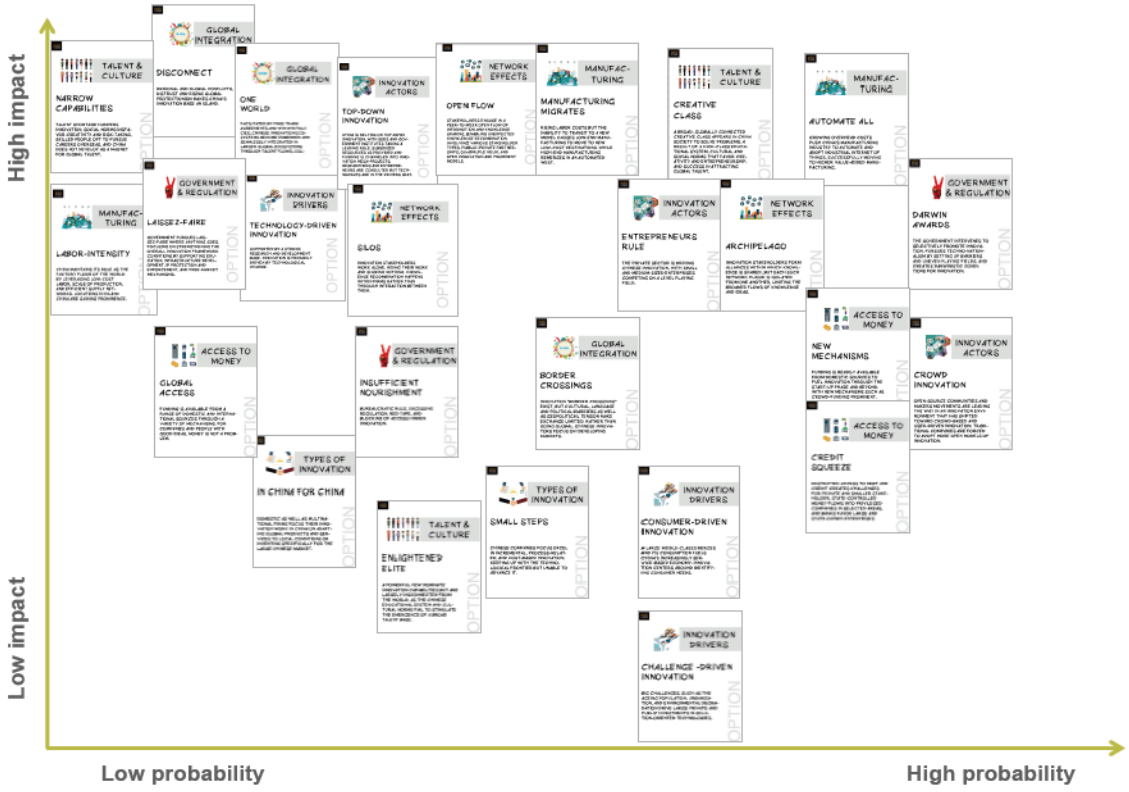


Figure 26: Probability & Impact of trends and drivers.

Draft Innovation Scenarios

Based on the innovation drivers previously discussed, each group created a scenario cross. The options were also statistically analyzed and projected to create an emergent scenario map.

One dimension selected by all groups was related to the **uncertainty** in the character of **government involvement**. This dimension was named differently by each group: entrepreneurial state vs restrictive state; lassez-fair vs. excessive control; and topdown controlling system vs. bottom-up nourishing eco-system.

The **second** dimension was also similar between the groups. One group described it in terms of **network effects and flows of knowledge** (silos vs. open flow). The second group added to this dimension the aspect of China's interconnectedness with the outside world (disconnected silos vs. integration with outside world). The third group related it to the type of innovators that will be dominant (start-up nation vs. technocratic industrial innovators).

This resulted in scenarios that were surprisingly similar between the groups. Some of the reoccurring or otherwise interesting themes of the scenarios are described below.

US-TOPIA

China becomes fully integrated in international knowledge ecosystems, knowledge flows freely between actors, global technology is fully accessibly, and the government

focuses on the framework conditions for innovation but does not take a big role in allocating resources. Powered by technology innovation and a world-class educational system, China manages to attract global talent and emerges as a new Silicon Valley-like hub, able to spurn new-to-the-world innovations and Chinese brands that appeal to consumers around the globe.

CENTRIFUGE

Innovation evolves within disconnected islands of collaboration, where companies and academic institutions form alliances but network effects remain limited and organizations go to great length to protect their own spheres of interest. There is creative evolution but little access to outside influences. Innovation activities happen only within each ‘centrifuge’ and are mainly focused on adapting global technologies to local conditions.

MITTELSTAND

Powered by manufacturing upgrading, China develops its own "Mittelstand" of small and medium-sized, private-owned industrial innovators that successfully climb the value-added ladder. By combining their strengths in flexible mass production, fast learning, and fast execution with new breakthroughs in automation and Industrial Internet of Things they prevent manufacturing from migrating to lower-cost locations.

PLANNED INNOVATION

The state is the entrepreneur, actively picking winners by allocating resources and tilting the playing field. The focus is on large-scale innovation projects such as space travel and infrastructure projects. The domestic market is dominated by players that have been cultivated in a protected environment of limited competition and subsidized inputs, but that are unable to compete globally. Governmental research institutes play a big role in basic and applied research.

RESILIENCE

In an environment of restrictive government policies and stifling institutions, IT enabled structures facilitate knowledge flows and community-based collaboration around the big challenges facing society. Innovation is open-source and user-driven and happens despite – not thanks to – the government.

ANNEX 5: 2nd Participatory Workshop, Shanghai (16 May 2017)

The second participatory workshop took place on May 16th 2017 in Shanghai, in cooperation with the **Joint Research Centre (JRC)** of the European Commission. The objective of this workshop was to engage with policy makers in China (Europeans and Chinese) and get their feedback on possible long-term actions to support bilateral cooperation.

The around 40 participants represented Chinese and European policy makers, researchers and businesses. The workshop was held within the Dragon Star Plus Project and it was financed by the European Commission and supported by the EU delegation in China.

The workshop was divided into two parts. In the morning, participants were presented the China 2030 scenarios, while in the afternoon session was organized in cooperation the Policy Lab of the JRC and engaged European and Chinese stakeholders in a discussion over the China 2030 scenarios and the strategies for cooperation.

The author cooperated with Laurent Bontoux from the JRC in order to adapt the Scenario Exploration System (SES) developed by the Policy Lab/JRC, and use it to engage policy makers in a long-term discussion based on the China 2030 scenarios.

The overall purpose of SES is to make participants feel alternative unconventional futures and act, by thinking and conversing systemically outside of their usual frame of reference. The SES uses two contrasting scenarios to challenge the assumptions of the participants and offer them space to respond to alternative and changing framework conditions.

The outcome of the utilization of SES China, the main inputs received from the participant, and the evaluation of the developed scenario exploration system, are presented in the following sections of ANNEX 5.

SES China version - Basic workshop information

In the Shanghai SES workshop there were 31 participants in five (5) tables, and at each table participants interacted, and experienced plausible futures through roleplaying practicing one of the five (5) different roles: Chinese Government, European Commission, Industry, Academia and Young Researcher/Public Voice. There were also game masters on each table guiding the process.

During the first round, participants face unexpected challenges on their journey to achieve their long-term objectives; they discover their space of freedom and the importance of the systemic elements by exploring two contrasting scenarios. The second round functions in the same way, but the scenario specifics, drivers, roles and visions are set in the frame of, and with context from, the selected topic. This increased realism is used to improve preparedness, for strategy development or for "future-

proofing" in general. Each session ends up constructing a unique story that is recorded for further analysis.

After three (3) hours of interacting and “role playing”, the following points were gathered and identified as important strategic recommendations.

Scenario Specific Recommendations

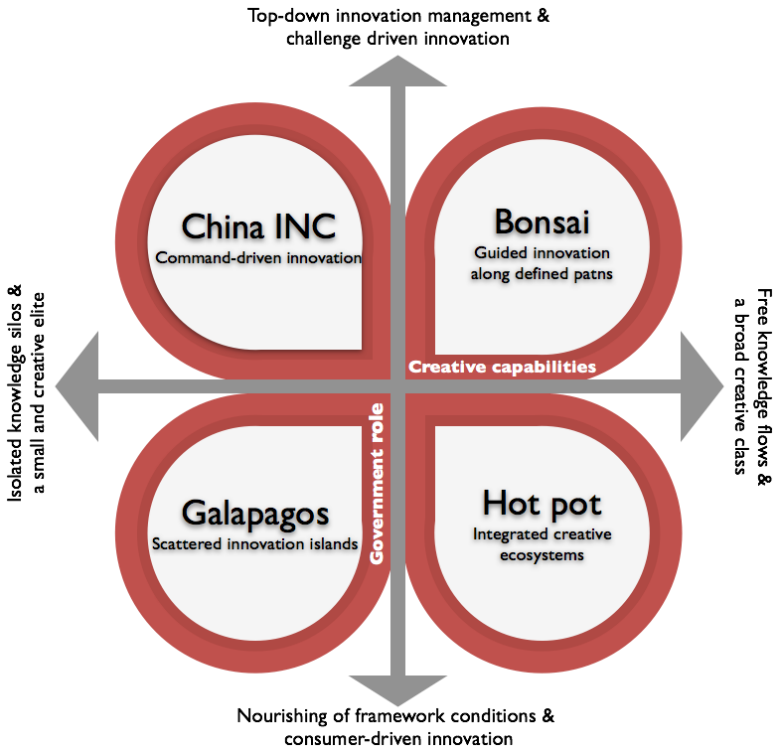


Figure 27: The final set of innovation scenarios.

China INC Scenario

1. The Chinese government should invest more on STI and focus on improving STI personnel

2. Access for international researchers to research activities (and infrastructures) in China must be one of the important goals, supported by a growth of mutual funding.

3. Relocate international talents and knowledge to China, to support excellence in STI strategic areas, must be a priority.

4. Major stakeholders should constantly develop foresight studies to secure the best results.

5. The EU should develop a permanent mechanism to better understand the Chinese local circumstances in terms of what is going on in the market, STI, priorities and

possibilities for collaboration with Chinese, and it should also organize more STI events and better coordinate its resources.

6. Industries (both local and global) must work together with the Chinese government to increase their efficiency. At the same time, they should be more innovative in developing new business models for the Chinese and global markets.

7. More emphasis should be given on promoting and showcasing actions focusing on Chinese STI knowledge & strengths.

8. The EU must constantly communicate with the Chinese government to make sure about a fair legislation system.

9. The EU must constantly communicate with the Chinese government to work together and fully cooperate on tackling global inequality

10. The Chinese government should take more leadership type actions in coordinating STI on international level, invest in resources on long term STI projects (challenges) and support – work closer with United Nations on human future needs.

11. Academia, when working in China, should be able to constantly raise funds, build alliances and change models to adapt to new rules.

12. Chinese Academia must build alliances and connect with international knowledge and business actors in order to be world leaders. Building trust thus is essential.

13.Public voice recommends that the Chinese Government changes its legislation to provide more support to the whole STI ecosystem needs (transparency, IPR protection, banking rules, etc.) and allowing for build alliances and having more SME participating in it.

Galapagos Scenario

1. EU Industry must invest both in STI and general Business facilities to get as much as possible out from the Chinese big market and should cover an extra mile, to accomplish that. Support from both EU and local groups and cooperation with governmental Chinese bodies will ensure long term success.

2. Chinese government should be focusing on bringing together EU and Chinese triple helix entities to overcome the trust gap.

3. Chinese government should invest on local capabilities for global excellence with a long term perspective and on the parallel works towards a more friendly innovation ecosystem through flexible taxation, better communication, cofounding mechanisms simplification and efficient legislative context, to improve international collaboration.

4. Chinese academia should heavily invest to be global leaders in many areas, and One Belt One Road initiative is seen as a platform of extroversion and entrance to more markets.

5. EU must push for more open communication channels, campaigning a lot to make sure its voice is heard and pushing hard for more fair legislation i.e. taxation for start-ups, standardization, and constant cooperation with Chinese stakeholders

6. EU should invest in STI projects, fund basic co-research projects based on excellence.

7. EU should tighten its links and build the missing infrastructure between Chinese and European researchers and create a balanced collaboration network of excellence in basic research. In order to overcome the scattered innovation landscape EU should launch a joint long-term call, built up infrastructures and finally invested in joint consortia engaged in sustainable development.

8. Chinese government should explore international collaboration on STI results and business models to valorize them

9. EU and China should support industrial research collaboration focusing on industrial private partners.

10. Scattered innovation and knowledge islands seemed to be overcome by creating a balanced collaboration framework and nurturing trust relationships.

BONSAI Scenario

1. EU industry must invest in STI and other business activities, but make alliances with local partners

2. Chinese Government must invest heavily in local STI competences, but at the same time will try to make the ecosystem as friendly as possible mainly for local entities through incentives like taxation, and legislation.

3. Chinese Academia must invest a lot in STI infrastructure and personnel, and collaborate with stakeholders to become a global power.

4. The EU will try to persuade the Chinese Government to open up ecosystem by more transparent legislation, standardization, will invest in STI infrastructure to ensure EU interests in the power game and will promote its interests through campaigns and summits.

5. EU and China must build new programs based on alliances in the whole STI value chain.

6. EU and China must focus more in building infrastructures that are covering all research fields, both in China and EU, by co-defining common challenges and goals.

7. EU and China must cooperate more on building together stronger global brands and promote them in the global markets, now that the technology transfer phase has finished.

8. The Chinese Government must promote its global role as an STI leader focusing on strategic alliances and co-investments.

9. China's global role will inevitably force its government in taking more emphasis on STI policies regarding global challenges. That collaboration is an important strategy to tackle them in the long run.

Hot Pot Scenario

1. Academia in China should expand and develop alliances in a number of different areas to experiment and see what works. It should also invest in talent and securing it won't leave. Lastly academia should campaign more to promote activism and highlight international tech links importance.

2. The European Union must invest in STI but mainly coordinate better its actions and focus on huge global challenges like water scarcity.

3. The Public Voice feels strong with all stakeholders expanding alliances, better coordinating actions on sustainability, and investing in creativity.

4. The Public voice also feels strong with EU and China promoting their common values and societal good, by co-investing a lot in STI (infrastructures, HR, etc.)

5. The Chinese Government should focus more on actions that will eliminate entrepreneurship barriers and strengthening networking with European innovation partners

6. Industry (Chinese) should form global partnerships, raise capital, develop products, license and retail globally.

7. The Chinese Government should quickly change/reform its education system to adapt to a very dynamic global consumer environment, focusing a lot on Creativity.

8. The Chinese Government should immediately make economic reforms in all activity parameters (tax, cooperation incentives, etc.), to be able to be a viable leader in the global markets.

9. EU and China should form rules and participate in ethical, social impact funds.

General Recommendations

- In the top-down command scenario, it was very difficult to collaborate even when some environmental crisis variable drivers came up. This indicates that it is in everybody's interest to strive for engagement, cooperation and mutual benefits.

- Actions/strategies to integrate the innovation ecosystems of China and Europe came up in various ways. It is important not only to think about the giants, but also about the start-up scene and the smaller companies. Having infrastructures (such as incubators, co-working spaces, mentorship programs, etc.) to support these small companies from Europe to "test the waters" in China and vice versa are very important.

