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# A STUDY OF CHINESE INNOVATION POLICY MIX FOR CIVILIAN DRONES

Master's thesis

Technology governance 2018

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Tallinn 2018

## Author's Declaration

I declare that I have compiled the paper independently
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The document length is 14,587 words from the introduction to the end of conclusion.

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The paper conforms to requirements in force

Chairman of the Defence Committee:
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## Abstract

Civilian drones are mainly used for capturing images that are out of reach. As the technology advanced, they have contributed in many ways for the society. The market for civilian drones is growing rapidly worldwide, however, the regulatory concerns also increase. Many countries including China, have released policies to control civilian drones, which brings a great challenge for the development of the industry. This thesis analyzes the current policy mix for civilian drones in China from the areas of regulatory, economic and financial, and soft instruments, and discusses the possible impact for the industry in terms of stimulating innovation.



Key Words: Civilian Drones, Innovation, Policy Mix

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# Introduction

Defined by the Civil Aviation Administration of China (CAAC), a civil unmanned aerial vehicle (UAV, also known as the drone), is "*an aircraft without a human pilot onboard but equipped with a flight control system, which is not used for military, police and customs missions*".[1] The usual functions of civilian drones are capturing images that are out of reach so that they contribute to the safety and efficiency in many areas such as filmmaking, agriculture, conservation, search and rescue, and energy infrastructure (information collected from DJI Innovation Science and Technology Co., Ltd, a major drone manufacturer based in China). Based on the new forecast from Gartner, Inc., a consultancy company, production of drones for personal and commercial use is growing rapidly, with the global market revenue expected to increase 34 percent and reach more than 6 billion dollars in 2017.[2]

Drones have potential impacts and implications across a wide range of areas (EPIC, 2005, 2013; Elias, 2012). Despite bringing conveniences for human lives, it's necessary to pay attention to drones' negative impacts which may exist economically and environmentally (Clarke and Moses 2014). Information shared by civilian drone users on several online communities (such as DJI Forum, yuneecpilots.com, Discussion Forum, Quadcopter Forum and etc.) says that before everyone can order their own drone, model aircraft enthusiasts used to design, assemble and debug their own sets which require engineering knowledge as well as safety awareness. However today, civilian drones have become consumer goods that can be easily purchased by anyone who is interested in new technology. In the civilian contexts, drones create benefits as well as new sources of harm to the public safety (Clarke and Moses 2014). Several accidents were published in various countries. In Australia, a

[1] "Regulations on Real-name Registration of Civil Unmanned Aerial Vehicles Formally Issued by CAAC". CAAC (2017), available at: http://www.caac.gov.cn/en/XWZX/201705/t20170524_44222.html.

[2] "Gartner Says Almost 3 Million Personal and Commercial Drones Will Be Shipped in 2017". Gartner (2017), available at: https://www.gartner.com/newsroom/id/3602317.

Westpac Rescue chopper has narrowly avoided collision with a drone which was well above its maximum allowed altitude (Coyne 2014), and one water bombing helicopter under fire-extinguishing task was disturbed by an unapproved "irresponsible" drone flying nearby (Crozier 2013). In China, one drone crashed into a truck on the highway that has caused two passengers injured, and the operator claimed that it was the first time he flew his drone (Wu 2016). It is believed that the full implications of the human interaction with drones are not fully understood or properly managed (Armstrong 2010).

In the case of China, a rough statistics done by DJI says 7 out of every 10 explosions posted online are resulted from erroneous operation by new users who just bought their first drones (Bode 2016). The widespread civilian applications of drones has brought regulatory challenges for the government (Levush 2016). China has recently put effect new laws requiring civilian drones over a certain size to be registered under real names, in an effort to improve the safety of its skies (Reuters 2017). Recent technological advancements in aviation have increased challenges not only for the end users but also for the flight operators and the aviation authorities (Wright 2014). Over the years, China has been at the center of various technological developments in aviation, which led to the development of civilian drones (Liu and Peng 2015). Despite the rapid emergence of the drone technology, UAV regulations have remained heterogeneous and embryonic of the national laws (Wright 2014). Various researchers have identified that technology has developed at a rapid rate that has outpaced the legislation and policymaking.

China has programs supporting basic scientific research in this field such as the Yangtze River Scholars Programme[3] and the CAS Hundred Talents Program[4] as well as an increased funding for the programs

[3] *"The program began in August 1998. The Changjiang Scholar (Yangtze River) award, is the highest academic award issued to an individual in higher education by the Ministry of Education of the People's Republic of China. The initial funding for this program was provided by the Li Ka Shing Foundation, with the goal of helping Chinese university research attain the highest levels internationally."* Quoted from "Changjiang Scholars Program", China University of Mining an Technology, available at: http://eng.cumt.edu.cn/whangjiangwcholarswrogram/list.htm.

[4] *"The Chinese Academy of Sciences (CAS) was founded in November, 1949. Comprising a comprehensive research and development network, a merit-based learned society and a system of higher education, CAS has further defined its development strategy by emphasizing greater reliance on democratic management, openness and talent in the promotion of innovative research. CAS is committed to taking lead in achieving leap-frog development in S&T, in building a national highland for innovative talent, in establishing a national high-quality S&T think tank and in becoming a first-class research institution of international recognition, while focusing its efforts on world frontiers of science, major national needs and national economy. "* Quoted from "Global Recruitment of Pioneer 'Hundred Talents Program' of CAS". Chinese Academy of Sciences (2015), available at: http://english.cas.cn/join_us/jobs/201512/t20151204_157107.shtml.

that support innovation associated with technological advancements such as Spark[5] (Liu and Peng 2015). However, there are limitations in that most of the current policy frameworks have not integrated policy instruments essential in the design and fostering of an innovation culture (Cho 2012). On top of that, most of the program associated with the development of human resources crucial in promoting innovation is characterized by biases. For example, the programs favor science over technological competence and talent over quality, which create structural imbalances in S&T hampering innovation in the field of drone technology (DeGarmo 2004). The biases have argued to influence the decisions concerning the choice of policy instruments. The thesis looks at the current policy mix for the civilian drone industry in China by analyzing the policy instruments and the impact. Based on the existing knowledge, the thesis aims to find answers to the following research questions:

a) How have government interventions on civilian drones developed in China over the past decade (from 2009 to 2018)?

b) How to assess the impact of the prevalent intervention mechanism on the functioning of innovation system (or sector) in China?

The main research method is document analysis based on the combination of quantitative and qualitative research data. The quantitative data covers the market growth of civilian drones and the performance of Chinese firms. The qualitative research data includes policy instruments towards civilian drones in the past decade and the analysis of their impact on the industry.

To present the analysis, the paper is divided into five chapters. The current chapter offers reasoning for the selected topic and an overview of the thesis. The second chapter presents the theoretical discussion based on research articles and literature materials. The core chapter of the paper is the empirical discussion of the Chinese case of policy instruments towards civilian drones. The fourth chapter contains a discussion of the previous and potential impact the state intervention has brought to the industry. Finally, the main points are re-emphasized in the last chapter.

[5] "*The project seeks to upgrade standards of technology and management in China's rapidly growing rural non-state enterprise sector until recently, largely ignored by support services and still suffering from inadequate access to technology, qualified staff and business-oriented information. The project supports demonstration enterprise modernization subprojects in rural industries, upgrades the "Spark training program" for rural enterprise staff and helps an existing technology information system reorient its focus to small enterprises."* Quoted from "Rural Industrial Technology (Spark) Project". The World Bank, available at: http://projects.worldbank.org/P003529/rural-industrial-technology-spark-project?lang=en.

# 1 Theoretical Framework

This thesis studies how government intervention has influenced the development of a particular innovative technological product. In order to gain insights regarding innovation in civilian drones in China, there is a need to scrutinize the literature in this field. In this chapter, several related concepts are explained to build a framework for the further research. This thesis is depicted from the (technological) innovation system approach as the analytical tool for evaluating the basis for the state intervention. The next step is to analyze how and why government interventions are crucial to innovations, following which different policy instruments are explained. It's also necessary to understand why the civilian drone is the chosen technological product and what challenges it brings to the policy system. At last, the criteria for analyzing the impact of current policy system is proposed.

## 1.1. Rationales for state intervention from a systems approach to innovation

Innovation system approach is mostly used as a conceptual tool to understand and evaluate the processes underlying innovation, industrial transformation and economic growth and development, including the components that influence the technological change (Lundvall 2007 in general terms). The most important components of an innovation system are constituted by actors, networks and institutions (Carlsson and Stankiewicz 1991). Researchers have proposed several different innovation system concepts, among which the concept of *technological innovation systems* (TIS) (Bergek et al. 2007a) can be applicable as the most appropriate analytical tool in this thesis. Bergek et al. (2008a)

developed a scheme of analyzing TIS with certain steps. At the fundamental stage of the scheme, the components of a TIS are identified and some examples of each component are listed in Table 1.1. The main actors cover firms, government bodies, organisations (R&D or regulatory), etc. and by entering the innovation system each actor brings its specialised knowledge (ibid). The networks include learning networks and political networks which link different actors, share a set of expectations and even influence politically (ibid). The third component, institutions, is at the heart of the process whereby new technologies gain ground (Vasseur et al. 2013). Together, these institutions form so-to-say the rules-of-the-game.

Table 1.1. The structural components of a TIS

| Component of TIS | Examples |
|---|---|
| **Actors** | • Firms along the whole value chain of a technological product<br>• Universities and research institutes<br>• Public bodies<br>• Industry associations and organizations |
| **Networks** | • Standardization networks<br>• Technology platform consortia<br>• Public–private partnership<br>• University–industry links |
| **Institutions** | • Norms<br>• Laws<br>• Regulations<br>• Routines |

Source: Carlsson and Stankiewicz 1991; Bergek et al. 2008a

In this thesis, the component of institutions of the TIS for civilian drones in China will be the focus. Policy actions from the government, as a major institution in the TIS, can promote fundamental changes in product and process technology, and subsequently, drive innovation for the industry (Ashford et al. 1985). Existing research dives into the different state intervention and policy instruments supporting innovation, and it identifies that favorable policy intervention mechanisms support innovation whereas the unfavorable policies hinder changes which hamper technological advancement associated with economic growth (Borrás and Edquist 2013).