- Environmental areas are important for collaboration. Some actions/strategies revolved around smart cities and electrical vehicle technologies.

- Policies should support European companies to tap into and benefit from the speed of China's hardware manufacturing ecosystem.

- It is important to gather all the stakeholders and make sure policies translate into benefits for the various stakeholders, so that it is not on a too abstract level.

- The Chinese Government is generally more keen on cooperation on a policy-making level (with EC), than on a private level, with European industries.

- We should highlight the strategic action of academia to invest resources in the cooperation with the EC and the Chinese government. This was done in order to ensure personnel (excellence) will be attracted. Also it seems that it is in the interest of both the Chinese government and the EC, to facilitate programs like students exchanges between EU and Chinese universities (to guarantee a balanced mix of Chinese and EU students in universities both in Europe and China). Investing resources and funding in establishing these relations and guaranteeing a more stable future for students, was surely the most appreciated action by the public voice.

- The Chinese government (role) was consistently (in both scenarios) very keen on cooperation with the EU at a policy level, taking a long view.

- Academia was obsessed with raising funds, both from public sources and from industry and was engaged in some lobbying to that end. Its objective was to become one of the world's best.

- EU was mostly aligned with the Chinese interests in developing long-term cooperation.

- The Chinese Government is always keen to collaborate, and even coordinate global cooperation in STI. Actions towards improving innovation framework conditions (e.g. IPR framework) are always on the table.

- EC seems to have a traditional approach towards funding of STI addressing solutions to global problems, etc. The continuation of Framework Programs, seems logical and possibly creating another global funding scheme for global problems with the participation of China.

- EU Universities seem to heavily invest in cooperation, building global networks including China, and seeking to attract Chinese talents. A Chinese physical establishment seems to be a natural choice.

- United Nations should step in and claim a more dynamic position on decisions on the future of human beings.

- EU and China should use press (journalists) in their favor to push for more cooperation actions.

SES China session evaluation

After the end of the exercise, all participants were given a questionnaire to evaluate the methodology, and 23 questionnaires were collected back. The most important findings from the evaluation questionnaires are presented below.

China SES was considered a deeply learning, surprising and fun experience by the vast majority of the participants (87% and 70% respectively).

Figure 28: Post-session evaluation, overall learning experience.

In addition, SES China was highly valued among participants (by the 77% of the participants) for its capacity to serve as a tool for helping understanding the scenarios, while 78% of the participants declared that SES China helped them to establish a future oriented perspective and to develop a strategic perspective.

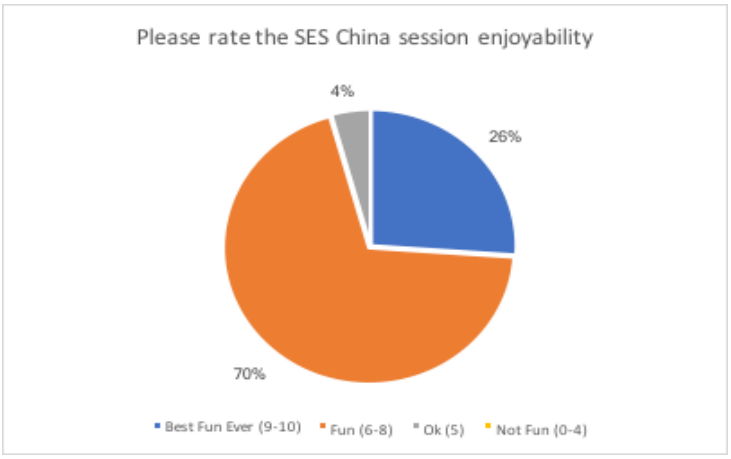


Figure 29: Post-session evaluation, session enjoyability.

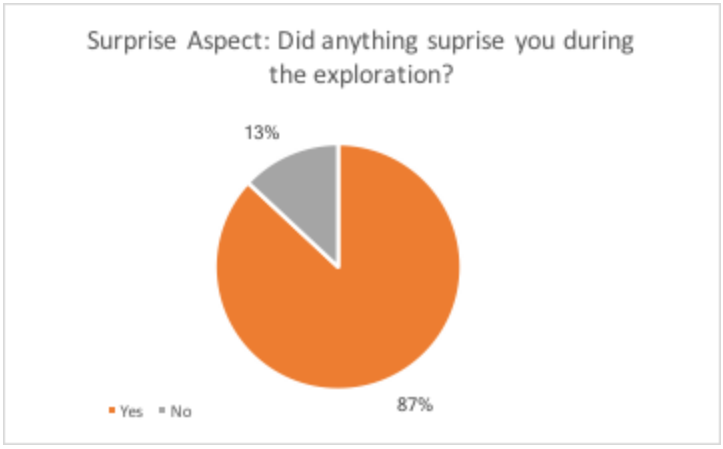


Figure 30: Post-session evaluation, surprise aspect.

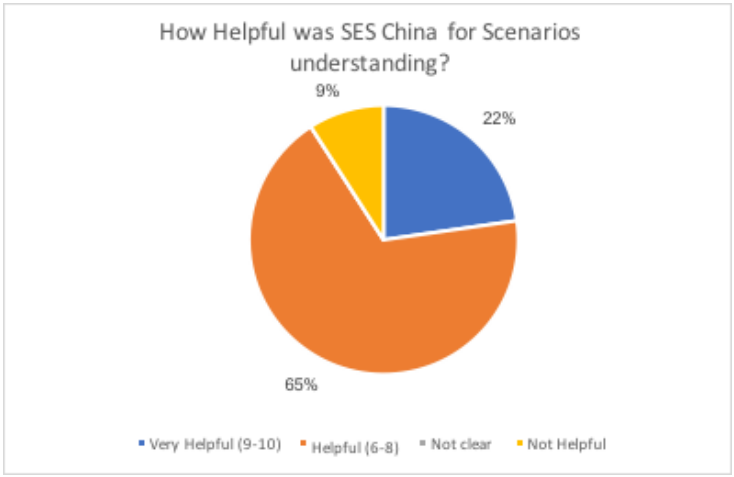


Figure 31: Post-session evaluation, helpful for scenario understanding.

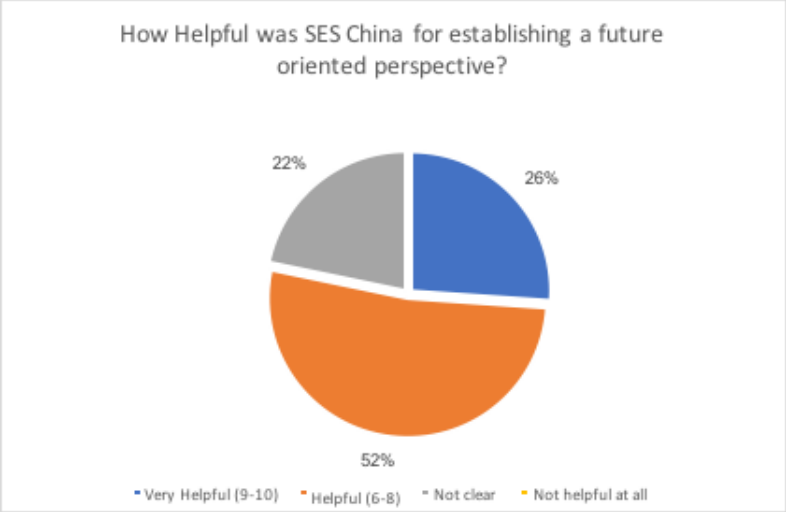


Figure 32: Post-session evaluation, helpful for establishing a future-oriented perspective

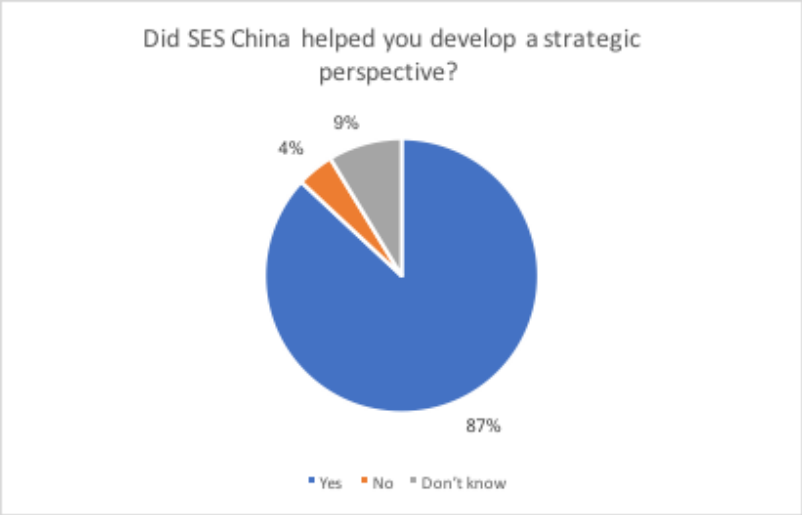


Figure 33: Post-session evaluation, helpful for establishing strategic perspective.

Some interesting inputs were received for specific aspects of SES China.

For the question: ***"What element(s) created the most enjoyment?"*** the following answers were received:

- *I was amazed by the unexpected decisions from other players*
- *It helps us imagine the future and take actions*
- *It helped me see the dynamics of actions*
- *The collaboration part is the most exciting element I enjoyed adopting a role and work well on it*
- *It was great being part in negotiations on future actions Discoursing balance decisions between participants*
- *Listening to colleagues and the different views and choices made*
- *The approaching to think strategically and project my ideas in the future*

- *The whole structure, innovative, dynamic Collaboration. People get in the role.*

For the question: ***"How will you remember this scenario exploration session?"*** the following answers were received:

- *A fun experience*
- *Inspiring hand-on practice*
- *Interesting exchange with people*
- *Interesting to learn about DragonStar Plus & Joint Research Lab An interesting experience*
- *Nice and new experience*
- *It is a very enjoyable session and it made the comprehension of each scenario cases to understand.*
- *Cooperation. How to think based in real life. Open mind to imagine Interesting, fun and inspiring*
- *Helps posing many questions*
- *A very nice learning exercise and pleasant afternoon*

SES China participants list

No.	Name	Organization	Position	Current Location
1	Tomas Larsson	KAIROS Future	Head of China Office	Shanghai, China
2	Nondas Christofilopoulos	PRAXI/FORTH	Head of International Cooperation	Thessaloniki, Greece
3	Laura Rampazzo	BSEAC	Project Manager	Beijing, China
4	Laurent Bontoux	Policy Lab / JRC	Foresight Researcher	Brussels, Belgium
5	Jessie Zhang	EURELATIONS	Project Manager	Zurich, Switzerland
6	Stavros Mantzanakis	EMETRIS SA	CEO	Thessaloniki, Greece
7	Elli Stepanovic	FFG		Vienna, Austria
8	Michelle Shao	Nottingham Univeristy Nigbo, China	Post Doctoral	Nigbo, China
9	Annie Dai	CSTEC		Beijing, China
10	Johannes Riegler	FFG		Vienna, Austria
11	Ralf König	FFG	International Cooperation	Vienna, Austria
12	Odette Paramor	Nottingham Univeristy Nigbo, China	Professor	Nigbo, China
13	Laurent Bochereau	EC Delegation in China	Head of Science and Technology	Beijing, China

14	Mei-NG Sino	European Union Chamber of Commerce in China		Beijing, China
15	GREGORIO MILLÁN CASTILLA	CDTI (SPANISH INNOVATION AGENCY)	R&D REPRESENTATIVE IN CHINA	Shanghai, China
16	鑫易	SouthEast University	Postdoc Researcher for Strategic Landscape Planning and Management	Nanjing, China
17	Rositsa Petrova	EC Delegation to China		Beijing, China
18	Anne Kari Johansen	Royal Norwegian Embassy Beijing - 挪威驻华大使馆	Counsellor (Science and Education)	Beijing, China
19	Jian Hao	Chinese Academy of Sciences - Shanghai Advanced Research Institute- Sustainable Technology Research Center	Associate Professor	Shanghai, China
20	Gaétan Messin	Consulat général de France à Shanghai	Attaché pour la Science et la Technologie	Shanghai, China
21	Taku Iwaki	JST Beijing Representative Office	Deputy Director	Beijing, China
22	Yvonne Tran	Consulate General of France in Shanghai	Deputy to the Attaché for Science and Technology	Shanghai, China
23	Gareth Taylor	British Consulate-General, Shanghai	Consul, Science & Innovation	Shanghai, China
24	Fanly Lee	YoungZone Culture (Shanghai) Co., Ltd.	Director	Shanghai, China
25	Fabien Pfaender	UTSEUS / ComplexCity lab	Associate Professor	Shanghai, China
26	Daoliang Li	CAU	Director of CICTA	Beijing, China
27	Xiangyun Guo	CAU		Beijing, China
28	Nikola Zivlak	Donghua University	Assistant Professor	Shanghai , China
29	Sam Linsen	Consulate Gereral of the Kingdom of the Netherlands in Shanghai	Officer for STI	Shanghai , China
30	Anouk van der Steen	Consulate Gereral of the Kingdom of the Netherlands in Shanghai	Officer for STI	Shanghai , China
31	Bart van Hezewijk	Consulate Gereral of the Kingdom of the Netherlands in Shanghai	Officer for STI	Shanghai , China
32	David van Petersen	Consulate Gereral of the Kingdom of the Netherlands in Shanghai	Officer for STI	Shanghai , China

33	Julia Kern	Consulate Gereral of the Kingdom of the Netherlands in Shanghai	Officer for STI	Shanghai , China
34	Zhijian Hu	CASTED	President	Beijing, China
35	Stella Dai	Arup University	Manager	Shanghai, China
36	Lingbing Zhou	Beijing S&T commission		Beijing, China
37	Chun Liu	Tongji University	Depute Director of Office of Science and Technology	Shanghai, China
38	Jiabo Jiang	International Technology Transfer Network	Project Specialist	Shanghai, China
39	Martin Bech	Innovation Centre Denmark, Shanghai	Innovation Attache	Shanghai, China
40	Quina Mario	Consulate General of Portugal in Shanghai	Consul for the Economic and Commercial Affairs	Shanghai, China
41	Margerita Turvani	University IUAV of Venice Italy	Professor	Venice, Italy
42	Elisa Yu	Tekes – The Finnish Funding Agency for Innovation	Senior Advisor	Shanghai, China
43	Chang Liu	Chinese Academy of Urban Planning		Bejing, China
44	Betty Liu		Intercultural Expert	Shanghai, China

ANNEX 6: Scenario Exploration System China

The change of civilisation that we have embarked on is creating a range of consequences that is difficult to fathom. Such an uncertain context makes it essential to help people get a grasp on what possible changes could affect them, how they could come about and what they could do about them. The need to face these combined challenges calls for novel, empowering approaches to prepare the future, accessible to all. To that end, the European Commission's Joint Research Centre (JRC) embarked on an innovative effort combining scenario building and serious gaming techniques. This combined approach makes it possible for any participant to explore plausible alternative pathways to the future from their own perspective and to test any realistic strategy of their choice to reach their desired long-term objectives in a world that changes as players journey into the future.

The initial engagement platform that was developed by JRC has been adapted to the *China 2030 innovation scenarios,* offering the possibility to explore the innovation future of China. The *China 2030* scenarios is the outcome of a cooperative foresight work that took place simultaneously in EU and China, aiming to produce scenarios for the global innovation environment in 2030, drawing special focus in the cooperation potential between EU and China. The research team has utilised a combination of foresight methodologies such us desk-study analysis, Delphi, media scanning, interviews, exploratory workshops, and patent/paper analysis, in order to identify critical drivers and trends, and draw plausible scenarios for China in 2030.

Purpose and principle of the engagement platform

The purpose of the Scenario Exploration System (SES) is to have participants experience and act through plausible alternative futures, by thinking and conversing systemically outside of their usual frame of reference. The SES uses two contrasting scenarios to challenge the assumptions of the participants and offer them space to respond to alternative and changing framework conditions. Over the course of a session in the *China 2030* edition of the SES, **four *explorers*** representing ***two Governmental Policy Makers*** (one from Europe and one from China***), an Industry*** and ***a Research or Technological Organisation (RTO)*** act over three rounds to reach their visions in a 15 year time horizon. After every round, a ***Young Researcher*** analyses the actions taken by the other participants and values them with respect to their estimated future impact. Achieving by by the other participants and values them with respect to their estimated future impact.

Achieving success takes several forms: wielding the most influence; achieving one's own vision; or winning collectively by how close the game has brought the players to a common goal (e.g. a sustainable future). The session can be run either to enlarge the frames of reference for participants or to explore specific issues. In the first mode, participants face unexpected challenges on their journey to achieve their long-term objectives ; they discover their space of freedom and the importance of the systemic elements by exploring two contrasting scenarios. The second mode functions in the same way, but the scenario specifics, drivers, roles and visions are set in the frame of, and with context from, the selected topic. This increased realism is used to improve preparedness, for strategy development or for "future-proofing" in general. Forms are

used to harvest the contents of each session to support debriefing and discussion. Each session ends up constructing a unique story that is recorded for further analysis.

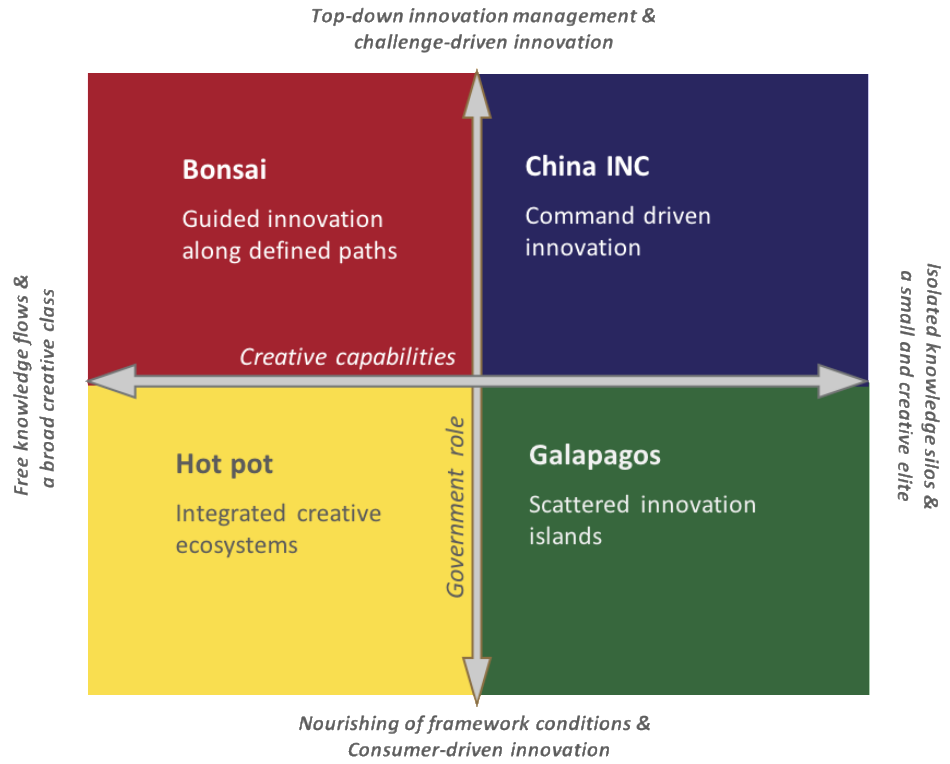


Figure 34: The 4 scenarios that were used for the development of SES China.

Game Roles

SES China is a role-playing game, but the roles are adaptable to fit the needs of a specific session.

The game *SES China has been tested with the following roles:*

- *Policy Maker Chinese Government*
- *Policy Maker European Commission or EU Member State*
- *Industry (EU or Chinese)*
- *Academia (EU)*
- *Young research (EU or Chinese)*

How to Play: Round 1 Example

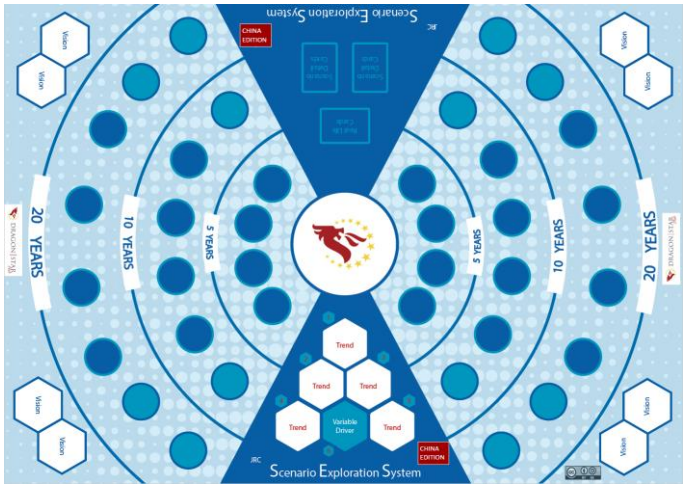


Figure 35: The SES China playing board.

The Exploration Master will set up the board at the start of each session with the following components:

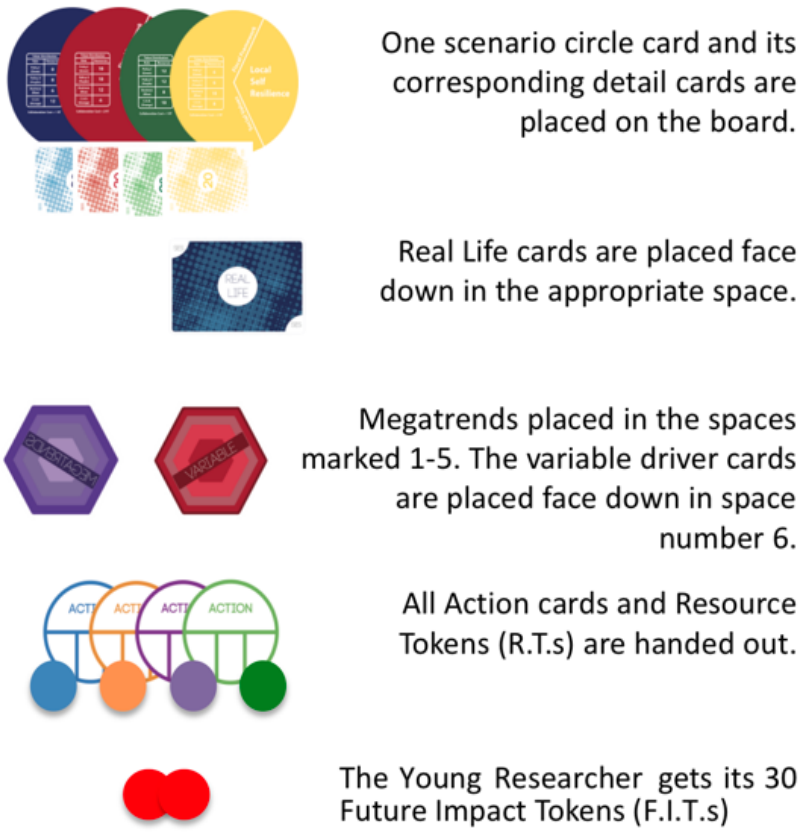


Figure 36: SES China, the game components.

Game Components

The game components are the scenario parameters that are used in the game to simulate the alternative future scenarios for China that have been produced after the scientific research:

The Global Megatrends cards are the following:

1. Environmental degradation
2. Consumer class
3. Hyper-connectivity
4. The new generation
5. Urbanization
6. Globalization

The Variable trends cards are following:

- Automation
- Ageing population
- Converging technology
- Increased pollution
- Water scarcity
- Male to female power shift
- Growing inequality
- Post materialist values
- Creativity ideal
- Tech-enabled wellbeing
- Connectivity
- Digitalization
- Resource efficiency
- Distributed value creation[40]
- Value perception shifts[41]
- Information abundance[42]

In addition, to the above cards that are utilised in every scenario, there are scenario specific cards, and parameters that define for example the resources available to the different role-players for a specific scenario, and present some developments taking place for every scenario. The different game components for every scenario are the following:

[40] Open source, 3D printing, prosumers, user-driven innovation, ecosystem innovation.

[41] People will perceive value in new things. Usership instead of ownership. In a world where most things are 3D printed, more value will be perceived in wood and crafts.

[42] The amount of information grows exponentially. More info is generated every month than was generated through thousands of years of history. This means information overload among consumers/citizens but also new business models around data.

Scenario Cards

1a-2a: China INC – Command-driven innovation

Figure 37: SES China, Scenario card China INC

Resource distribution:

- Chinese government – high : 12
- European Commission – low: 6
- Industry – low: 6
- Academia – medium: 8
- Collaboration cost:1

5 years

- European companies concerned about unfair treatment. In China for China dominant strategy among MNCs
- Chinese acquisitions increasingly blocked in the West
- Strict enforcement of environmental regulations
- High-tech and infrastructure deals with other states
- The state finances global expansion of high-tech champions
- China leading in deep-sea exploration

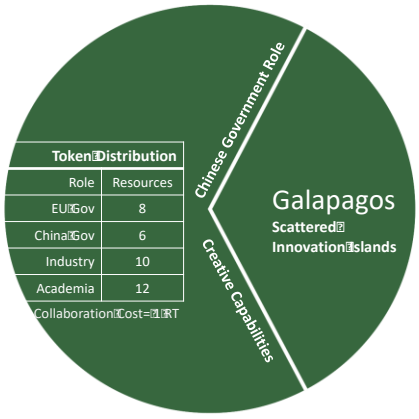
10 years

- Mutual distrust and large barriers between Europe and China
- Spectacular successes but also inefficiencies and failures
- Low-cost manufacturing migrates to other countries
- Key technologies in the service of national interests
- Large, engineering-driven enterprises dominate innovation
- Elite research institutes solve prioritized challenges
- China makes its own jet engine and rocket turbine engine
- Large clean-up projects of soil, water, and air pollution

20 years

- China first country to send manned mission to Mars
- High-tech enables strong geopolitical position
- Separate Western and China-centred innovation spheres
- Large investments to tackle environmental challenges
- Leads global innovation in specific targeted areas
- Lags in picking up new innovation opportunities

1b-2a: Galapagos – Scattered innovation islands



Resource distribution:

- Chinese government – low: 6
- European Commission – medium:8
- Industry – medium-high: 10
- Academia – high: 12
- Collaboration cost: 1

Figure 38: SES China, Scenario card Galapagos.

5 years

- Creative elite directs assembly-line style innovation
- Innovation through brute force, e.g. large labs
- Innovative products with limited diffusion outside China
- Innovation hampered by lack of knowledge flows
- Universities strong innovation force amid industry fragmentation[43]
- European companies partner with individual companies

10 years

- Chinese companies lead in life science innovation
- Alliances rather than ecosystems drive innovation
- Universities major source of new knowledge
- Adaptations of global ideas (e.g. Business models, manufacturing, products) to Chinese markets
- Inability to push large shifts needed for environmental sustainability
- China looking to Europe as partner for revitalizing innovation

20 years

- Chinese researchers lead in brain science and gene editing
- Small number of innovation giants among global leaders
- Hopes of innovation-driven growth remain unrealized
- Mutual trust between Europe and China
- Weak system-level integration, strong individual EU-China links
- Large challenges, e.g. environmental, remain unsolved

[43] Because the industry is fragmented and weak, universities constitute a relatively strong force for innovation.

1a-2b: Bonsai – Guided innovation along defined paths

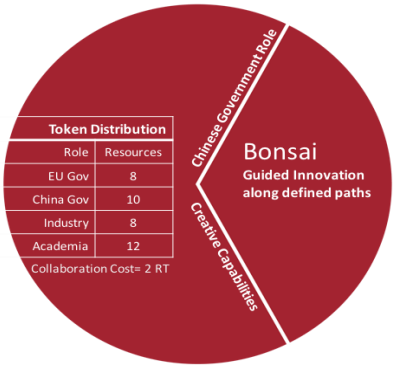


Figure 39: SES China, Scenario card Bonsai

Resource distribution:

- Chinese government – medium-high: 10
- European Commission – medium: 8
- Industry – medium: 8
- Academia – high: 12
- Collaboration cost: 2

5 years

- Innovation stimulated by allocation of resources to key areas
- China excels in incremental innovation
- Autonomous electrical cars dominate in all major cities
- Unexpected innovation in the shadow of state policy
- European companies grumble but swayed by large market[44]
- Increased influence in foreign pop culture production
- Foreign companies reluctant to locate core R&D to China
- Decreased reliance on Chinese manufacturing through automation

10 years

- Small number of Chinese champions leading in most industries
- China leading in AI applications
- China respected but distrusted among European populations
- Domestic content value of core components reaches 70%
- Chinese brands dominate in developing nations
- Supported smart grid and green tech ecosystem drives sustainability
- China strong talent magnet in specific sectors
- Bureaucratic rule limits outside-the-box thinking

20 years

- China overtakes U.S. in number of top universities
- China top global player in areas of national interest
- China known as fast follower in non-strategic areas
- Domestic semiconductor capabilities reduce reliance
- State-led and unsupported innovation two separate systems
- Huge consumer market enable rapid consumer-driven innovation

[44] European companies are unhappy about unequal treatment, but China is still an important focus for them because of the great benefits that the big market brings.

- Chinese brands have difficulties appealing to Western audience

1b-2b: Hot pot – Integrated creative ecosystems

Figure 40: SES China, Scenario card Hot Pot.