Public policy instruments are defined as "*a set of techniques to ensure support and effect (or prevent) social change*" (Vedung 1998). Different countries have various policy interventions and tools that shape the innovation environment, therefore one needs to acknowledge the context-specificity attached

to different policy mix[6] (Flanagan et al. 2011) and policy instruments (Borrás and Edquist 2013). In most cases, these instruments are chosen, designed, and implemented based on specific factors such as a particular policy context (innovation system), specific problem, specific time, and specific political-ideological situations (ibid). The innovation system perspective looks at how to develop the capacities and behaviour of different actors while relying on different incentive mechanisms, therefore, it's important that policy aims at remedying poor functionality in innovation system by strengthening inducement mechanisms and weakening blocking mechanisms (Bergek et al. 2008).

Various researchers have argued that government interventions are closely linked to technological change. Historical linkages between the evolution of governance and evolution of technologies – the theory of 'coevolution' – have proved that the interaction of economic and social factors within the surrounding environment is usually associated with technology changes (von Tunzelmann 2003). The evolution of governance affects the evolution of technology (or conversely) from the aspects of institutional development, power relations, incentives (or disincentives), and knowledge bases (ibid; Vedung 1998). Edquist (2011) also indicated that Government interventions influence every important determinant of the innovation process, covering the aspects of knowledge input, market formation, provision of constituents, and supportive elements. More specifically, government interventions which focus on the deficient and missing aspects in the policy system can enhance firms' capabilities (adaptability and efficient exploitation of opportunities) to operate in the challenging globalized context where firms experiencing dynamic business environment (ibid).

When there is an innovation, a new paradigm arrives and diffuses which may redefine industry structures together with new infrastructure and networks, and this is how technological innovations usually bring challenges to the policymakers (Perez 2012). With the complexity of innovation process and policy mix, government interventions might have negative impact on the development and diffusion of innovation, for example, the Public-Private Partnerships (PPPs)[7] (Leiringer 2006). There are possibilities that pressures from increasing control of governments trigger military activities (technologies), which probably contribute to the public security but have dubious effect on the industry

[6] Based on Flanagan et al. (2011), policy mix is "*imported from economic policy debates and implies a focus on interactions and interdependencies between different policies as they affect the extent to which policy goals are realised*".

[7] Leiringer (2006) has pointed out that although PPP ("*a long-term contractual relationship between governments and enterprises*") controls exposure to risks, it hinders the innovation process with its stringent nature of contract within which can be barriers for the private sector to make changes.

(von Tunzelmann 2003). And the feature of TIS focusing on a state-centered perspective, rather a broader perspective of social development can have limitations, for example, the underinvestment in research or the problem of external costs, the range of legitimate justification resulted in institutional failures (Weber and Rohracher 2012).

## 1.2. Taxonomy of policy instruments in innovation policy

Policy instruments can be divided into three broad categories. The categories comprise of the regulatory instruments, economic and financial instruments, and the soft instruments (Bemelmans-Videc et al. 2003), which are also characterized as "*sticks*, *carrots and sermons*" (Vedung 1998). This model of classification is known as a three-fold typology which provides for the definition of useful criteria when choosing and designing instruments in the phase of formulating innovation policy. This three-fold typology has been the most accepted and widely used classification in many practical contexts (Bruijn and Hufen 1998; Salamon 2002) despite there is an alternative categorization of policy instruments (Linder and Peters 1998; Hood and Margetts 2007). The value advantage of the three-fold typology allows easy navigation in innovation policy and makes sense of the existing complexities (Borrás and Edquist 2013). The three-fold typology can be explained as follows.

a) **Regulatory instruments** are the classical instruments of politics and consists of all regulatory political interventions which influence social and economic actions (Krott 2005). Commonly, there are many different types of regulatory instruments (often referred to as direct regulations) which are obligatory in nature (Borrás and Edquist 2013) and comprising primary and secondary legislation, licenses and concessions aimed at controlling the action of firms. For example, intellectual property rights, the regulations of research institutes such as universities and public research organizations, competition policy about R&D alliances, competition policy regulations in terms of R&D and innovative activities by firms in the market, bioethical regulations and specific industrial standards are all effective tools for the regulation of social and market interactions (ibid; Vedung 1998). The normative authority of governments is considered as the most important feature of these instruments (Vedung 1998). As a very traditional function of governments, the regulatory instruments are the

fundamental policy instruments of the modern state and continue to be the robust and frequently used instrument. By employing legal tools to regulate social and market interactions, regulatory instruments have either a direct or indirect relationship with innovation (Borrás and Edquist 2013). For example, in the direct relationship, the regulations are explicitly designed to affect innovative behaviour. And the influence can be positive or/and negative, as they bring both opportunities and restrictions to the innovation process (Heller and Eisenberg 1998).

b) **Economic and financial instruments** often target specific goals for economic activities and influence the development and spread of innovations. Being very broad in nature, economic and financial instruments have been intensively applied in the area of innovation policy (Borrás and Edquist 2013). Economic tools are not as obligatory as the regulatory ones since they always let the subjects decide whether to take the action or not and have the power to make desired behaviours cheaper and undesired ones more expensive (Vedung 1998). They serve to provide specific fiscal incentives or disincentives which support specific economic and social activities (Borrás and Edquist 2013). The use of incentives and/or disincentives (or penalties) represses the energies and offers the belief (Vedung 1998). Different sub-types of economic and financial instruments as shown in Table 1.2.

Table 1.2. Examples of economic and financial instruments

| Economic means in cash: |
|---|
| Positive incentives (encouraging and promoting):<br>• Cash transfers<br>• Cash grants<br>• Subsidies<br>• Reduced-interest loans<br>• Loan guarantees<br>Disincentives (discouraging and restraining)<br>• Taxes<br>• Charges<br>• Customs duties<br>• Tariffs |
| Economic means in kind: |
| Positive incentives:<br>• Government provision of goods and services<br>• Private provision of goods and services under government contracts<br>• Vouchers |

Source: Vedung (1998)

c) **Soft instruments** usually use the information to educate the public or certain groups about an issue, to raise concerns through soft messages. Characterized by being voluntary and non-coercive (Borrás and Edquist 2013), soft instruments tend to shift people's behaviour or awareness towards some kind of topics that may be facing in the society. In most cases, soft instruments are used to complement the financial and regulatory instruments for providing recommendations and offer contractual agreements or normative appeals.

Table 1.3. Examples of policy instruments in innovation policy

| | |
|---|---|
| Regulatory Instruments | • Intellectual Property Rights<br>• Universities and PROs statutes<br>• Competition policy about R&D alliances<br>• Ethics Laws<br>• Standards |
| Economic and Financial Instruments | • 'En block' support to research organizations and universities<br>• Competitive research funding<br>• Tax exemptions<br>• Support to venture and seed capital |
| Soft Instruments | • Voluntary standardization<br>• Codes of Conduct<br>• Public-private partnerships<br>• Voluntary agreements |

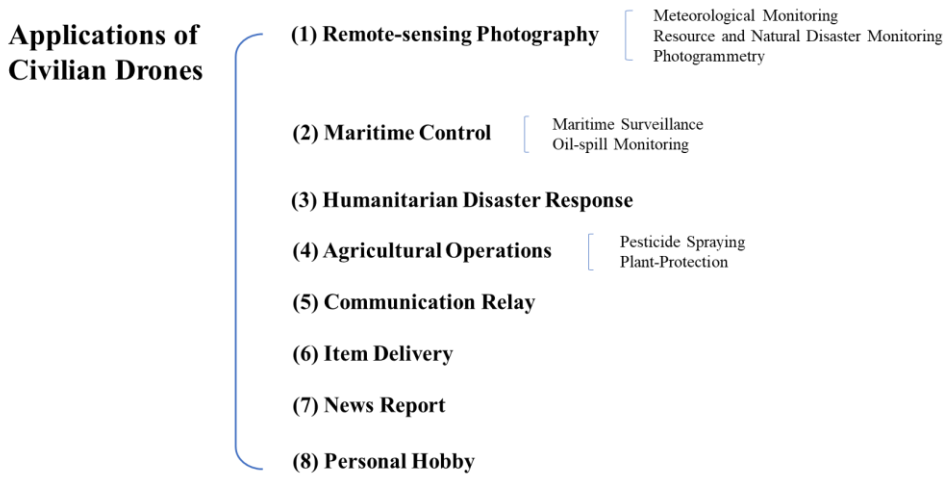
Source: Borrás and Edquist (2013) & Vedung (1998)

Policy instruments are critical aspects of the innovation (Borrás and Edquist 2013) and can be seen as "*the set of techniques by which governmental authorities wield power in attempting to ensure support and effect or prevent social change*" (Vedung 1998). The three-fold classification of policy instruments can be applied to innovation policy and examples are given in Table 1.3. Government policies serve to create a suitable environment for the growth of any business entity. On top of that, innovation policy instruments foster innovation in specific areas by providing the necessary incentives and disincentives essential for growth. It is imperative to evaluate the government policies to identify the regulations and policies towards civilian drones in China.

## 1.3. Drones and the key challenges for government interventions

Drones can be divided into military drones and civilian drones. Civilian drones refer to '*aircraft equipped with flight control systems, without pilot-operated, and engaged in non-military, police or customs missions, excluding aeronautical models, unmanned free balloons and tethered balloons'* (CAAC 2017). In recent years, drones have been widely used in many civil fields due to its unique performance, including administrative management, industrial and agricultural production, commerce and other fields (Gasiorowski-Denis 2015). Based on the product information given by major manufacturers on their official webpage[8] (DJI; 3D Robotics; Parrot; AscTec; Microdrones; EHANG; AEE; PowerVision), the application of civilian drones can be concluded as in Figure 1.1.