Resource distribution:

- Chinese government – low: 6
- European Commission – medium: 8
- Industry – high: 12
- Academia – medium: 8
- Collaboration cost: 1

5 years

- Vibrant startup ecosystem
- Educational reform focuses on creativity
- Economic reform stresses market mechanisms
- Home-grown popular culture wins global appeal
- Rapid cycles give China lead in consumer goods
- Strong ecosystems emerge around new opportunities
- Creative shift as post-00s enter labor force

10 years

- China becomes leading global talent magnet
- Chinese art and design flourish globally
- Unique Chinese style blends tradition and novelty
- China inseparable part of global knowledge ecosystems
- Automation cement China's role in global manufacturing
- Chinese brands dominate in European homes
- A mix of industry and research entities push innovation

20 years

- China becomes the leading Nobel Prize nation
- New ideas and thinking give rise to new industries
- China admired and studied as innovation model
- Chinese luxury brands take on legacy brands globally
- Creative new approaches to AI and 3D printing emerge
- Chinese researchers most cited in quantum computing
- Coordination and infrastructure suffer due to passive state

ANNEX 7: Bibliometric & Patent Analysis

The bibliometric and patent analysis was implemented with the support of KAIROS Future, a Stock

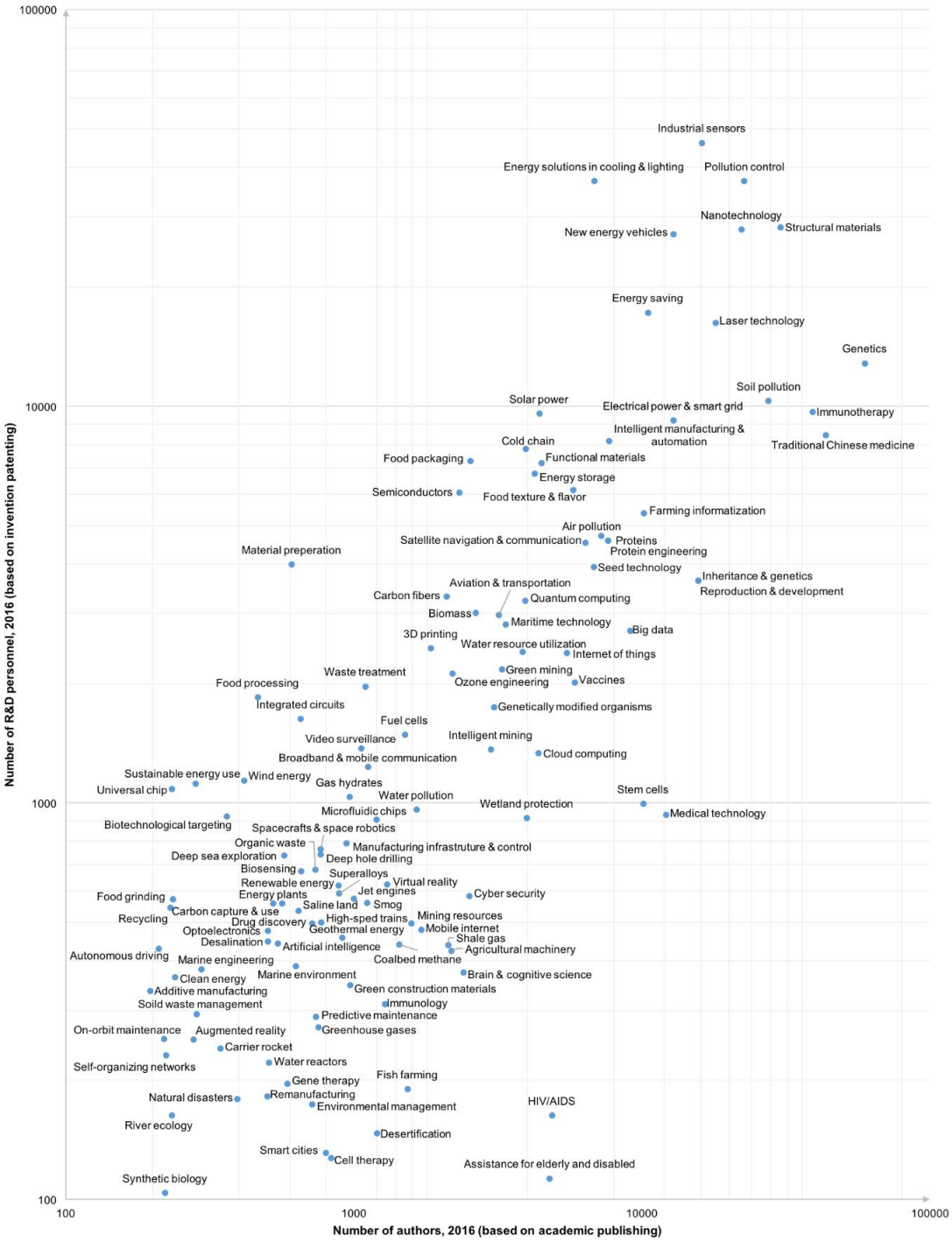


Figure 41: Human resources invested in prioritized R&D areas.

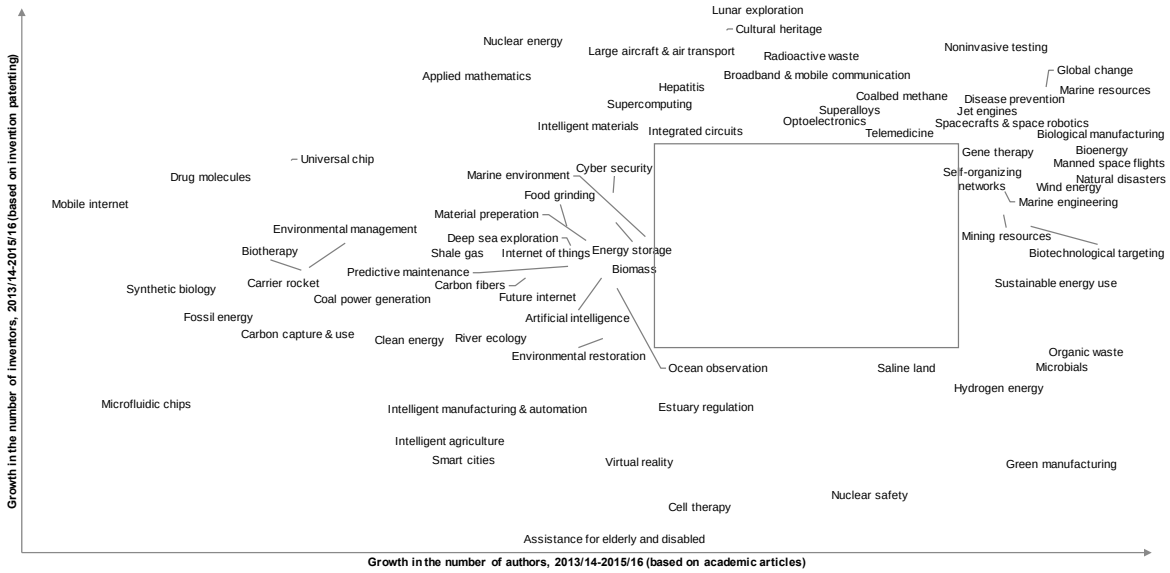


Figure 42: Number of authors of academic articles (academic researchers) and inventors of invention patents (R&D personnel) in areas targeted by government policy.

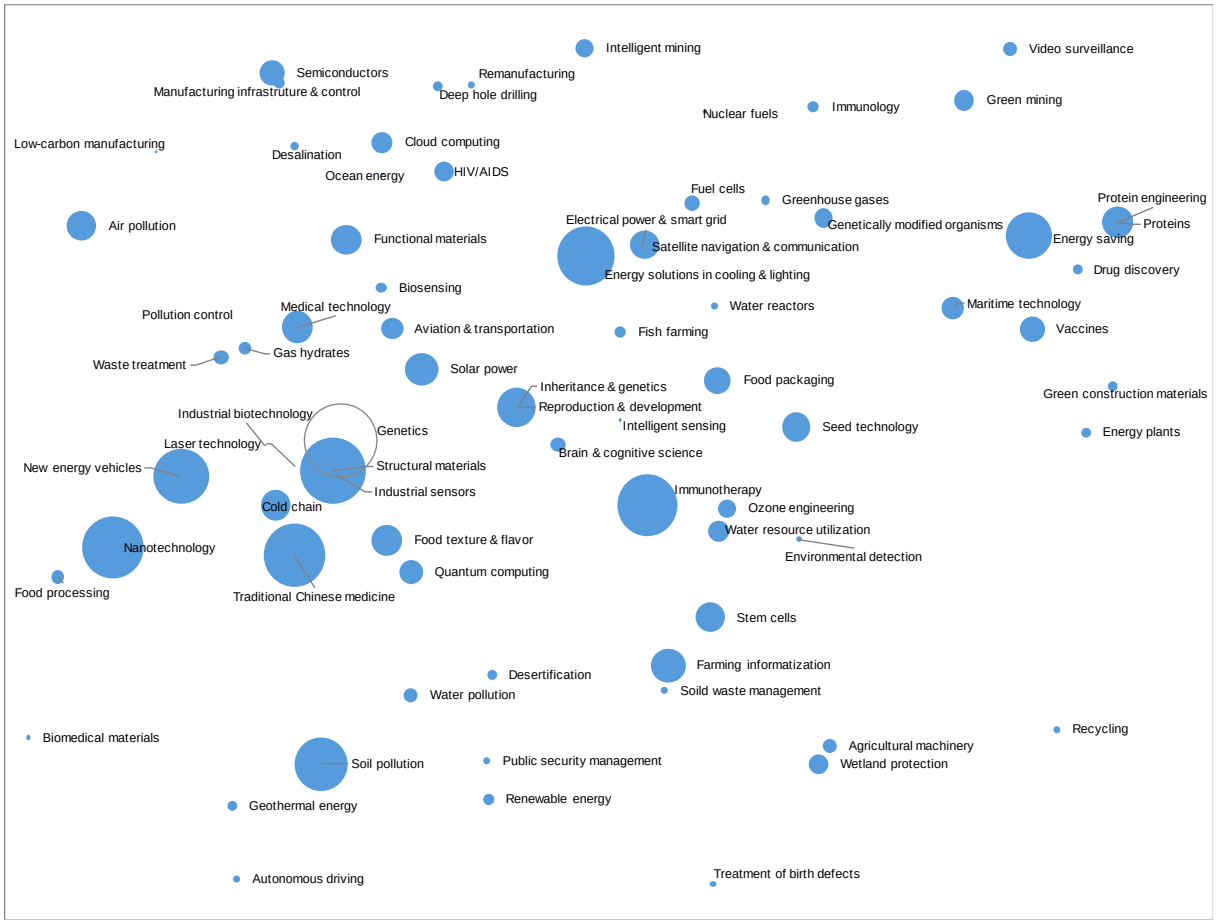


Figure 43: Growth in number of inventors (based on invention patenting) and authors (based on academic publishing) between the periods 2013-2014 and 2014-2015.

The geographical distribution of China's knowledge resources

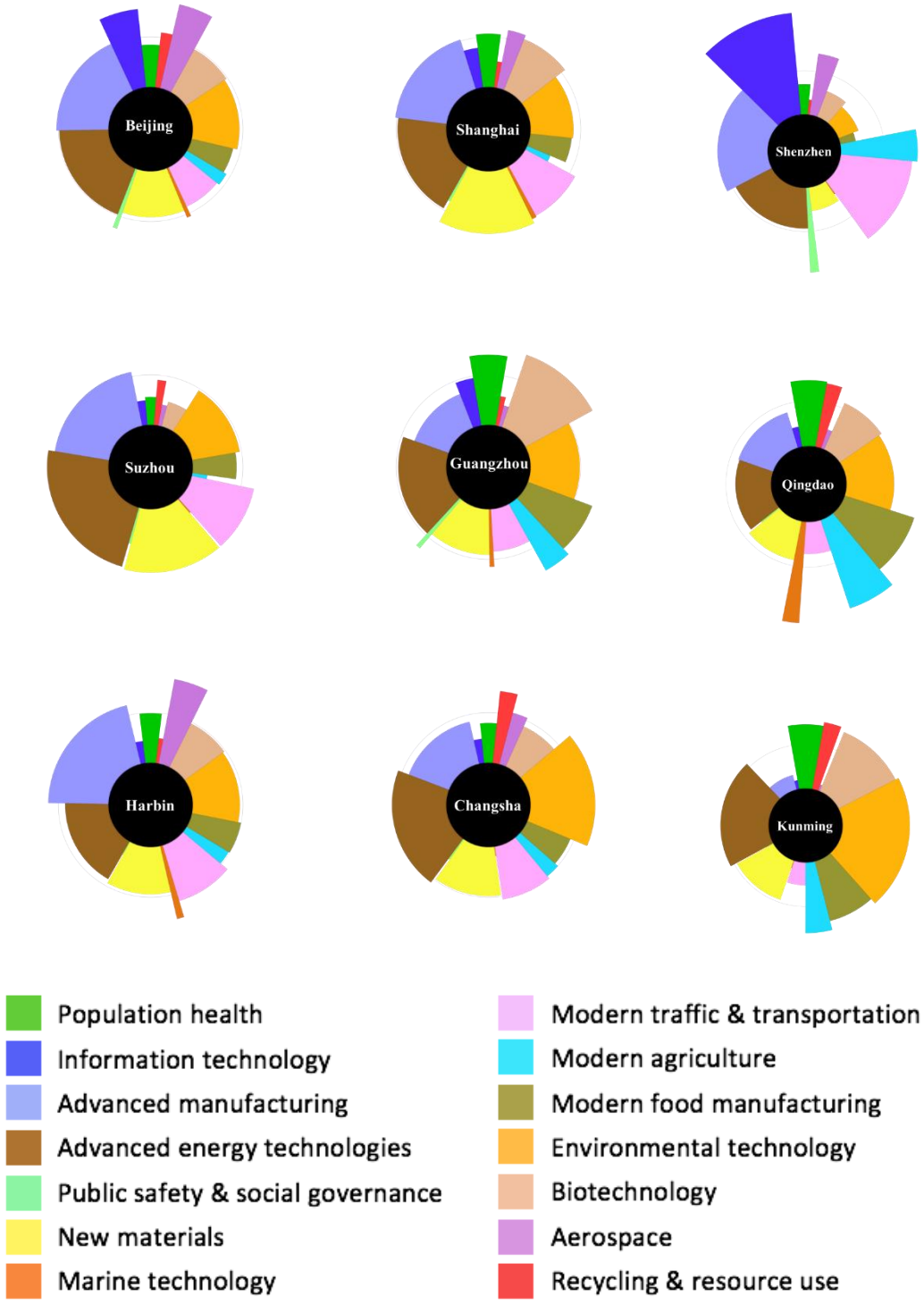


Figure 44: Charts showing the relative strength in different cities with regards to overall areas prioritized in government policy documents, based on invention patenting.

City	Number of inventors, 2015-2016	Especially strong areas of research and development (not the strongest areas in each city, but rather the ones standing out compared to other cities)
Beijing	142,000	Treatment of birth defects, broadband & mobile communication, satellite navigation & communication, spacecrafts & space robotics, electrical power & smart grid, genetics, semiconductors, industrial sensors, laser technology, nanotechnology.
Shanghai	70,500	Semiconductors, immunotherapy, integrated circuits, nanotechnology, genetics, reproduction & development, laser technology, noninvasive testing, industrial sensors, energy solutions in cooling & lighting
Nanjing	46,000	Industrial sensors, satellite navigation & communication, genetics, electrical power & smart grid, nanotechnology, pollution control, energy storage, seed technology, wetland protection, soil pollution
Guangzhou	40,500	Stem cells, genetics, gas hydrates, farming informatisation, electrical power & smart grid, biomass, immunotherapy, vaccines, pollution control, nanotechnology
Shenzhen	39,400	Broadband & mobile communication, seed technology, new energy vehicles, satellite navigation & communication, cyber security, medical technology, mobile internet, augmented reality, video surveillance, laser technology
Wuhan	38,600	Laser technology, genetics, maritime technology, genetically modified organisms, quantum computing, pollution control, nanotechnology, energy solutions in cooling & lighting, industrial sensors, vaccines
Hangzhou	36,000	Video surveillance, genetics, industrial sensors, genetically modified organisms, deep sea exploration, drug discovery, pollution control, nanotechnology, genetics, distributed energy supply
Xi'an	34,800	Aviation & transportation, industrial sensors, solar power, jet engines, energy solutions in cooling & lighting, additive manufacturing, new energy vehicles, laser technology, geothermal energy, green mining
Chengdu	34,100	Shale gas, water reactors, industrial sensors, drug molecules, traditional Chinese medicine, integrated circuits, high-sped trains, Internet of things, new energy vehicles, solar power
Tianjin	31,300	Traditional Chinese medicine, desalination, pollution control, industrial sensors, energy solutions in cooling & lighting, new energy vehicles, cold chain, immunotherapy, organic waste, nanotechnology
Suzhou	30,400	Structural materials, solar power, new energy vehicles, energy solutions in cooling & lighting, industrial sensors, nanotechnology, energy saving, carbon fibres, pollution control, food packaging
Qingdao	26,000	Traditional Chinese medicine, farming informatisation, marine environment, food packaging, structural materials, deep sea exploration, pollution control, immunotherapy, energy plants, nanotechnology

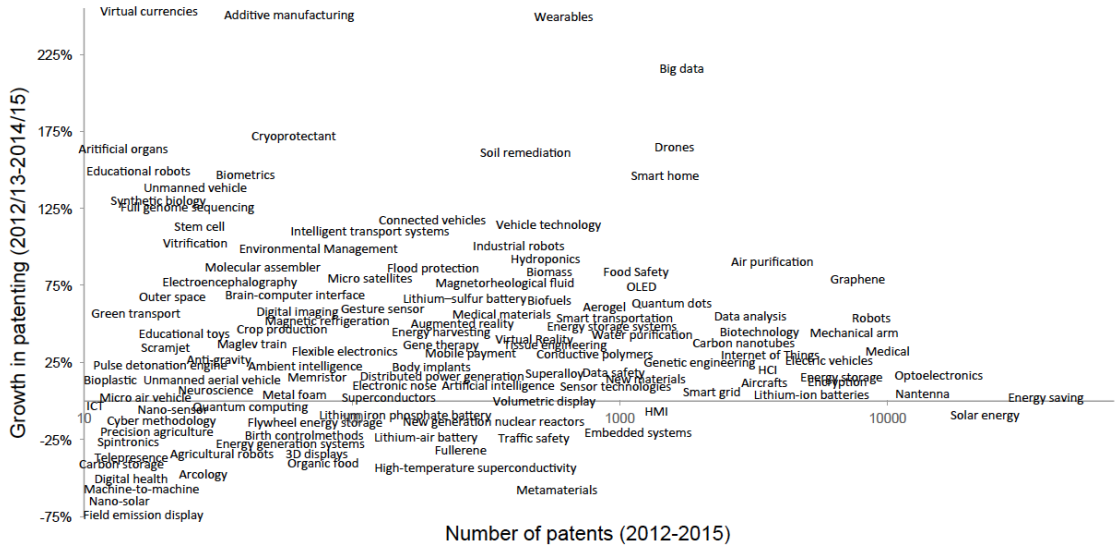


Figure 45: Emerging technologies in Chinese R&D.

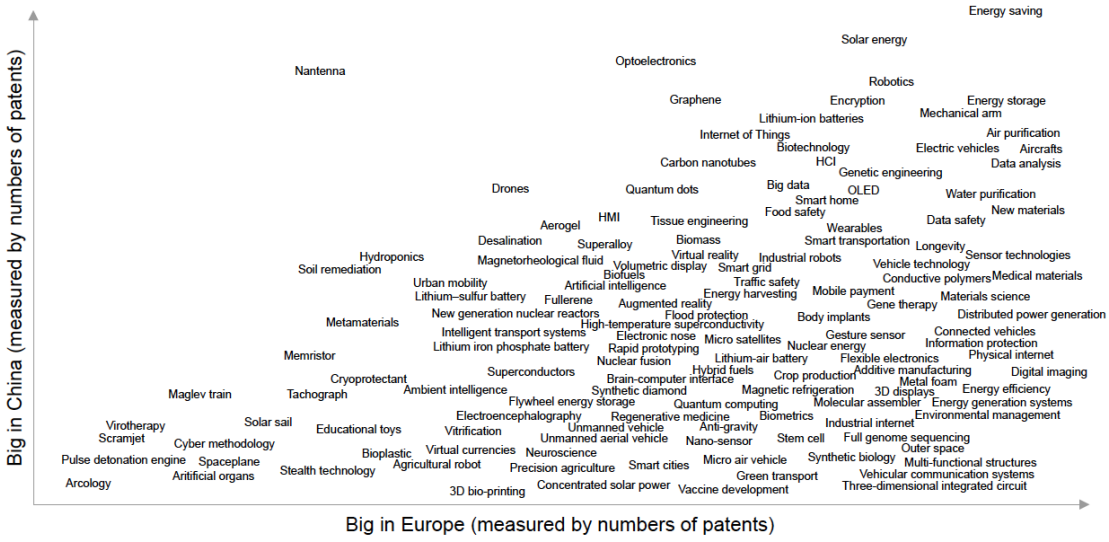


Figure 46: Emerging technology gaps and complementarities.

ANNEX 8: Technological and Innovation Trends and Indicators

Growing high-tech exports from China

The diagram below (*figure 47*) shows China's revenue from high-tech export from 2006 to 2012 (in bn RMB). Telecom equipment has the largest share, followed by computer equipment and pharmaceutical products.

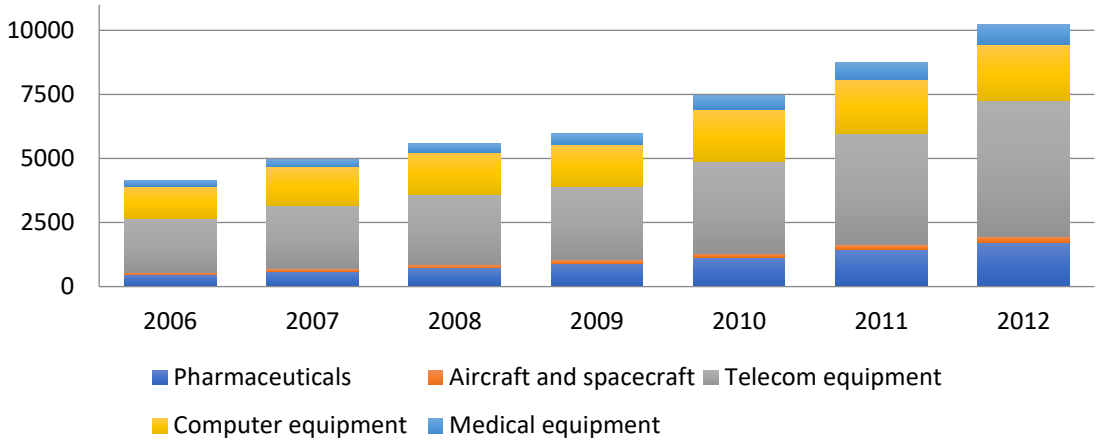
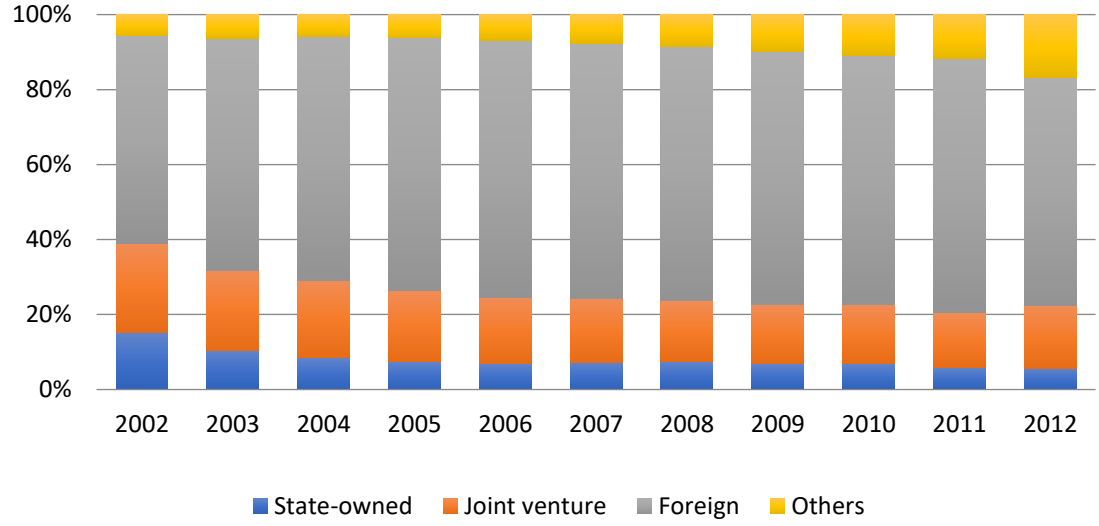


Figure 47: Growth of high tech exports from China. *Source: Ministry of Science and Technology of China*

Foreign companies are less dominant

The diagram below shows the share of high-tech export by ownership. Even though private, domestic (Chinese) companies are increasing their share, that still remains low



as percentage in the total high – tech exports.

Figure 48: Share of high-tech export by ownership. *Source: Ministry of Science and Technology of China*

Chinese companies building their brands

International trademark filings by Chinese companies (chart below) have grown rapidly, reflecting an ambition to build international brands.

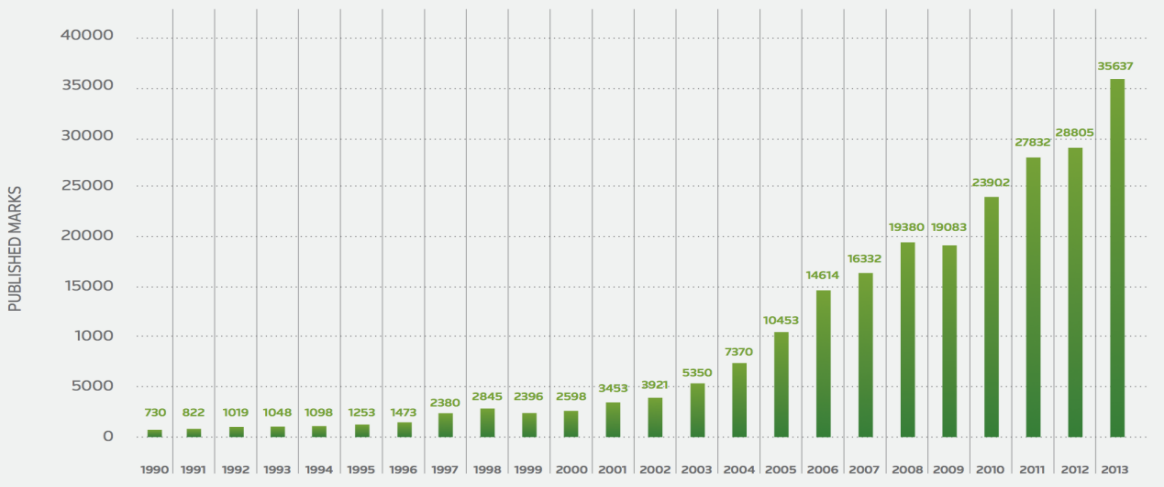


Figure 49: International trademark fillings by Chinese companies. ***Source:*** *Thomson CompuMark SAEGIS on SERION*

Overseas Chinese are returning

While an increasing number of Chinese are opting to study abroad, more and more Chinese are also returning home. The ratio between the two groups is approaching 0.9.

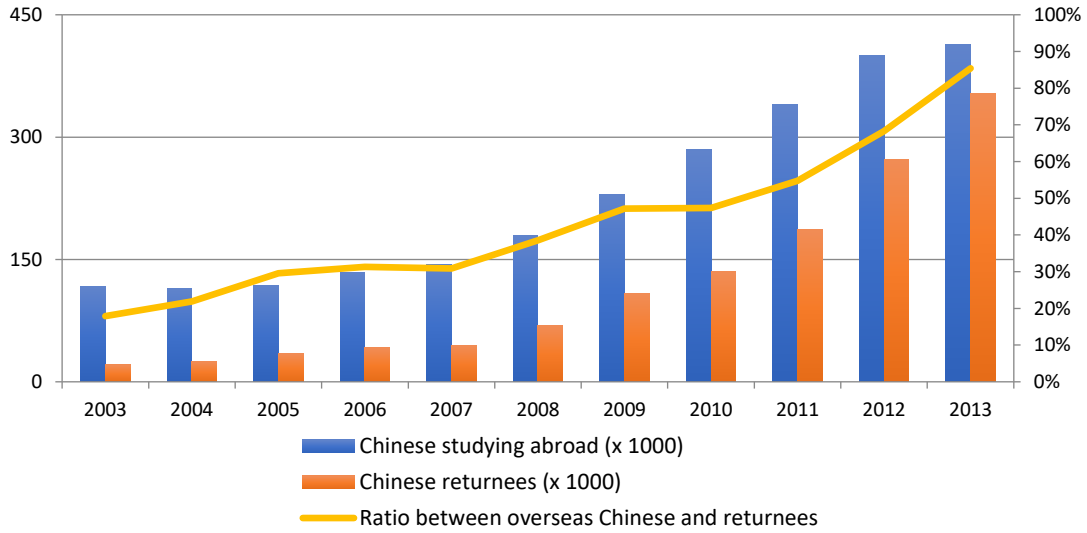


Figure 50: Annual report on the development of Chinese returnees 2013, Analysis: Kairos Future

Entrepreneurial returnees go to Beijing
Beijing is the area that attracts the highest number of returnees, followed by Shanghai. Almost half of the returnees opt to start their own business.