Figure 1.1. The application of civilian drones




Source: DJI; 3D Robotics; Parrot; AscTec; Microdrones; EHANG; AEE; PowerVision

[8] The information on applications of civilian drones are collected and summarized from webpages:
"DJI Store". DJI, available at: https://store.dji.com/?gclid=Cj0KCQjw1-fVBRC3ARIsAIifYOPTAZnDF5npECXvLAWk5V-3Kzj-_gyvmSt4t9TszJIgq8o41CF_58IaArFnEALw_wcB;
"Aerial data at your fingertips". 3D Robotics, available at: https://3dr.com/features/;
"Product overview". Ascending Technologies, available at: http://wiki.asctec.de/display/AR/Product+Overview;
"Unmanned applied solutions". Microdrones, available at: https://www.microdrones.com/en/industry-experts/;
"About Ehang". Ehang, available at: http://www.ehang.com/about/;
"Drones". AEE, available at: https://www.aeeusa.com/aee-drones.html;
"PowerVision Store". PowerVision, available at: https://store.us.powervision.me/.

Civilian drones can be classified into consumer (or hobbyist) and commercial drones by the applications. Consumer drones are specifically for personal hobbies while commercial drones have wider industrial usage.[9] Based on the Annual Report of the Civilian UAV Market Research by EVTank (2015), the total number of drones sold globally is about 390,000 with civilian drones accounted for 96%, among which consumer drone sales is approximately twice of the commercial drone over the past few years. In the U.S., the drone market used to be in a nascent phase and had yet to break into the mainstream, however in 2015, the industry bloomed when the Federal Aviation Administration (FAA) granted over hundreds of new exemptions for firms to operate drones. The number of drone operators registered with FAA was steadily increasing after the exemptions (BI Intelligence 2016; 2017). The Goldman Sachs Research (2017) has forecasted a 100 billion US dollars market opportunity for drones by 2020 (for both civilian and civil drones). It's also expected that by 2020 there would be 7.8 million consumer drone shipments and 3.3 billion US dollars revenue, versus only 450,000 shipments and 700 million US dollars revenue in 2014 (ibid).

Many countries are faced with regulatory problems and actively seeking solutions to establish a complete policy system in the area of drones. According to the FAA, civilian drones weighed more than 0.5 pounds (about 0.23 kg) must be registered and marked with the registration number (as in the case of a motor vehicle engine identification code) for future reference.[10] In Australia, the Civil Aviation Safety Authority (CASA) announced that drones cannot fly over 120 meters in major cities and towns, and must maintain a safe distance of more than 30 meters with pedestrians and are prohibited during nights.[11] In Japan, the Civil Aviation Bureau (CAB) first passed the Small UAV Flight Control Act, prescribing the outer radius of about 300 meters of the Prime Minister's official residence, the Parliament, the Royal Palace and other important facilities as "no-fly zone", and offenders will be fined or sentenced for one year or less in prison.[12]

[9] Instead of clear definition, the comparison for consumer and commercial drones can only be found mostly on media and a limited number of published articles. Here is a brief differentiation summarized from "Hobbyist drones vs. commercial/research drones: how to tell the difference" Robota.us, available at: http://www.robota.us/how-to/hobbyist-drones-vs-commercialresearch-drones-tell-difference/.

[10] "Unmanned Aircraft Systems". FAA (2017), available at: https://www.faa.gov/uas/getting_started/.

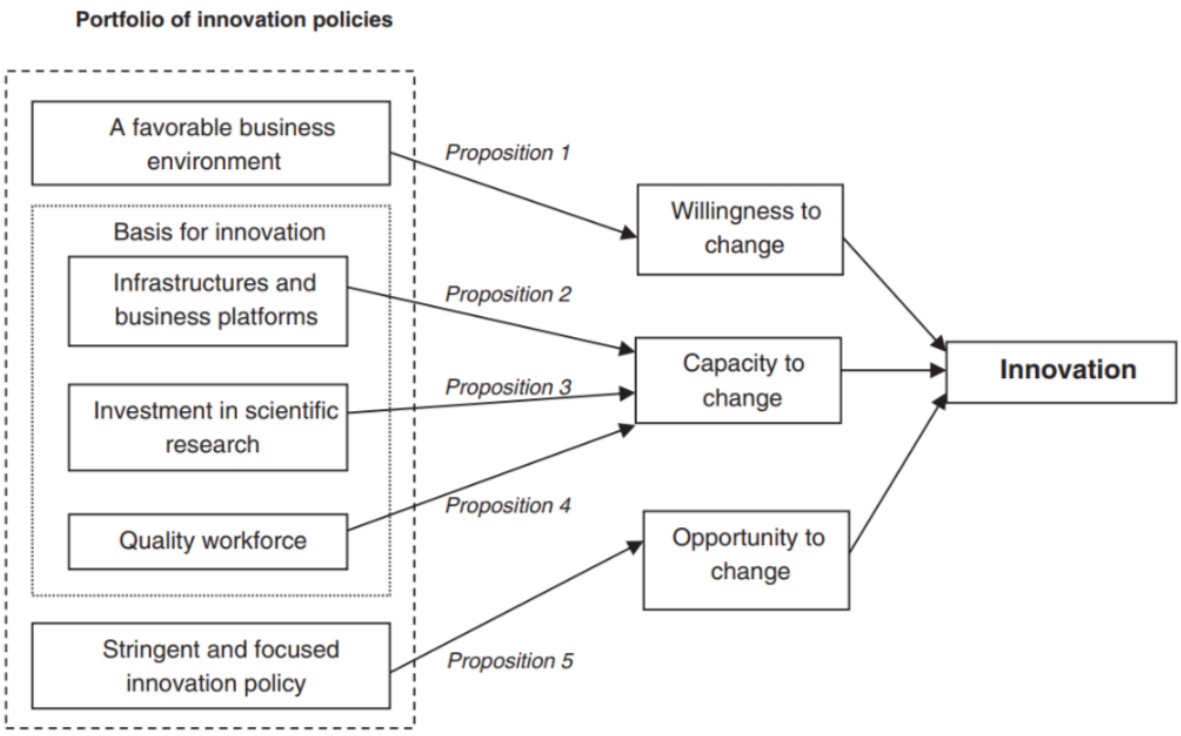
[11] "Flying drones/remotely piloted aircraft in Australia". CASA (2017), available at: https://www.casa.gov.au/aircraft/landing-page/flying-drones-australia.

[12] "Japan's safety rules on Unmanned Aircraft (UA)/Drone". CAB (2015), available at: http://www.mlit.go.jp/en/koku/uas.html.

Recent technological advancements in aviation have increased challenges not only for the end users but also for the flight operators and the aviation authorities (Wright 2014). Despite the rapid emergence of the drone technology, UAV regulations have remained heterogeneous and embryonic of the national laws (Wright 2014). Various researchers have identified that technology has developed at a rapid rate that has outpaced the legislation and policymaking. As a result, it has created a barrier for research and development because most of the scientific projects are hindered by the current regulatory frameworks for both public and private innovations (Kan et al. 2001). As a consequence, societal gains and market opportunities in technology have not been fully utilized and exploited. Poorly documented flight approval times and administrative processes are some examples of the common problems associated with the current UAV regulations, which brings limitation to the desired flexibilities of civilian drones and hinder the widespread application of UAV technologies (Stöcker et al. 2017).

Consequently, there is a need to analyze and assess the development in the area from the perspective of TIS. The problem of defining the role of government policy in TISs be solved by assessing the mediating factors. It's believed that the presence of active enterpreneurs are the prime indication to examine the function of an innovation system (Hekket et al. 2006). For enterpreneurs, the major contributors to a technological change in the business are the willingness, the capacity, and the opportunity to change (Ashford 2000). Patanakul and Pinto (2014) has also argued that these three elements are important in any technological change, therefore policy makers should take them into consideration and provide a supportive environment. In this case, it's effective to evaluate the innovation system from these three elements: the willingness to change depends on the enerpreneur's own will and knowledge on possible changes; the capacity to change is about how capable the firm is to generate innovation based on its know-how within the industry; and the opportunity to change is influenced by the government interventions, business environment and other internal/external demands (ibid).

Figure 1.2. A framework for understanding the roles of government policy and innovation




Source: Patanakul and Pinto 2014; Ashford 2000

Based on Patanakul and Pinto (2014), a framework presenting the connection between such supportive environment and innovation is proposed. In general, the supportive environment includes 1) a favorable business environment, 2) a basis for innovation to flourish, and 3) a clear and specific target (see also Figure 1.2.):

- The first proposition, as the baseline for the other propositions, indicates the relationship between firm's willingness to change and the TIS – "*the more the innovation policy creates a favorable business environment, the more it enhances the willingness of firms to change, resulting in higher numbers of innovations*". The innovation policy can be seen as a pull factor for entrepreneurs to conduct change in the businesses. For example, in the case of US, tax and substantial incentives, open and competitive markets, lending support for SMEs are all proved to enhance the firm's willingness to change thus accelerate innovations (Whitehouse 2011; Patanakul and Pinto 2014). Consequently, it's an effective measurement for the performance of

an innovation system whether firms are willing to change and how far they carry out those changes.

- For entrepreneurs who are determined to change, the capacity to change is the second contributor to innovation. In this phase, three important elements have formed the basis for innovation – "*infrastructure and business platforms, investment in scientific research, and quality workforce*" (Patanakul and Pinto 2014). What these elements have in common is that they are all about the integration of different individuals, in other words, the integration of "*human imagination, intuition, and creativity of individuals from various fields*", and one role of the government is to build networks and make sure that individuals can freely share knowledge and resources (Goh, 2005). Programs supporting basic scientific research can be a good platform for individuals to get together. The reward from the programs also attract researchers and promote technological progress. In this case, whether firms have the capacity to change is a proper reflection on the functionality of innovation systems.