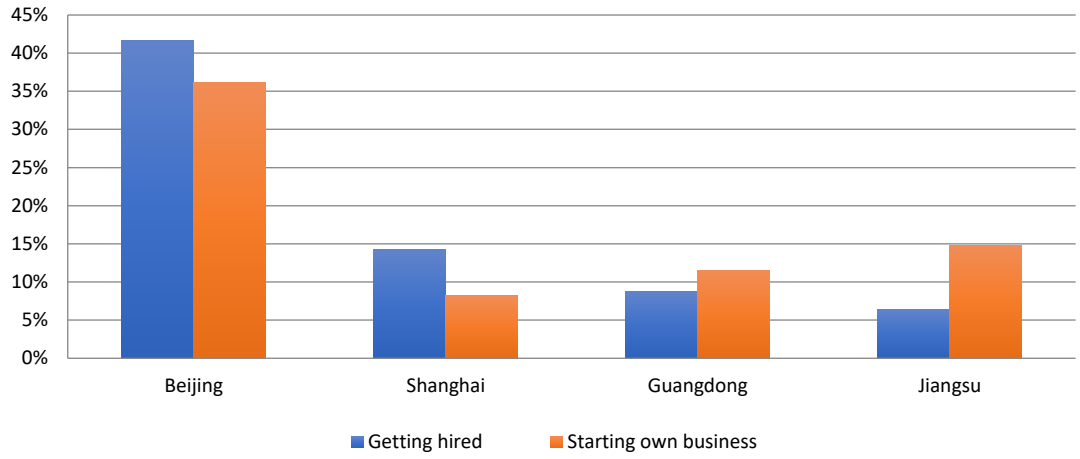


Figure 51: Entrepreneurial returnees to Chinese cities. *Source: Annual report on the development of Chinese returnees 2013, Analysis: Kairos Future*

SMEs innovate in IT, energy and health
Distribution of funding from Innofund, a Chinese government funding program for innovative SME projects, shows activity in IT, energy, health & manufacturing.
Not displayed in the chart: Security 2%, Education 2%, Mobile internet 2%, E-commerce 2%, Space 1%, Food 1%, Creative work 1%, Urbanization1%

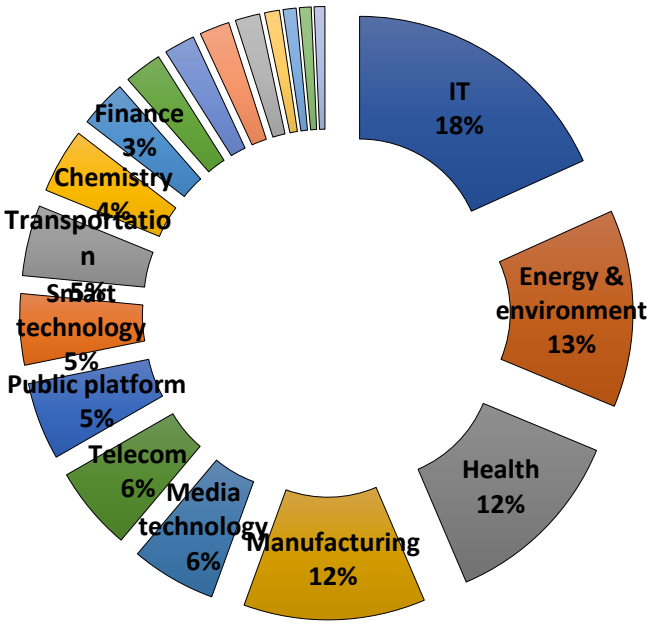
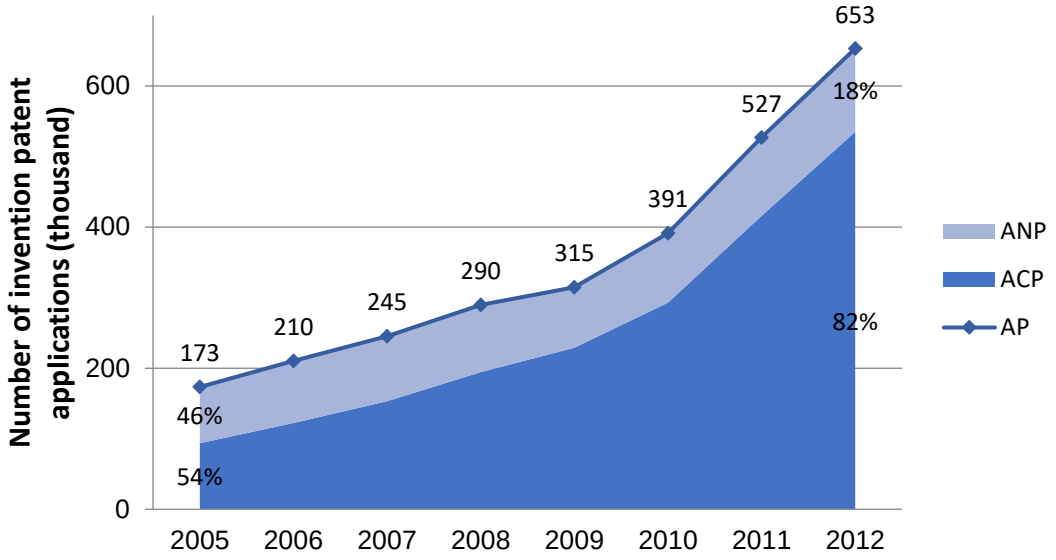


Figure 52: Funding of innovative SMES. *Source: Innofund, Analysis: Kairos Future*

Chinese companies file more patents

Invention patent applications are growing (see chart below); Chinese entities occupy a larger share. Incentives have pushed them to codify more of their intellectual property.

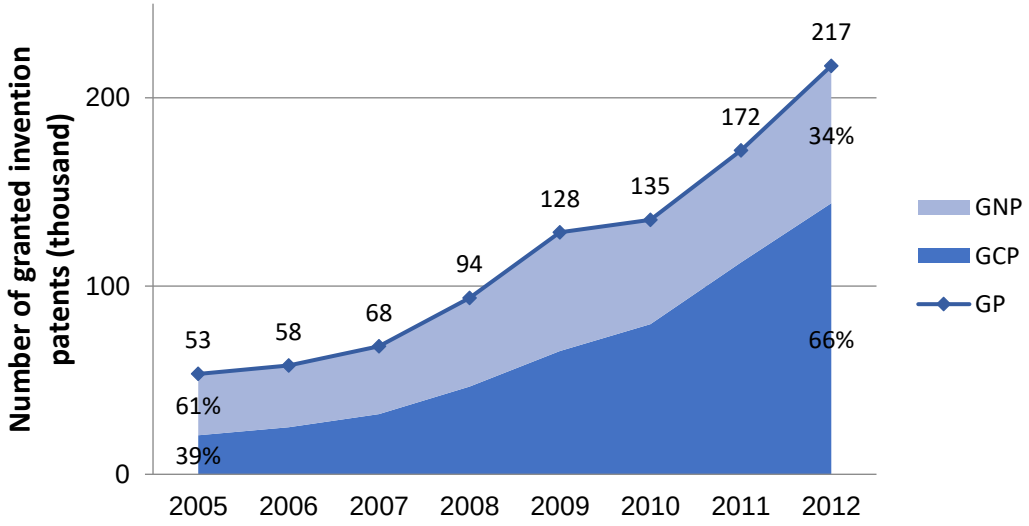


ANP: Non-Chinese priority patent applications; **ACP:** Chinese priority patent applications; **AP:** applications sum.

Figure 53: Patent applications in priority and non-priority areas. *Source: SIPO; Analysis: Kairos Future*

Chinese companies are granted more patents

The number of granted patents is rising quickly (see chart below). This happens despite the fact that Chinese authorities raising the bar to bring requirements in line with international practices.



GNP: Non-Chinesepriority patents granted; **GCP:**Chinesepriority patents granted; **GP:**grantedsum.

Figure 54: Patent growth. *Source: SIPO; Analysis: Kairos Future*

The quality of patents has not declined

Measured as granted patents' share of applications (see charts below), the quality of Chinese invention patent applications has not declined despite a rapid growth in patenting.

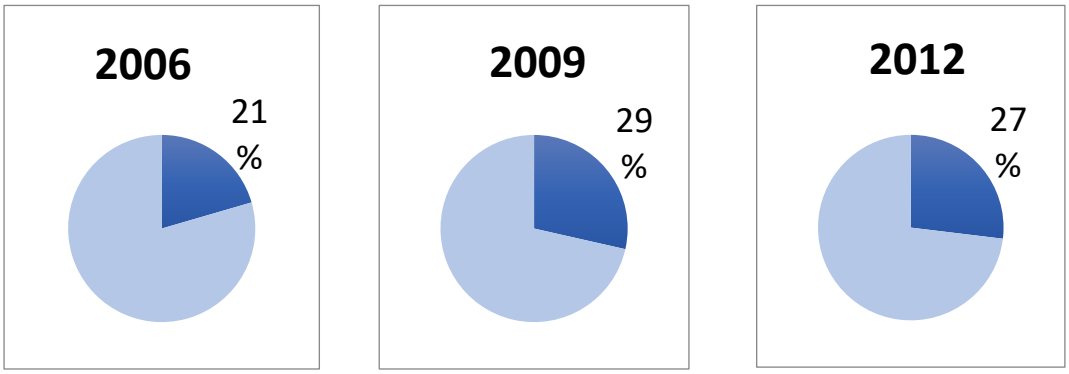
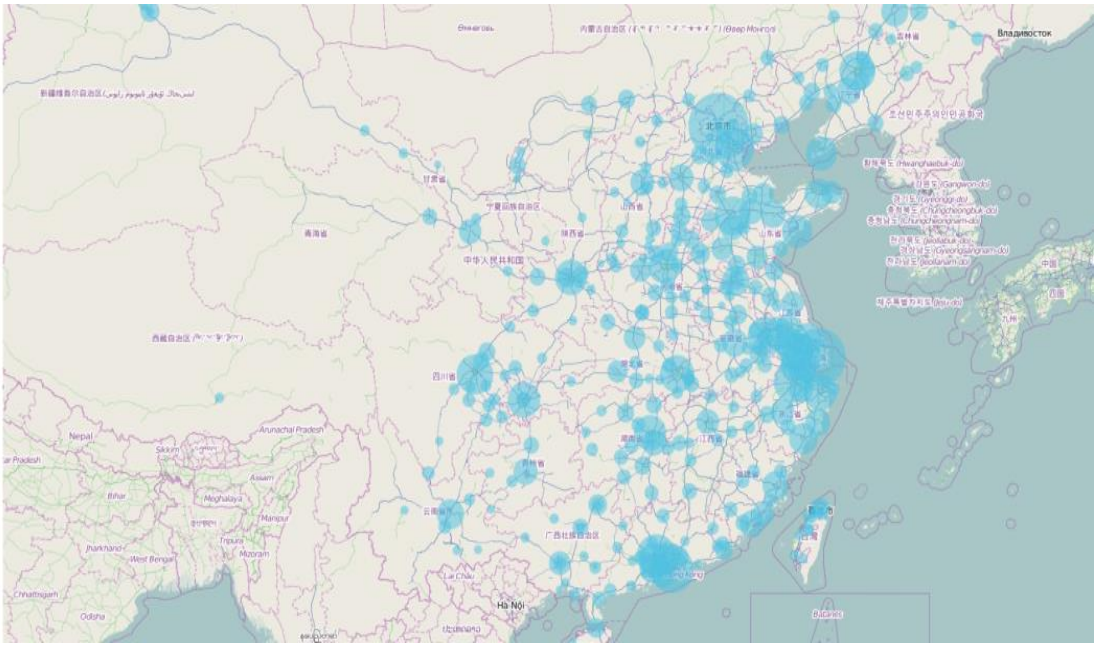


Figure 55: Patent applications against granted patents. *Source: SIPO, Analysis: Kairos Future*

The Chinese geography of R&D activity

The map below is showing that invention patenting is dominated by the Bohai Rim, Yangtze River Delta, and Pearl River Delta, but other costal and interior cities are active

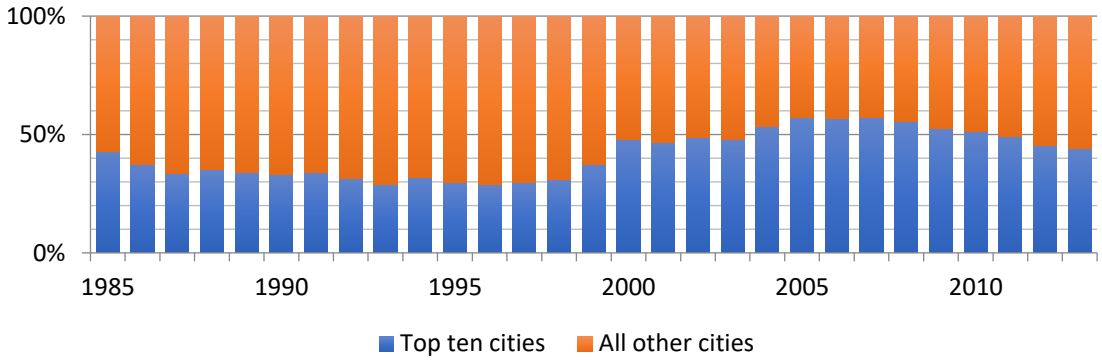


too.

Figure 56: Patent applications geography. *Source: SIPO, Analysis: Kairos Future*

Innovation is spreading geographically

Share of patent applications by top 10 cities vs. all other cities (chart) has declined since

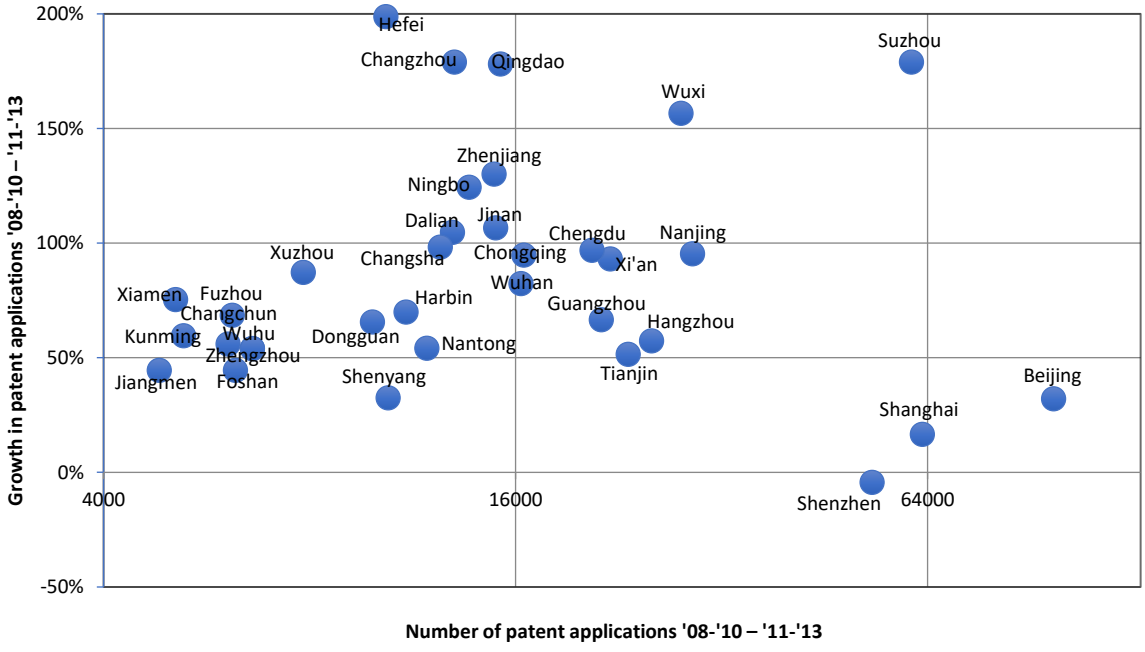


2007; R&D is increasingly happening away from the major centers.

Figure 57: Share of patent applications by top 10 cities. *Source: SIPO, Analysis: Kairos Future*

Cities on the rise

While Beijing, Shanghai, and Shenzhen maintain high R&D activity; other cities

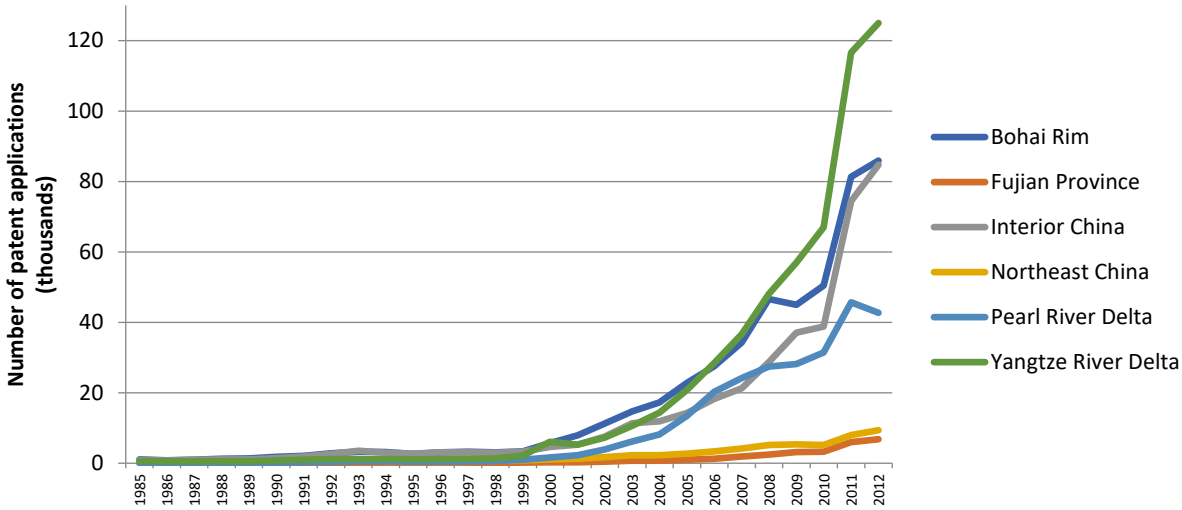


(Suzhou, Wuxi, Qingdao, Changzhou, Hefei) are rapidly stepping up their efforts.

Figure 58: Patent applications in the biggest Chinese cities. *Source: SIPO, Analysis: Kairos Future*

The Yangtze River Delta is rising

Patenting over time by region (diagram below) shows us, that the Yangtze River delta



is taking the lead in patenting activity, followed by the Bohai Rim and Interior China.

Figure 59: Patent applications by region. *Source: SIPO, Analysis: Kairos Future*

The backbone of China's R&D

The largest areas of patenting among Chinese entities (table) are telecom, IT,

Area of technology	Numb. of applications*	Rate of change**
Electrical digital data processing	40,851	87%
Transmission of digital information	26,613	24%
Analysis of materials	25,085	80%
Preparations for medical, dental or toilet purposes	23,231	33%
Semiconductor devices and electric solid state devices	17,200	70%
Wireless communication networks	15,334	-9%
Compositions of macromolecular compounds	12,972	113%
Measuring electric or magnetic variables	12,938	146%
Micro-organisms or enzymes	11,086	62%
Treatment of water, waste-water, sewage, or sludge	10,684	62%
Foods, foodstuffs, or non-alcoholic beverages	10,639	92%
Heterocyclic compounds	10,384	56%
Treatment of natural stone	10,358	83%
Pictorial communication, e.g. TV	10,250	18%
Chemical or physical processes	10,095	52%
Acyclic or carbocyclic compounds	9,903	22%
Systems for electric power supply or distribution	8,986	175%
Separation	8,919	90%
Conversion of chemical into electrical energy, e.g. batteries	7,880	90%
Control or regulating of systems	7,106	106%
Heat or laser cutting, soldering, welding	7,019	105%
Coating compositions	6,841	96%
Alloys	6,775	76%
Shaping or joining of plastics	6,585	126%

pharmaceuticals, materials, chemistry, and semiconductor technology.

***** *Refers to the number of invention patent applications in a given area 2011-2013*

****** *Refers to the growth in the number of invention patent applications between '08-'10 and '11-'13*

Figure 60: Patent applications per thematic area. *Source: SIPO, Analysis: Kairos Future*

Fastest growing areas of patenting

Area of technology	Numb. of applications*	Rate of change**
Workshop equipment	538	368%
Cooling and freezing apparatus	2,335	354%
Transport and storage devices	5,562	264%
Layered products	4,005	250%
Handling thin or filamentary material	2,371	246%
Tools or bench devices	2,047	242%
Dredging and soil-shifting	917	241%
Servicing vehicles	511	241%
Hoisting, lifting, and pushing	1,082	234%
Machines for packaging	2,317	233%
Catching of animals	671	231%
Chairs, sofas, and beds	846	222%
Coffee and tea	2,028	221%
Outerwear, protective garments	1,178	210%
Details/components of machine tools	4,000	208%
Soil working in agriculture	682	204%
Electric power boards/substations/switches	1,724	204%
Working of metal sheets/tubes/rods	5,123	203%
Household or table equipment	1,861	202%
Cleaning in general	2,078	200%
Tables, desks, and office furniture	993	198%
Working of wire	519	197%
Fluid systems	1,945	195%
Printing machines and presses	1,094	193%

The fastest-growing areas of patenting among Chinese entities (table) are mostly low-tech: manufacturing, construction, and agricultural equipment and apparatus.

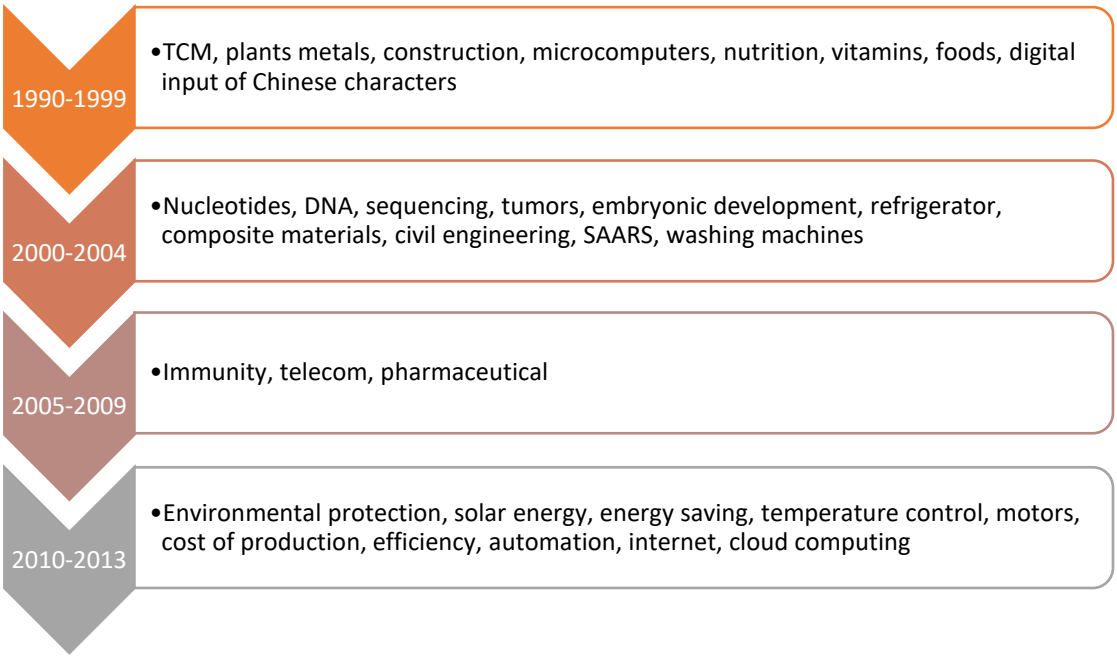
***** *Refers to the number of invention patent applications in a given area 2011-2013*

****** *Refers to the growth in the number of invention patent applications between '08-'10 and '11-'13*

Figure 61: Patent applications growth rate per thematic area. *Source: SIPO, Analysis: Kairos Future*

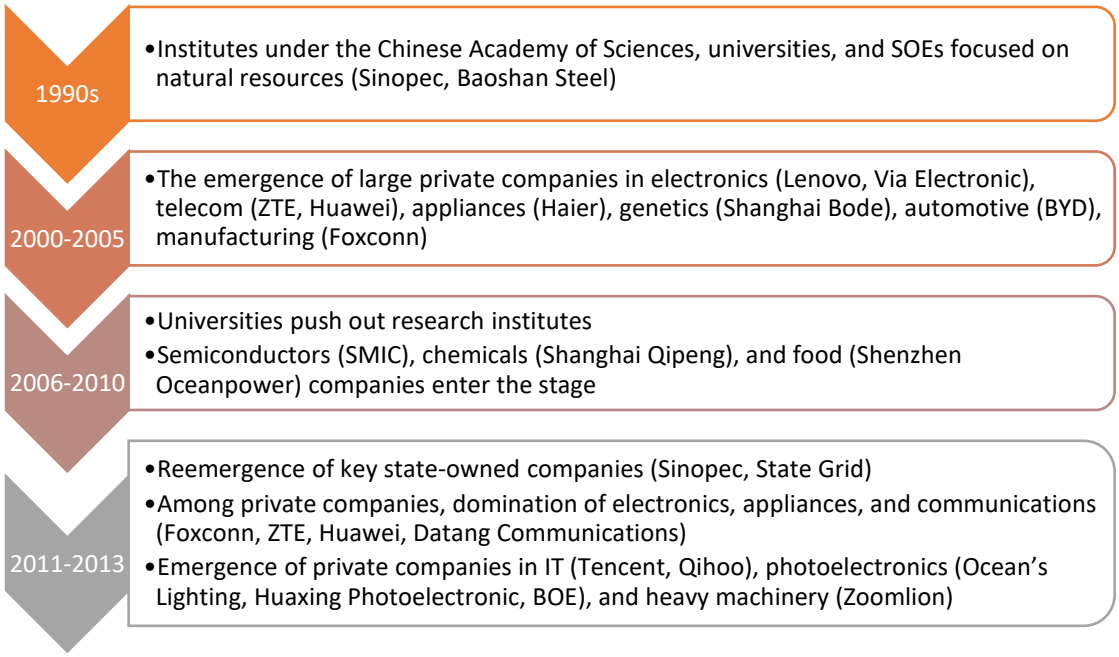
Specific R&D topics over time

Based on words used in Chinese invention patent abstracts, the focus of Chinese R&D has shifted toward environmental protection, automation, and cloud computing.



Evolution of the R&D actors' landscape

Key patenting entities now include private companies in electronics, appliances, communications, and IT, as well as SOEs in key sectors and major universities



Main Conclusions

China's **innovation scene** has seen several changes since the financial crisis and global economic downturn:

- Domestic companies taking an increasing share of high-tech exports
- A growing focus among domestic companies to build their own international brands, accompanies by a steady growth in the number of trademarks registered overseas.

- An uptick in the number of returnees from overseas, last year almost equaling the number of Chinese leaving the country to study abroad. With over one million returnees since 2009 and almost half of them starting their own business, Chinese with overseas experiences and networks is a growing force in China's innovation ecosystem.

Geographical patterns of innovation are changing:

- While the top ten cities still make up almost half of all invention patent applications in China, their share has been declining since 2007, indicating a shift from the largest innovation centers toward the long tail of smaller cities.
- Cities in interior China – notably Chengdu, Xi'an and Wuhan – are rising rapidly, but the highest momentum are in coastal second and third tier cities, especially Suzhou, Wuxi, Qingdao, Changzhou, Nanjing, and Hangzhou.
- Most of these rising stars are in the Yangtze River Delta which, through a combination of government policy and driven entrepreneurs, is emerging as the major region for R&D in China.
- It is followed by the Bohai Economic Rim, where Qingdao, Jinan, and Dalian are emerging centers of innovation, alongside the incumbent hubs Beijing and Tianjin.
- The Pearl River Delta has lost some of its earlier momentum due to a slowing Shenzhen, where patenting has been dominated by a few large actors (ZTE, Huawei, Foxconn, and Ocean's King). However, Guangzhou as well as the manufacturing hubs of Dongguan, Foshan, and Jiangmenare quickly climbing the value chain.

Innovation in China is driven by a new set of actors:

- The center of gravity of R&D in China has undergone a shift from state research institutes toward universities, from state-owned companies toward private companies, and from the largest R&D actors toward the long tail of smaller actors
- R&D in China is now dominated by major universities, state-owned enterprises in key sectors (notably State Grid and SINOPEC), as well as private companies in areas spanning IT (Tencent, Qihoo, Qizhi), electronics/ photoelectronics/microelectronics (Foxconn, Ocean's Lighting, BOE, SMIC), telecom (Huawei. ZTE, Yulong), and heavy machinery (Zoomlion).

The content of the Chinese innovation effort is changing shape:

- While telecom, IT, electronics, and pharmaceuticals remain the backbone of China's R&D effort, the fastest growing areas of patenting are considerably low-tech, relating to the key sectors of manufacturing, construction, and agriculture. This indicates that actors that have traditionally been far down the supply-chain are now moving toward higher value-added. One scenario is that China will see the emergence of its own "Mittelstand" of innovative manufacturers, benefitting from hands-on knowledge of the manufacturing processes that have been outsourced to China throughout the last decades.
- In recent years, Chinese R&D has become increasingly concerned with environmental protection, energy saving, and efficiency.

ANNEX 9: Global Megatrends

Working towards composing our long-term scenarios for the innovation environment in China by 2030 The first step was the identification of relevant megatrends described in future studies worldwide, and then to verify them through the Delphi method.

The concept of megatrend was first introduced by John Naisbit, in the book Megatrends (Naisbitt, 1982), describing a long-term, transformational process with global reach, broad scope, and a fundamental and dramatic impact. In this context, we were looking for the main megatrends changing the Chinese, as well as the global innovation environment.

The desktop research has initial revealed around 20 Megatrends, regularly cited in academic papers, foresight books, executive reports, and the media. All these trends have substantial impact on the European and Global economy, society, and policies; however, it was decided to focus on 5 of them, which are creating the greater opportunities and risks for the businesses and public RTOs.

MEGATREND 1: Richer & Older [Demographics]

- 8.3 billion people on earth by 2030 (from 6.9 billion today); 33.2 years the median age;
- 59% the global urbanization rate;
- China's infertility rate rose to around 12.5% of people of childbearing age, more than four times higher than it was 20 years ago.

The human race is growing older and richer with a growing middle class and widening inequalities across societies. By 2030, the global middle class is expected to reach 5.0

billion, from current's 1.8 billion. In addition, the global middle class (annual income of $14,600 to $29,200 for a family of four) is expected to grow by 66%, to a total of about 3 billion more consumers with increased purchasing power and expectations, while China's cities alone will be home to nearly 1 billion people.

At the same time, life-expectancy is increasing by two years every decade, while fertility rate is declining. As an outcome, the latest growth estimates for the world population contrast with earlier forecasts of a substantial global population increase. Over the next 20 years, the world population will increase by 1.4 billion people to 8.3 billion, up 20% (0.9% or 70 million people p.a.) from 6.9 billion today.

The decline in fertility rates in many emerging countries could be greater than forecast and off-set continuing high-fertility rates in Sub-Saharan Africa and in India. With life-expectancy overall increasing, the world population could peak at around 8.3 billion towards 2030, followed however by a gradual fall to reach the current levels towards the end of the 21st century. As expected, developing countries will grow nearly seven times faster than the developed countries, increasing their share of the global population to 85% (from the current 82%).

Changing demographics will have a profound impact on geopolitical and economic trends worldwide affecting global trade, services, and business models.

Another direct and already seen result is the changing workforce. In many European countries it is estimated that the workforce has reached its peak (or it will reach it in the next few years), and the working population in Europe is expected to decline by 21 million by 2030. Europe-based organizations will face radical shifts in workplace design, agility of employees and leadership styles. Managing diversity and exploiting talent throughout Europe will be key challenges.