- Finally, the more the innovation policy is stringent and focused which means a clear and specific goal is set for each policy, the more the opportunity to change firms have, and hence the better chances for innovations.

Moreover, since the civilian drone is the subject in both the TIS and the public safety, it's necessary to take the interactions and interdependencies between policies - the policy mix - into consideration, especially when assessing the impact of policy instruments. The impact of policy instruments can be seen as "*a blend, or combination, of different instruments, sometimes enacted at different times and often for somewhat different purposes*" (Bressers and O'Toole 2005). The complexity of innovation policy brings challenges on assessing its influence, however, the idea of policy mix provides an extra framework. The term is effectively used as a synonym for 'innovation policy' (Flanagan et al. 2011). When it comes to innovation policy, the policy goals sometimes lead to additions and contradictions on other policies, as Nauwelaers and Wintjes (2008) indicated that innovation has "invaded" the agendas of many traditional policy fields. Pollitt (2008) also drew attention on the non-linear, path-dependent dynamics in policy systems, emphasized the importance of the relationship between these and other dynamics such as budget and planning cycles and economic cycles. Five types of policy mix and their interactions are given in Table 1.4.

Based on the framework by Bressers and O'Toole (2005), Flanagan et al. (2011) have developed a framework that uses "*different dimensions in which interactions can occur*" instead of "*forms of influence*", which are the dimensions of policy space, governance space and geographical space. However, in the case of innovation system for civilian drones in China, those dimensions are less effective since China has rather clear boundaries of policy implementation for different sectors and provinces. In Flanagan's framework, the possible sources of tension in the policy mix come from policy rationales, goals and implementation approaches, which can be applied when analyzing the interactions between safety rules and innovation policies for civilian drones in China and makes a good combination with the previous framework.

Table 1.4. Five forms of influence or confluence and possible sources of tension in the policy mix

| **Different types of policy-mix** | **Influence / confluence** |
|---|---|
| Multiple instruments aiming one goal | Increased intensity of government interventions |
| Multiple instruments with different targets involved in the same process | Integration of multiple instruments into one system for the targeting group |
| Interactions between instruments taken at different levels of multi-level governance | Policies and interventions at different levels of governance |
| Interactions and tensions across policy domains | Competition and co-operation between different divisions |
| Interactions mediated through processes in a broader system | Increased complexity of policy system, mutual strengthening or weakening the influence of policy instruments |
| **The possible source of tension in policy mix** | |
| • Policy rationale<br>• Policy goal<br>• Implementation approach | |

Source: Flanagan 2011, Bressers and O'Toole 2005

# 2 Empirical Part

## 2.1. Methodology

The paper will follow an exploratory research methodology in gathering data for the study. In this case, the researcher will rely on the use of published data from secondary sources in the form of published material on the subject matter and primary sources in the form of interviews with the key stakeholders from associated department, industry organizations and major manufacturers. The case study examined a single "*example of a class of phenomena*"[13] in details (Abercrombie et al. 1984) and can produce the context-depedent knowledge (Flyvbjerg 2006). Historical institutionalism (HI) will also be applied to analyze past trends and current information which can then be used to predict the future. HI focuses on empirical questions and as an approach to studying policies, it considers historical context a direct factor on changes (Steinmo 2008).

The object of the research is civilian drone manufacturer and its development in The People's Republic of China. For the theoretical framework, published materials from magazines and academic journals are used to find relevant information for the study. According to the main research area of this thesis, several types of academic journals are selected. For example, academic journals on public policy, civil aviation and technology R&D are the most relevant ones. The choice of these sources is informed by their authority, relevance, and reliability. As for the empirical part, apart from the magazines and

[13] The original definition of Case Study by Abercrombie et al. (1984) is: "*detailed examination of a single example of a class of phenomena, a case study cannot provide reliable information about the broader class*." However, Flyvbjerg (2006) has re-evaluated the contribution Case Study has on scientific development and negated the latter part of this definition.

journals mentioned above, the researcher also work with regulative materials from the public sector in China (not only the ones especially for civilian drones but also other relative fields such as the civil aviation, high-tech R&D, etc.). Due to the issue of the limit of authority, some documents cannot be found in its original format, however, there are available summaries and interpretations from the research institute and the media on the specific document that can be learned. The timeframe of research materials for the empirical part is from the year of 2009 to 2018[14], still, there are a few important documents that are out of the selected timeframe studied in the research process for better understanding the whole picture of Chinese innovation system. Interviews with key stakeholders within the industry are conducted as a surplus which validates the assessment based on document analysis. However, some stakeholders are quite sensitive with the topic of current policy system and not willing to share their judgement on the related issues, short interviews via mobile phones seem to be the most appropriate way for interviewees. Due to the particularity of the research topic – policy instruments for civilian drones in China – which is relatively new in the research field, the available information is rather limited. Also, the use of information from these sources could be limited by the inability to find up-to-date publications on the subject.

## 2.2. The development of civilian drones in China

The development of civilian drones in China can be divided into three stages (Song and Liu 2016):

***(1) The starting stage of civilian drones (from the mid-1980s to early 21st centuries)***

Before the 1980s, the unmanned aircraft was mainly used for military purposes (Keane and Carr 2013; Blom 2009). The research and development (R&D) unit were mainly Chinese national military-industrial sector and universities with military background (Hsu et al. 2013). Nanjing University for

[14] The year of 2008 can be considered a turning point for civilian drones (explained in the next sub-chapter) and the industry started to grow fast since then. With such context, the government began to realize the urge and importance to take specific intervention actions. Although there were existing policy instruments for high-tech industries in general, it makes more sense to focus on policies designed to regulate civilian drones, of which the timeline is from 2009 till the present.

Aeronautics and Astronautics (NUAA) has specialized in tactical-level UAV development since the university's establishment in the 1950s and completed the radioactivity measurement with drones during nuclear tests in the late 1970s (Fisher 2011). In the mid-1980s, Northwestern Polytechnic University (NPU) started to develop civilian drones and its initial model was first put into use for civil aviation exploration (Song and Liu 2016). Since China was experiencing the economic transition at that period, on the one hand, with almost zero demand from the civilian market the military sector monopolized the technology, and on the other hand, the entry barrier of civil aviation was high for private-owned enterprises (ibid; Park et al. 2006).

***(2) The rise of civilian drones (from 2008 to 2011)***

On 12 May 2008, Wenchuan (in southwest China) suffered the most catastrophic earthquake[15] (Richter 8) ever since China was founded. The rescue was very difficult at that moment since Wenchuan is a small town in the high-altitude area. During the rescue, drones have helped detect the area areas and assessed damage public buildings and population-dense locations.[16] Drones have fully performed their functions during the rescue mission and became the hot news. People's Liberation Army Air Force (PLAAF) officers and other Chinese analysts argue that China should continue to develop advanced UAVs to perform a wide range of missions. Chinese analysts continue to publish a large volume of research in areas related to UAVs and numerous Chinese defence industry organizations are involved in UAV research (Chase et al. 2015). In 2009, the former President Hu Jintao has strengthened the concept of *civil-military integration*[17] (CMI) and put forward the term *military-civil fusion* (MCF) (Levesque and Stokes 2016) which enabled a supportive environment for R&Ds in the private sector, especially in industries like civil aviation and drones.

[15] The Wenchuan earthquake occurred at 14:28:01 China Standard Time on May 12, 2008, measuring at 8.0 $M_s$, has affected the lives of more than 45.5 million people. From "Wenchuan earthquake, 2008". DisasterHistory.org, available at: http://www.disasterhistory.org/wenchuan-earthquake-2008.

[16] "China's Launching Drones to Fight back against Earthquakes". Wired.com (2017), available at: https://www.wired.com/2017/01/chinas-launching-drones-fight-back-earthquakes/.

[17] Since Mao's era, almost every national leader has deliberately sought to leverage the residual benefits of integrating military and civilian R&D, hence the concept of CMI came to its place. CMI has been proposed for advancing defence modernization and supporting economic development. See "The Value of Military-Civil Fusion in this Age", PLA Daily (2010), available at http://news.163.com/10/0704/07/6ANU120R00014AED.html.

***(3) The expanding market of civilian drones (from 2012 to the present)***

Estimates show that there are about 500 drone makers worldwide of which 80 percent are Chinese (Faust 2016). The country is home to 8 of the 13 leading drone brands worldwide. The Chinese city of Shenzhen can be seen as the global hub for the making of drones. It is believed that about 70 percent of all the drones manufactured globally are produced in the city (Ballaster et al. 2017). The development of the civilian drones in China has been spearheaded by accommodative financial instruments in the country like governmental grants on innovative ideas (Chandler 2017) as well as accessibility of affordable loans. Also, the Chinese government supports the industries that provide cheap and reliable raw materials that play a key role in companies like DJI in the development of effective recreational drones. The drone manufacturer DJI that produces the popular Phantom brand is based in Shenzhen and has a market share of nearly 70 percent globally is a good example of how financial instruments have played a crucial role in drone development (Hall 2017).

While China has established a reputation as the largest manufacturer of drones, it is also the largest consumer market for the same. Estimates show that sales of commercial-quality drones in China could hit 950,000 units by 2019 – a feat that would mean a 300 percent rise in four years (Sandvik and Jumbert 2017). The market value of the civilian drone industry in China is believed to have risen to a value of 60 billion Yuan or about $9.1 billion in 2017 from what it was in 2016 (Bissonnette and Smith 2017). Commercial applications will fuel the growth as more and more businesses find uses for the drones. For example, Alibaba is working on plans to use drones to deliver packages to offshore locations that are otherwise difficult to access.[18]

The widespread use of civilian drones poses a certain threat to the air and ground safety in China. On February 29, 2013, UFOs appeared in the airspace to the east of the Beijing Capital International Airport, causing take-off delay for more than ten flights and air avoidance for two flights. After the investigation, this incident was caused by a company flying survey drones. The 4 men operating the drone are detained by the local police and have been charged with "endangering public security" and

[18] "Alibaba's drones deliver packages to islands". The Economic Times (2017), available at: https://economictimes.indiatimes.com/news/international/business/alibabas-drones-deliver-packages-to-islands/articleshow/61545583.cms.

"seriously interrupting flight order".[19] On one evening of April 2016, a jail in Fuzhou found a drone flying around and hovering over it, which is likely to drop dangerous goods or spying on regulatory facilities.[20] In the same year, one drone "black fly" on the expressway in Ningbo crashed and hit the truck accidentally, resulting in two passengers' minor injuries and smashed the front windshield glass of the truck.[21] Also, a unit of Chinese army found a small drone during the drill that was photographing so that they had to shoot it down with a rifle.[22] In April 2017, within one week, four drones "black-fly" incidents occurred in Chengdu Shuangliu International Airport, resulting in nearly 100 flight delays and tens of thousands of people stranded.[23] Authorities at the time reported that 58 flights were diverted to other airports while four had to return in what was perhaps one of the worst cases of interruptions caused by drones (Leavitt 2017).

## 2.3. Government interventions

### 2.3.1. The key areas at focus for state intervention (key industrial areas and policy actions)

China, like any other country in the world, has experienced an upsurge in the number of civilian drones in use. While they have primarily been used for recreational purposes, drones are also increasingly being utilized for commercial uses (Krishna 2017). There is scope for more innovative uses of drones in ways such as delivering essential supplies to far-flung areas that might not be covered by transport and communication networks. However, drones have also brought about a lot of concerns and especially those related to the unmanned air vehicles (UAVs) straying into the flight paths of aircraft.

[19] "Unannounced appearance of mapping drone delays 10 flights at Beijing Airport – 4 drone operators detained by police". Personal Drones (2014), available at: http://www.personal-drones.net/unannounced-appearance-of-mapping-drone-delays-10-flights-at-beijing-airport-4-drone-operators-detained-by-police/.

[20] Xue, J. (2016) "'UAV night break prison': flights need to be legal and regulated". Opinion.Huanqiu.com (2016), available at: http://opinion.huanqiu.com/plrd/2016-04/8825114.html.

[21] Wu, T. (2016) "Ningbo: a drone "black fly" crashed and smashed". The Paper (2016), available at: http://www.thepaper.cn/newsDetail_forward_1546553.

[22] "Drone was shoot down during Chinese Air Force Missile Brigade training". Sina.com (2016), available at: http://mil.news.sina.com.cn/china/2016-12-01/doc-ifxyiayq1894734.shtml.

[23] "Man detained for illegally flying drone near airport in southwest China". China Plus (2017), available at: http://chinaplus.cri.cn/news/china/9/20170424/3527.html.

The manufacture and use of drones in China has become quite a phenomenon over the past few years. DJI, the Chinese drone maker, has risen to become a global leader and controls about two-thirds of the world market (Pennsyvania Bar Institute 2017). A lot of the success that DJI and other Chinese drone makers have experienced is down to the support that they receive from their respective governments.

One of the key ways in which the state is doing this is by promoting the use of drones in transportation. In 2016, Chinese drone manufacturer, Ehang, presented a concept at that year's Consumer Electronics Show (CES) for the world's first drone that is capable of carrying a human passenger.[24] It is something that could find a lot of uses as urban areas become more crowded and the need to get around faster increases. While it might take a bit of time before transportation drones become mainstream, efforts by the Chinese government may accelerate the realization of this dream (Custers 2016). The authorities in the Asian nation see the use of the unmanned vehicles as being beneficial to the transport industry as they will improve safety, efficiency, and quality. The Ministry of Transport of China is in the process of drafting technical standards and developing the drone technology that will be used in the industry.[25] The support by the government could prove to be significant in the years to come. The ministry of transport sees bright prospects for drone technology that is already in use in other areas such as self-steering boats and automatic rail transport (Chong and Sweeney 2017). To that end, the ministry has undertaken to build test sites where more research is to be carried out.

Another area in which the government has supported the use of drones is in Agriculture. In the quest for more productivity, China sees UAVs as providing a lot of useful solutions. For example, farmers in the nation's grain-producing areas are now using drones to spray their crops (Sloggett 2015). Doing so ensures more efficiency and better targeting of crops. Most importantly, this kind of support is crucial for manufacturers who will likely see an increase in their sales. This kind of innovation is bound to have a lot of beneficial impacts on the industry and lead to even faster growth in the adoption of drone technology. As the rise of civilian drones in China (ever since the year of 2008), the Chinese government has conducted several policy actions for civilian drones. Based on the information given by several departments and research institutes, an overview of key policy actions for civilian drones in China from the year of 2009 till 2018 is given in Table 2.1.

[24] "First passenger drone makes its debut at CES". The Guardian (2016), available at: https://www.theguardian.com/technology/2016/jan/07/first-passenger-drone-makes-world-debut.
[25] "China to support drone technology in transportation". ChinaDaily (2018), available at: http://www.chinadaily.com.cn/a/201802/08/WS5a7bf019a3106e7dcc13b932.html.

Table 2.1. The timeline of key policy actions for civilian drones in China (2009 - 2017)

| Time | Issued by | Terms | Content |
|---|---|---|---|
| 2009 | CAAC | ① *Provisions on Managing Air Traffic of Unmanned Civil Aircraft* (MD-TM-2009-002)[26] | Basic air traffic rules for civil UAVs are established, including the official nationality registration procedures and operational application procedures for civil UAVs |
| | CAAC | ② *Civilian UAV Air Traffic Management Measures*[27] | Several standards are drafted for the traffic control of civil UAVs (abolished in September 2016) |
| 2010 | State Council & CMC | ③ *Guideline on Deepening the Reforms on Low-Altitude Airspace Management*[28] | Reform the management of low-altitude airspace within 5 to 10 years |
| 2012 | CAAC | ④ *Civil UAV Airworthiness Management Meeting Minutes* (ALD-UAV-01)[29] | Checklists and testing methods for civil UAVs are formulated;<br>Operational security and restrictions are emphasized |
| | MIIT | ⑤ The launch of the research on "Basic Conditions and Evaluation Methods for Civil UAV Firms" (Gao 2017) | The research (led by the AVIC China Aero-Polytechnology Establishment) covers the assessment of R&D personnel, technical capabilities, equipment and quality control of civil UAV manufacturers in China[30], aiming to publish standards for UAV firms. |
| 2013 | CAAC | ⑥ *Interim Provisions on the Administration of Civil UAV Pilots* (AC-61-FS-2013-20) [31] | Drafted the fundamental standards for civil UAV pilots (abolished in July 2016) |
| 2014 | State Council & CMC | ⑦ *Low-altitude Airspace Regulations (Provisional)*[32] | Reconceptualize the low-altitude airspace for civil UAV applications |
| | CAAC | ⑧ *Notice on Relevant Issues of Pilot Qualification Management for Civil UAVs* ([2014] 27)[33] | Authorise the Aircraft Owners and Pilots Association of China (AOPA – China) to be in charge of the civil UAV pilot certification as of April 2014;<br>In April 2015, CAAC reauthorized the AOPA – China for a period of 3 years under the same term (see document [2015] 34[34]) |
| | State Council & CMC | ⑨ *Guideline on Deepening the Reforms on Low-Altitude Airspace Managemen*[35] | The management reform of airspace below a true altitude of 1000 meters have been conducted in many major cities in China (including Guangzhou Flight Control Zone, Hainan Island, and etc.) |

[26] Original document available at: https://perma.cc/UJ4F-N4L7.
[27] Since it's been abolished from September 2016 when the updated version is released, the original document can no longer be found online.
[28] Original document available at: http://www.shenyang.gov.cn/zwgk/system/2010/11/02/000115034.shtml.
[29] Summary of the document is available at: http://www.sohu.com/a/2112314_115926.
[30] Analysis of the Airworthiness Management Status of China's Civilian UAVs. Available at: http://news.carnoc.com/list/293/293102.html.
[31] Original document available at: https://perma.cc/V4PT-9ER6.
[32] Original document available at: http://news.carnoc.com/list/288/288814.html.
[33] Instead of the original document, an updated version can only be found online (see footnote 30).
[34] Original document available at: http://www.caac.gov.cn/XXGK/XXGK/ZFGW/201606/t20160621_38593.html.
[35] Following the *Guideline on Deepening the Reforms on Low-Altitude Airspace Management* of 2010, this document put forward new guidelines on the same topic with more details which is a step forward for the reform of low-altitude airspace management in China. However, instead of the original document (2014 version), only a summary can be found via the media: http://www.chinanews.com/gn/2014/12-01/6832262.shtml.

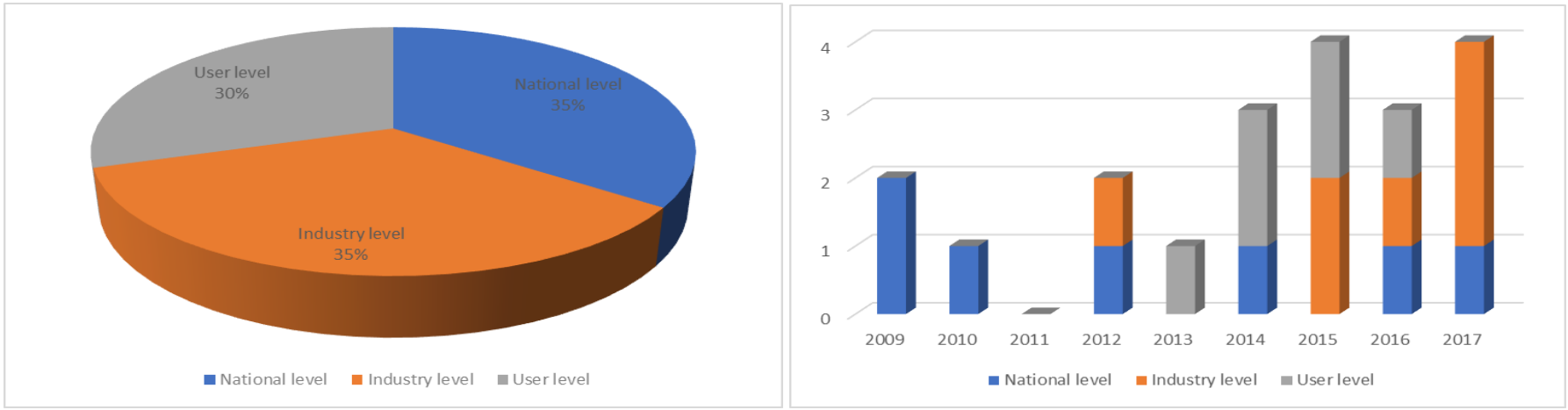
| | | | |
|---|---|---|---|
| | | | and strive to spread the reform to the whole country in 2015, which indicates that the low-altitude airspace resource management in China is in its completing and refining process. |
| 2015 | CAAC | ⑩ *Interim Provisions for Low Level Operation of Light and Small Unmanned Aircraft Systems* (AC-91-FS-2015-31) [36] | First "traffic rules"; Officially classified civil UAVs by the weight and function;<br>Defined the duties, authority and responsibilities of pilots, as well as the basic requirements for safe operation |
| | State Council | ⑪ *Made in China 2025*[37] | The development of UAV industry will be one of the focused areas in the near future |
| | CAAC | ⑫ *Draft Interim Rules on the Administration of General Aviation Business Activities Using Civil Unmanned Aircraft Systems*[38] | A more stringent requirements are developed, especially for drone operations during business activities |
| | MIIT | ⑬ *A Notice on Frequency Usage of Unmanned Aerial Vehicle Systems*[39] | Three radio frequency bands for unmanned aircraft systems are officially set, among which the radio frequency especially for police UAVs is set |
| 2016 | CAAC | ⑭ *Regulations on Civil Unmanned Aircraft System Pilot* (AC-61-FS-2016-20R1)[40] | Updated the categorization of civil drones;<br>Clarified the different duties of pilots for each type of civil drones |
| | CAAC | ⑮ *Air Traffic Management Measures for Civil Unmanned Aircraft Systems* (MD-TM-2016-004)[41] | An updated version of the *Civilian UAV Air Traffic Management Measures* (2009);<br>Broadened and completed the standards of traffic control for civil UAVs |
| | CAAC | ⑯ *Interim Measures for the Management of Business Activities Using Civil Unmanned Aircraft Systems (Draft for Soliciting Opinions)* | Published in early 2016 for openly soliciting opinions, and an updated version was released in March 2018[42] |
| 2017 | CAAC | ⑰ *Regulations on Real-name Registration of Civil Unmanned Aerial Vehicles* (AP-45-AA-2017-03)[43] | For users: "real-name" registration starting from June 2017;<br>For manufacturers: the document has listed the required information from manufacturers for each drone sold which also need to be put into the registration;<br>A QR code with all important information given by the authorities must be attached to the drone after its registration |
| | MIIT | ⑱ *Notice on the Launching of Reporting Mechanism of Civil UAV Manufacturers* | From 2017, the statistics (incl. R&D and manufacture) for civilian drones officially started for improving the management of the industry |

[36] Original document available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201601/t20160113_26519.html;
English version available at: https://droneregulations.info/China/CN.html.
[37] English version of the original document is available at: http://www.cittadellascienza.it/cina/wp-content/uploads/2017/02/IoT-ONE-Made-in-China-2025.pdf.
[38] Instead of the original document, a summary can be found at: "China Launches First Operational Rules for Civil Unmanned Aircraft" https://www.hlmediacomms.com/2016/01/21/china-launches-first-operational-rules-for-civil-unmanned-aircraft/.
[39] Original document available at: http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057735/n3057748/n3057752/c3653837/content.html.
[40] Original document available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170527593445127625.pdf.
[41] Original document available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=4f8ae58a-7489-4fc9-8e6f-88737f3731ba&code=UAV#down.
[42] Original document (2018 version) available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201804/t20180409_56265.html.
[43] Original document is available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170517409761154678.pdf.
English summary of the document is available at: http://www.caac.gov.cn/en/XWZX/201705/t20170524_44222.html.

| | | | |
|---|---|---|---|
| | | ([2017]314)[44] | |
| | MIIT et al[45]. | ⑲ *Construction Guide of UAV Standard System (2017 – 2018 edition)*[46] | From the perspective of management and technology, a framework of the standard system for UAVs was proposed: (1) fundamental standards (incl. classification, identification, and etc.) (2) management standards (incl. registration, manufacturing, operation, and etc.) (3) technology standards |
| | CAAC | ⑳ *Fence of Unmanned Aircraft System* (MH/T 2008-2017)[47] & *Interface Specifications of Unmanned Aircraft and Cloud System* (MH/T 2009-2017)[48] | These standards gave instructions on R&D of civilian drones and were drafted by the research institutes from both public sector and private sector |

Source: collated from NPC; CAAC; State Council; CMC; MIIT

Figure 2.1. The number of key policy actions categorized by national level, industry level and user level (from 2009 to 2017)




Source: collated from NPC; CAAC; State Council; CMC; MIIT

[44] Original document available at: http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5653966/content.html.

[45] This document was released by MIIT associated the Standardization Administration of China (SAC), the Ministry of Science and Technology of China (MOST), the Ministry of Public Security of China (MPS), the Ministry of Agriculture and Rural Affairs of China (MOA), the General Administration of Sport of China, the National Energy Administration (NEA) and the CAAC.

[46] Original document available at: http://www.miit.gov.cn/n1146290/n4388791/c5703886/content.html.

[47] Original document available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=a070ac6b-5096-4de9-976f-000282f97036&code=UAV#down.

[48] Original document available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=f3c12dcd-866b-4fe8-97b1-930e2a7d320c&code=UAV#down.

The policy actions in the past decade have covered several topics and each topic is targeting a certain group. Based on the information collected, these actions are categorized into three levels – national, industry and user (Table 2.2.). From the number of policy actions taken for each level (Figure 2.1.), there are trends that: (1) the number of policy actions has seen an increasing trend in the past decade; (2) the focus of policy actions started from the national level and gradually moved on to the user level and industry level; (3) there is a significant rise in the number of policy actions at the industry level from 2017.

Table 2.2. Categorization of key policy actions by different target groups

| **The target group of each policy action** | **Policy actions** | | |
|---|---|---|---|
| | **Regulatory** | **Economic** | **Soft** |
| National level<br>(nationality registration & airworthiness management) | ①②③④⑨⑮ | | ⑰ |
| Industry level<br>(R&D, sales,[49] usage and export management) | ⑤⑬⑯⑲⑳ | ⑪ | ⑱ |
| Pilot/user level<br>(operational and pilot management) | ⑥⑦ | | ⑧⑩⑫⑭ |

Source: collated from NPC; CAAC; State Council; CMC; MIIT

Overall, the regulatory instrument is the most prevailed as they provide basic standards and fundamental rules for civilian drones. And they tend to target more on the national level and the industry level. Economic and financial instruments are commonly used to offer incentives to the private sector and thus promote innovation. However, few instruments listed here doesn't necessarily mean that the government has lost its focus on developing the industry. Due to the particularity of civilian drone that it is within the range of high-tech industry like smartphones, AI devices and many other consumer goods, and meanwhile it's involved in the civil aviation industry and shares a high percentage of technologies with military drones which can potentially, or has already brought risks to the public security, the policy actions from the past decade majorly brought out standards, rules and

[49] In terms of sales, no relevant policy action has been published for civilian drones. *Official Notice on Strengthening the Export Control on Certain Dual-Use Items* (No. 31/2015) was released in July 2015 by the Ministry of Commerce and General Administration of Customs for UAVs in general which provides restrictive terms on export. However, the restrictions are only for UAVs with certain features which, based on the author's comparison, belong to the scope of military UAVs although it's not clearly stated in the document. Consequently, despite this is the only document on the sales of drones, it's not listed here. Original document is available at: http://www.mofcom.gov.cn/article/b/c/201507/20150701067575.shtml.

codes of conduct to regulate the civilian drone industry in specific, while many other economic incentives targeting high-tech industries are also effective for civilian drone enterprises which are not listed here but will be introduced in this chapter.

### 2.3.2. Regulatory instruments

#### *(1) Standards*

The China's civil aviation laws and regulations are executed from three phases: strategies, laws and regulations. In addition, different operational divisions of CAAC (including the Airworthiness Dep., the Flight Dep., the Transport Dep., the Airport Dep., the Air Traffic Control Management Office, the Aviation Safety Office, etc.) also developed several standards and normative documents within their respective mandates.[50] In accordance with civil aviation laws, regulations, rules and normative documents mentioned above, CAAC also authorizes industry associations to make necessary working documents within the scope of their management and stipulate the administration of drone pilots.[51] For example, AOPA – China has published several documents under the authorization of CAAC in terms of civil UAV pilot certification.[52]

One of the concerns that surround the development of drones is standards. It becomes all the more important in light of the numerous safety concerns that have come with the increase in the use of drones. It is for that reason that China has come up with a draft of regulations which will govern the use of drones and ensure that there is sustainable development in the industry (Jaffer 2016). The exercise was led by the CAAC as the body tasked with regulating the country's airspace.

In June 2009, the CAAC issued the normative document of *Provisions on Managing Air Traffic of Civil Unmanned Aircraft*.[53] It basically established the rules on air traffic control for civil drones which stated that units and individuals that organize and implement civil drone activities shall apply for the designation and use of airspace in accordance with the *Regulation on Flight Control of General*

[50] "About CAAC – Departments". CAAC, available at: http://www.caac.gov.cn/en/GYMH/BMJS/.
[51] "About CAAC – Main Functions of CAAC". CAAC, available at: http://www.caac.gov.cn/en/GYMH/ZYZN/.
[52] Aircraft Owners and Pilots Association of China (AOPA - China) is the first civil aviation association obtained qualification (from 2014) for formulation and publication of standards. It has released several standards in terms of civil UAV pilot certification. The number of pilot certifications approved by AOPA – China has increased from 243 in 2014 to 14,145 in 2017. See AOPA – China 2017 Annual Work Report. AOPA (2017), available at: http://www.aopa.org.cn/Content_Detail.asp?Column_ID=44848&C_ID=20012464.
[53] Original document available at: https://perma.cc/UJ4F-N4L7.

*Aviation*,[54] and accept the management of flight activities and air traffic services. This provides a fundamental regulative environment for civilian drones. However, it did not classify civilian drones nor delineate the corresponding use of airspace. At the same year, CAAC released *Civilian UAV Air Traffic Management Measures*[55] drafting several standards for the traffic control of civil UAVs. These have been the very first steps to control the safety issue from the national level that general rules and guidance are given to corresponding operational departments and regional government bodies. With the release of *Air Traffic Management Measures for Civil Unmanned Aircraft Systems*[56] in 2016, as an updated version of the 2009 edition, the standards of civil UAV traffic control are broadened and completed.

Another important aspect of regulations is the completion of infrastructure for civilian drones. After the Wenchuan earthquake hit the south of China in 2008, the civilian drone has proved its functionality in rescue missions and largely saved the labor cost and minimize the risk of human injuries. Both public and private sector have realized the potential of civilian drones and determined to develop this innovative technological product. However, the wide operation of civilian drones requires certain conditions. The State Council and CMC together released the *Guideline on Deepening the Reforms on Low-Altitude Airspace Management*[57] in August 2010. The reform aimed to gradually open up the low-altitude airspace resources in China gradually within 5 to 10 years. It divided the process into three phases: pilot phase (by the year of 2011), promotion phase (from 2011 to 2015) and deepening phase (from 2016 to 2020). This move is seen as a big step forward for promoting innovation of civilian drones (Han and Shi 2012) as it contributed to the completion of infrastructure for civilian drones and determined to relax the restrictions in low-altitude airspace operations after the lesson learned from the catastrophic earthquake (Hsu 2014).

Besides, after launching the research on "Basic Conditions and Evaluation Methods for Civil UAC Firms" in 2012 (Gao 2017) which mainly covered the assessment of technical capabilities and quality control of UAV enterprises, several standards have been put into effect at the industry level, including

[54] *The Regulation on Flight Control of General Aviation* is an administrative regulation issued together by the State Council and CMC in 2003. It's valid for all commercial and recreational operations of aircraft except public transportations. The original document is available at: http://www.caac.gov.cn/XXGK/XXGK/FLFG/201510/t20151029_2794.html.

[55] Since it's been abolished from September 2016 when the updated version is released, the original document can no longer be found online.

[56] Original document available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=4f8ae58a-7489-4fc9-8e6f-88737f3731ba&code=UAV#down.

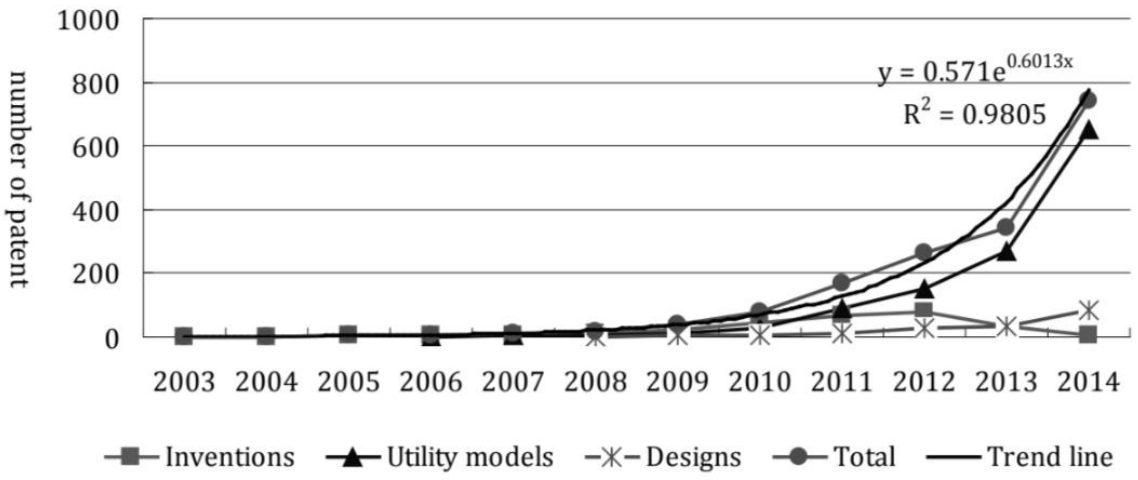
[57] Original document available at: http://www.shenyang.gov.cn/zwgk/system/2010/11/02/000115034.shtml.

basic standards (classification, etc.), management standards (manufacturing, registration, etc.) and technical standards (radio frequency, interface, etc.). Together, these standards help shape the framework of standardization of civilian drone manufacturers.

### *(2) Intellectual Property Rights*

Besides several national standards, the instrument of intellectual property rights gradually plays its role. Unlike standards mentioned above are specially built for civilian drones, the intellectual property rights[58] (mainly refers to the patent in this thesis) is generic in terms of regulating technology R&Ds. Since this thesis is focused on the state intervention for civilian drones, the analysis of overall patent law in China is of little contribution to the research question.

Figure 2.2. The number of patents on UAVs in China (from 2003 to 2014)




Source: Liu 2016

However, a patent analysis of civilian drones may be important on evaluating the innovation system of the field, since it indicates the amount and focused area of technological activity (Bergek et al. 2008a) in firms, organizations and among individuals hence reflect the innovation process. Figure 2.2. implies

[58] Chinese government has submitted the application for admission to the World Intellectual Property Organization and became a member state as of June 1980. Afterwards, China has gradually released the *Trademark Law* (1982), the *Patent Law* (1984) and the *Copyright Law* (1990) together completing the protection system of intellectual property rights. See: Govt. White Papers – Intellectual Property Protection in China (1994) (available at http://www.china.org.cn/e-white/intellectual/index.htm) and Govt. White Papers – New Progress in China's Protection of Intellectual Property Rights (2005) (available at http://www.china.org.cn/e-white/20050421/index.htm).

that the number of valid patents on UAVs in China has grown exponentially (Liu 2016), especially from the year of 2009 when the industry started to rise. According to the report of Drone Technology Patent Landscape Analysis (LexInnova 2016), the top four giants in patent filings for drones (including both military and civilian) in China are listed in Table 2.3. Assignees of drone patents are consist of traditional civil aviation enterprises, military enterprises (mostly SOEs), high-tech SMEs, universities and research institutes.[59] Research has shown that high-tech SMEs gradually become the main force in the development of UAV technology. Apart from leading enterprises like DJI, several less well-known start-ups such as Ewatt (72 patents), ZeroTech (42 patents), Dakini UavTec (36 patents), and AEE Shenzhen (31 patents) are ranked in the top 10 assignees owning the highest numbers of UAV patents in the single year of 2015 (Shen 2017).

Table 2.3. The rank of patent filings for drones in China

| Assignee | Number of patents (up to the year of 2016) |
|---|---|
| DJI | 125 |
| Beijing University of Aeronautics and Astronautics | 96 |
| State Grid Corporation of China | 53 |
| Nanjing University of Aeronautics and Astronautics | 50 |

Source: LexInnova 2016

### 2.3.3. Economic and financial instruments

Recently, China has established a number of economic and technological development zones (ETDZs) which offer various preferential policies, covering tax, foreign exchange, employment, etc., to qualified enterprises (Deloitte 2017). The government is pushing forward policies that will see the private sector a similar footing as the state businesses in terms of funding and protection. The plan of "Made in China 2025"[60] (initiated in 2015) aims to improve the country's technology industry with various economic and financial instruments, and the civil UAV industry is among the most focused area in the plan. R&D grants, subsidies and preferential tax are prevailed incentives for enabling capacities of high-tech enterprises.

[59] "Analysis of Patent Information in Drone Technical Field". China Intellectual Property Right Net (2016), available at: http://www.cnipr.com/xy/swzs/zccx/201707/t20170718_211692.html.

[60] English version of the original document is available at: http://www.cittadellascienza.it/cina/wp-content/uploads/2017/02/IoT-ONE-Made-in-China-2025.pdf.

### *(1) R&D grants*

The Chinese government has played a significant role in technological advancement through the establishment of public research centers and universities (Zhang and Wu 2004) and usually, immediate returns from the research institutions are not required but grant them total autonomy on the allocated funds (Hao, Qiu, and Cervantes 2016). A brief comparison between the mainstream programs is given in Table 2.4. In general, these programmes are designed to attract talents and professionals both domestic and from overseas to participate in the R&D of high-tech industries. Research subsidies and grants are the prevail supportive means. Based on a professor who has participated in the R&D of first civilian drones in China, the supportive programmes are very important to his research work as he has benefited from not only the research subsidies but also the networks and platform brought by the supportive programmes.[61]

Table 2.4. Supporting programs for R&Ds in China

| **Program** | **Issued by** | **Target group** | **Supportive means** |
|---|---|---|---|
| The National Science Fund for Distinguished Young Scholars (launched in 1994) | National Natural Science Foundation of China (NSFC) | Young scholars with outstanding achievements from domestic and overseas | Funding (for self-selected research directions) (NSFC 2017) |
| Torch Program (launched in 1999) | State Council | Tech-based SMEs | Public and private funds; attracting investment; promote technology innovations[62] |
| Spark Program (launched in 2002) | Ministry of Science and Technology of China[63] | Rural SMEs | Funds for rural S&T projects; support services |
| The Recruitment Program of Global Experts (known as the Thousand Talents Plan, launched in 2008) | Organization Department of the Communist Party of China | Overseas top talent from key technology fields | Enabling working conditions; living welfare; grants and research subsidies; preferential policies[64] |

[61] Professor of X University. Author's interview at China (Shanghai) International UAV Exhibition & Development Forum 2018. Notes of the interviewer. Shanghai. 3 April 2018.

[62] "Innovation fund". ChinaTorch.org, available at: http://www.chinatorch.gov.cn/english/xhtml/fund.html.

[63] "Notice of the MOST on 'Administrative Measures for the Spark Program'". MOST (2002), available at: http://www.most.gov.cn/fggw/zfwj/zfwj2002/200512/t20051214_54965.htm. Also, an interpretation version can be viewed at "Spark Programme", Embassy of China in Ireland, http://ie.china-embassy.org/eng/ScienceTech/ScienceandTechnologyDevelopmentProgrammes/t112842.htm.

[64] "The thousand talents plan". 1000plan.org, available at: http://www.1000plan.org/en/plan.html.

| | | | |
|---|---|---|---|
| The National Special Support Program for High-level Talents (launched in 2012) | Central Committee of the Communist Party of China & State Council | Chinese talents in the fields of natural science, engineering and social science[65] | Research subsidies; preferential policies; service support (ibid) |
| The China Postdoc Innovation Talent Supporting Program (launched in 2016) | Ministry of Human Resource and Social Security of China (MOHRSS) | Newly graduated postdoctoral fellow in high-tech fields | A grant of 600,000 RMB (about 79,400 euro) per candidate for every two years is funded for supporting research work if entering domestic universities or research institutes[66] |
| National Science and Technology Achievements Outreach Program | MOST | S&T industries | Environment building for S&T industries[67] |

Source: information collated from NSFC, 1000plan.org, State Council, MOHRSS & MOST

The National Natural Science Foundation of China (NSFC), as the largest scientific funding agency in China, has made considerable efforts to promote basic and applied research (Wan et al. 2015). Besides R&D projects, the NSFC also supports academic exchange platforms like the Shuangqing Forum to promote an innovative culture and create a favorable environment for researchers (Huang et al. 2016). Also, local governments and state-owned companies have set up funds for investment in local tech companies to eclipse private VC funds in China.[68]

***(2) Subsidies for civilian drones***

One industry to depend on drones is agriculture, which took advantage of the multifunctional capabilities of the drones to assist the farmers in completing tasks like watering their fields, spraying pesticides on particular crops thereby decreasing health risks, and rapidly recognizing areas in their property where problems occur (Miller 2015). The efficiency of drones is higher than that of manual labour for particular duties within the agricultural sector. This makes it imperative to develop methods that will assist farmers to achieve efficient production of crops they need through embracing

[65] The plan was proposed to establish an innovation and entrepreneurial talent system that complements and integrates with the overseas talents from the Thousand Talents Plan. See: "The National Special Support Program for High-level Talents". Rencai.com, available at: http://rencai.people.com.cn/GB/362597/370672/index.html.

[66] "2018 Postdoctoral Innovation Talent Support Program Highlights". Mohrss (2018), available at: http://www.mohrss.gov.cn/SYrlzyhshbzb/dongtaixinwen/buneiyaowen/201803/t20180301_289072.html.

[67] "S&T programmes", MOST, available at: http://www.most.gov.cn/eng/programmes1/200610/t20061008_36199.htm.

[68] "China fuels boom in domestic tech start-ups". FTtimes (2017), available at: https://www.ft.com/content/b63ee746-afc6-11e7-aab9-abaa44b1e130.

technology to reduce the manual labour hours currently needed. With this context, the Ministry of Agriculture and Rural Affairs of China (MOA), the Ministry of Finance of China (MOF) and CAAC together released a notice on the subsidies terms for agricultural drones, especially in the area of plant protection.[69] The subsidies for each drone can be up to 30,000 RMB (approximately 3,970 euros) and the total amount of subsidies for each pilot province is within 10 million RMB (approximately 1.3 million euros).[70]

***(3) Tax mechanism for high-tech enterprises***

The tax mechanism in China is set up by the Ministry of Science and Technology, the Ministry of Finance and the State Administration of Taxation. Ever since China's enterprise income tax took effect in January 2008, there has been an implementation of a series of tax incentives for new technological enterprises.[71] If an enterprise is certified as high-new technology enterprises (HNTEs), the principal incentives include a 15% preferential tax rate and a 50% or 75% "super deduction" for qualifying R&D expenditure (Deloitte 2017). The major criteria for a qualified NHTE cover the number of patents owned, the percentage of R&D personnel, R&D expenditure and annual income[72]. Such criteria are focused on the R&D progress and quality laborforce of enterprises. Therefore, the tax preferential policies have an indirect impact on the innovation capacities of SMEs. In addition, income derived from a qualified technology transfer[73] not exceeding 5 million RMB annually is exempt from corporate income tax (CIT), and for the portion exceeding 5 million RMB, half-reduced CIT is levied.[74] This also encourages firms to bring technologies to the marketplace, based on which potential networks can be

[69] "MOA, MOF and CAAC jointly issued notices - subsidy plant protection UAVs". MOF (2017), available: http://www.mof.gov.cn/zhengwuxinxi/caizhengxinwen/201709/t20170928_2713895.htm.

[70] See "Ministry of Agriculture Notice: Subsidizing Plant Protection Unmanned Aircraft". Xinhua.net (2017), available at: http://uav.xinhuanet.com/2017-09/25/c_129711879.htm.

[71] "The new Enterprise Income Tax law". Treasury Today (2008), available at: http://treasurytoday.com/2008/china/issue1/the-new-enterprise-income-tax-law.

[72] "Announcement on issues concerning the preferential policies on NHTE Income Tax". State Administration of Taxation (2017), available at: http://www.chinatax.gov.cn/n810341/n810765/n2511651/n2511693/c2805187/content.html.

[73] The concept of technology transfer—the transfer of the results of research from universities to the commercial sector—is said to have had its origins in a report made, to the President in 1945 by Vannevar Bush entitled "Science—The Endless Frontier." (COGR 1998)
COGR (1998). University technology transfer: evolution and revolutions. COGR, New York, available at: http://www.cogr.edu/sites/default/files/University_Technology_Transfer-__Evolution_and_Revolutions.pdf.

[74] "China's Tax Incentives for High-Tech Enterprises." China Breifing (2013), available at: http://www.china-briefing.com/news/2013/08/08/chinas-tax-incentives-for-high-tech-enterprises.html.

built between universities and firms to share knowledge and better promote customized innovations for the market.

### 2.3.4. Soft instruments

#### *(1) Voluntary standardization*

To make sure drones are properly regulated, the CAAC has issued its first traffic rules at the end of 2015 – *Interim Provisions for Low Level Operation of Light and Small Unmanned Aircraft Systems*[75] – which categorized civilian drones based on weight and function (Table 2.5.), and indicated different requirements towards each category. China, like many other countries in the world, requires individuals to maintain a VLOS with their drones at all times, which defines one of the most profound soft instruments in the use of civilian drones (Chamberlain 2017). As a voluntary standardization aspect, this requirement means that UAVs flying within the VLOS have to be operated within the daytime even though it does not apply to drones flying beyond visual line of sight (BVLOS). However, all drones whether flying within VLOS and BVLOS must give way to manned aircraft. In July 2016, the CAAC continued to published the *Regulations on Civil Unmanned Aircraft System Pilot*[76] to update the categorization (category XI and XII of Table 2.5.) which is defined by a mix of specific weight, application domain (agriculture), configuration (airship), and operational requirements of civil UAVs (Ren et al. 2017).

Table 2.5. Light & Small Civilian Unmanned Aircraft Category

| Category | Net Weight (kilogram) | Flying Weight (kilogram) |
|---|---|---|
| I | 0<W⩽1.5 | |
| II | 1.5<W⩽15 | 1.5<W⩽7 |
| III | 4<W⩽15 | 7<W⩽25 |
| IV | 15<W⩽116 | 25<W⩽150 |
| V | Plant Protection Class | |
| VI | Unmanned Airship | |
| VII | UAV of category I and II that can perform 100 meters BVLOS | |
| XI | 116<W⩽5700 | 150<W⩽5700 |
| XII | W>5700 | |

Source: CAAC

[75] Original document available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201601/t20160113_26519.html. English version available at: https://droneregulations.info/China/CN.html.
[76] Original document available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170527593445127625.pdf.

On May 16, 2017, the CAAC issued the *Regulations on Real-name Registration of Civil Unmanned Aerial Vehicles*,[77] which requires the owners of civil UAVs to register in real name starting from June 2017. It's also stressed in the document that from August 31, 2017, civil UAV owners failing to register in real name and stick the registration marks in accordance with this regulation will be regarded as violating the law and will be subject to limitations with respect to the use of UAVs and punishment by regulatory authorities. As part of the raft of new regulative measures, owners of drones that weigh more than 250 grams or 55 pounds are required to have them registered under their real names (Horowitz et al. 2017). The requirement essentially means that everyone with a drone would need to have it registered. For illustrative purposes, the DJI Spark which is the smallest drone that the company makes weighs over 250 grams (Boyle 2017).

The process of the registration is elaborate and