As the global population rises, the urban share of the population will also continue to rise at high speed (8.5%) and growth will even accelerate compared to the last 20 years (7.8%). By 2030, 4.9 billion people, or 59% of the world's population, will live in cities, starting from 3.5 billion today (50% of the world's population). This means an increase of 40% in absolute numbers. The developed countries will still have a far larger share of urban population than the developing countries in 2030. However, the gap narrows by 2030, as the urbanization process is more pronounced in the developing countries.

2030 Projections

■ Ageing will be global. The world population growth will slow and peak, possibly within 20 years, at around 8.3 billion people;

■ A new global 'middle class' in the emerging countries will expand rapidly, mainly in cities, and particularly in Asia;

■ Dynamic and technologically empowered, this new group will be especially vulnerable, subject to increasing inequalities and unprecedented ageing;

■ Inequalities within countries will widen worldwide;

■ Migration may well further increase, in particular along South-South routes.

Uncertainties

■ Ageing in the emerging economies may affect their economic growth and domestic stability;

■ Growing inequalities in access to resources (education, health services) may trigger serious social discontent.

MEGATREND 2: GLOBALIZATION 2.0

- The world exports as share of GDP will raise from 26% (2010) to 33% (2030).
- GDP growth will continue at a rate of 1.8% p.a. in Developed countries, 7.9% in BRICs, and 5.9% in the Next Eleven.
- The middle class in the BRIC countries will grow by 150% to 2.0 billion people, and by 116% to 730 million people in the N-11 countries.

Globalization 2.0 is fundamentally different from Globalization 1.0, with the East playing a far more important role than being the workplace of the West. Western companies will still operate in the East, but under different circumstances; goods, people and capital will flow in multiple directions (not just from West to East, but also from East to West).

As economic power gradually shifts eastward (with China playing a central role), trade between emerging markets will flourish, raising new risks and opportunities for the European companies, as the East will rely less on the West for goods and services.

This raise of the emerging economies, will coincide with a raising urban middle class in these countries, that will set its own set of consumer demands, requesting further "glocalization" of products and services. As an outcome, different strategies and operational models will be a necessity for multinational corporations. In 2008, Goldman Sachs estimated that the number of "middle-incomers" ($6,000-30,000 annual income) was growing at a record 70 million per year, and expected to reach a growth rate of 90 million per year by 2030, adding 2 billion people into the middle income category. Even more impressively, McKinsey foresees that consumption in emerging markets will total $30 trillion annually by 2025, becoming "the biggest growth opportunity in the history of capitalism".

It should be however underlined that Globalization 2.0, is not replacing Globalization 1.0 that continue to exist, with Western multinationals continuing to operate distant low-cost bases. Nevertheless, many of these bases, due to increasing labor costs in the emerging economies (e.g. China), are expected to move to other countries (e.g. Bangladesh, Indonesia, Iran, Pakistan, Philippines, Vietnam, Nigeria, Egypt, etc).

2030 Projections

■ The middle class in the BRIC countries will grow 150%, from 0.8 billion people today to 2.0 billion in 2030, raising enormously the purchasing power of these countries.

■ The emerging equity markets will grow significantly by 9.3% p.a. to USD 80 trillion by 2030, while global equity market capitalization (in fixed 2010 USD) will increase by 6.2% p.a. from USD 43 trillion to USD 145 trillion in 2030.

■ By 2030, the combined real GDP of the N-11 will equal 30% of the BRIC's GDP and 11% of the world's GDP.

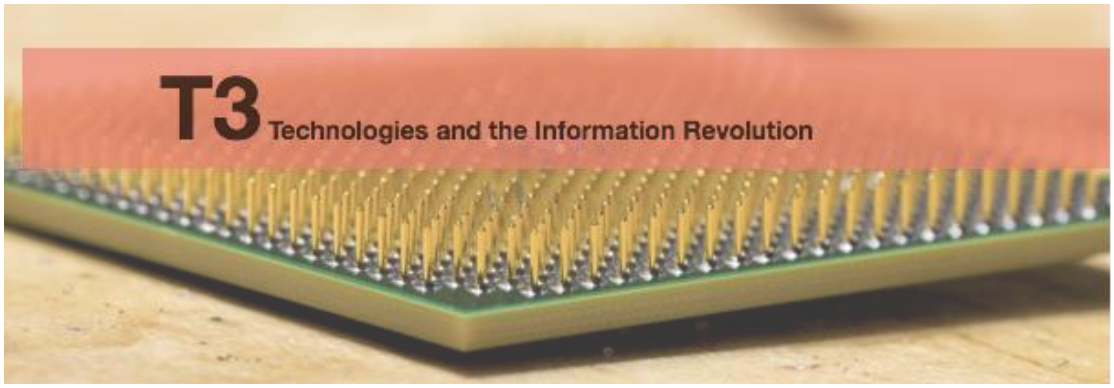
■ The ASEAN-5 GDP will equal 4.0% of global GDP in 2030 (almost as today).

Uncertainties

■ The political and financial role of Europe, and USA

• The political stability of BRIC, and ASEAN-5 countries.

MEGATREND 3: TECHNOLOGIES & THE INFORMATION REVOLUTION



- The number of mobile broadband users is going to reach 4,693 million by 2030 (from 0.788 million today). The average broadband speed will grow by a factor of 100 or more, from less than 1 Mbps to more than 100 Mbps in 2030.
- By 2025, more than 100 billion "things" will be connected to cloud computing systems.
- By 2020, European industrial companies will invest €140 billion annually in industrial internet applications
- 5 million jobs will be lost by 2020 due to rapid advancements in the fields of technology, such as artificial intelligence and machine learning (fourth industrial revolution).

The next decades will be shaped by the process of converging (and even merging) technologies through interdisciplinary developments across scientific fields. Platforms will be the main field to drive industrial development and business intelligence. Nanotechnology, biotechnology, IT, cognitive science, and robotics will drive innovations in several fields like health, nutrition, and logistics and will rapidly change our lives. The speed of the changes will be further accelerated with the support of artificial intelligence and the advent of quantum computing.

The innovation potential of the developed countries and the EU will remain ahead of the emerging economies and the N-11, as they have more financial and personal

resources available. However, by 2030 some other countries such as China and India will become major competitors of the latest technologies and innovations from developed countries.

The importance of technology will dramatically increase within the next twenty years as new technologies are being adopted faster and innovation cycles become shorter. This trend will continue by 2030 as product life cycles become even shorter, forcing companies to be always alerted and invest more heavily on R&D. The speed up of technology diffusion will reduce the technology gap between developed and developing countries (although income is an important asset for technology adoption) and will help reduce poverty and address several key challenges (clean water, food availability, etc).

At the same time digitization is a booming worldwide phenomenon, with western societies at the front but with emerging economies and undeveloped countries approaching with a quick pace. We are always connected and the separation between personal, private, and professional lives is becoming unclear.

The range of innovations of the next 20 years cannot be easily predicted, however important developments are expected in:

- Artificial Intelligence (A.I.) is anticipated to surpass human intelligence around 2030.
- The miniaturization of products, with nanotechnology remaining in the heart of future innovations, and affecting several industries such as ICT, and Health.
- Medical innovations, that will significantly improve quality of life (especially for the elderly), and prolong life expectancy.
- Energy sector; it is expected to have renewables vastly replacing the use of fossil fuels, mainly due to innovations in solar energy, geothermal energy, energy efficiency & storage, and possibly in nuclear fusion.
- Synthetic biology to produce bio-fuels, personalized medicine, healthier food, etc

2030 Projections

■ A technological revolution based on new industrial production, bio-scientific, communication and digital processes will transform societies;

■ The speed of technological change is accelerating;

■ Autonomous decision-making processes will rapidly rise;

■ Europe and the United States will remain world leaders in science and knowledge-creation, though worries persist in Europe about applied research.

Uncertainties

■ The speed of convergence of technologies remains uncertain;

■ Potentially fundamental impacts of technologies on people and societies at large could trigger unpredictable social reactions.

MEGATREND 4: CLIMATE CHANGE

- Global energy consumption is rising.
- Sea level rose 19cm from 1901 to 2010 and could rise an additional 26-98 cm by the end of the century.
- GHG emissions are about 54Gt of CO2 equivalent per year, and estimated to reach 68Gt in 2030.
- Half of the bee colonies in USA and Europe have collapsed during the last 2 decades.
- EU is on track to achieve its 2020 climate/energy objectives and committed to reduce GHG emissions by 40% from 1990 levels by 2030 (from 1990 levels), and to increase by 27% from 1990 the share of renewables.

Global change is real and almost irreversible. Nature's capacity to absorb human activity is diminishing, and global warming is increasingly causing extreme weather events around the world, leading to death, displacement and serious economic damage.

Global energy consumption is raising, GHC and global waste are increasing, and ecosystems (like bee colonies) are collapsing. A fifth of the world's irrigated soils are affected by salt, and this may cut crop yields by 70%.

At the same time, as we have seen earlier, the global middle class will increase from 1.8 billion in 2009 to 4.9 billion in 2030, raising interest on ecosystem services, and in 2014 for the first time in four decades, the world economy grew without a parallel rise in CO2 emissions.

It is estimated that adaption costs to climate change effects are likely to reach $300 billion per year by 2050, even with strong emission cuts, entailing a huge risk for countries and corporations not prepared to address this issue. Climate change will mostly affect the most fragile areas and populations in the world that depend on agriculture and fisheries, and may have serious consequences in terms of migration and economic prospects and performance.

On the other hand according to UNEP's Towards a Green Economy report, investing 2% of global GDP ($1.3 trillion per year) into 10 key sectors could kick-start the transition towards a low-carbon economy. In any case, climate change effects are expected to bring focus upon new technologies like electric cars, saltwater agriculture, carbon capture and reuse, solar power satellites, maglev (magnetic levitation)trains, urban systems ecology, cultivated meat, and to the establishment of global climate change collective intelligence systems to support better decisions and keep track.

2030 Projections

■ In 2030, between 1.9 and 2.6 billion people are likely to suffer from a lack of water.

■ GHC emissions are estimated to reach 68Gt in 2030.

■ Large-scale exploitation of natural resources will remain concentrated in a small number of dominant countries and regions;

■ Food and water supply will be about managing scarcity — a problem that will keep worsening due to climate change;

■ By 2030, 93% of the rise in energy consumption will be in non-OECD countries.

Uncertainties

■ The successful implementation of the Paris (2015) UN Convention on Climate Change.

■ The willingness of USA and China to apply stricter policies to reduce GHG emissions.

■ The price of fossil fuels. In addition, OPEC and Russia may lose market power

because of United States shale gas production.

■ The extent of rise in sea levels and ensuing natural disasters is uncertain, while more than 60 % of the global population lives in coastal areas;

■ Large-scale migrations triggered by floods, droughts and food shortages may affect Europe;

■ Arctic icecaps melting quickly and opening up new opportunities for natural resources and transport but with incalculable consequences for biological balance and dangerous feedbacks that will further accelerate climate change;

MEGATREND 5: SCARCITY OF RESOURCES

- By 2030 global water demand could be 40% more than the current supply, and half the world could be living in areas with severe water stress by 2030.
- Some 30% of global cereal production could be lost in current production regions due to water scarcity, yet new areas in Russia and Canada could open due to climate change.
- Over the last 20 years, inflation-adjusted food prices have doubled and may rise by an additional 150% by 2030.
- BP forecasts a 37% increase in world energy demand from 2013 to 2035, of which 96% will come from emerging economies.
- By 2035, China is expected to consume nearly 70% more energy than U.S.

As global population increases, and climate change effects are worsening, the problem of food and water resources management will be central in governmental policies. At the same time, the continuous exploitation and the growing demand of other natural resources like metals and fossil fuels, will increase geopolitical tensions and further raise the issue of resource management. This is because large-scale exploitation and

extraction of natural resources will still be highly concentrated in a small number of producer countries. Across nineteen (19) resources (including crops, timber, fish and meat, metals, fossil fuels and fertilizers) the three largest producers on average account for 56 % of global production. The eight dominant players are China, the United States, Australia, the European Union, Brazil, Russia, India and Indonesia (ESPAS, 2015).

At the same time, even in a best-case scenario, the effects of the present rising energy consumption will be lasting and even become a major problem in the future. The increase in global energy consumption will be linked mainly to population growth and rising income of the global middle class. The world is in a race to quickly make enough safe energy fast enough to meet the growing needs of an expanding and wealthier population. Solar power, and wind energy are offering an attractive alternative, while at the same time, some 58% of existing reactors are past the 30-year lifetime and should be decommissioned; however, fewer than 100 nuclear plants are scheduled to be closed by 2020. In 2030, liquid fuels are expected to provide 31% of the world's energy, down from 35% today and 38% in 1990. Number two in 2030 will be coal at 27%, slightly higher than in previous years – 26% today and 25% in 1990, followed by natural gas with 23% in 2030, the same figure as today.

2030 Projections

- 62% of the seafood eaten in 2030 will be farm-raised and 70% of that will be consumed in Asia. China is expected to produce 37% of the world's fish by 2030, while consuming 38% of the world's food fish.
- By 2030, Japan solar could reach 100GW of installed PV generation capacity, or 11.2% of electricity demand.
- Renewable energy sources can meet 57% of China's electricity demand in 2030 and 86% by 2050.
- Oil and gas production in the Caspian region will grow substantially by 2030; Kazakhstan and Turkmenistan lead the growth in oil and gas, respectively.
- Use of genomics to create plants that produce hydrogen instead of CO2; High-altitude wind generators will be broadly available.
- Some rear metals will run out.

Uncertainties

- OPEC and Russia may lose market and political power due to USA shale gas

production.

- Positive developments with nuclear fusion could change the energy landscape.
- Price of oil.

I, Epameinondas Christofilopoulos , declare that this thesis

"Economic Foresight & Scenario Thinking as a Planning Tool for Addressing China's Uncertain Environment"

and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
2. Where I have consulted the published work of others, this is always clearly attributed;
3. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
4. I have acknowledged all main sources of help;
5. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
6. Parts of this work have been published or presented as:

    - *Epaminondas Christofilopoulos, Stavros Mantzanakis "China 2025: Research & Innovation Landscape". Journal of Foresight and STI Governance, Vol.10 No3 (September 2016)*
    - *Epaminondas Christofilopoulos, Stavros Mantzanakis "China 2025: Research & Innovation Landscape", Phemonoe Lab publications, Greece, ISBN: 978-1-329-67025-9*
    - *Epaminondas Christofilopoulos, Stavros Mantzanakis, Tomas Larsson & Constantine Styliaras "China 2030 or the way towards a viable cooperation with China", Future of a Complex World, 12-13 June 2017, Turku, Finland.*
    - *Epaminondas Christofilopoulos, Stavros Mantzanakis Tomas Larsson, Elli B. Tzatzanis-Stepanovic, "From Valeta to Delphi, from Europe to China, an insight in foresight!" 23rd EARMA conference, 24-26 April 2017, Valeta, Malta.*
    - *Epaminondas CHRISTOFILOPOULOS, Stavros Mantzanakis "China 2025: Research & Innovation Landscape", 10th China Goes Global Conference, 27-28 July 2016, Macerata, Italy.*
    - *Epaminondas Christofilopoulos, Stavros Mantzanakis "China 2025: Research & Innovation Landscape", 5th International Conference "Foresight and STI Policy", 18-20 November 2015, Moscow, Russia*

Place: Thessaloniki

Date: 30 March 2018

Signature: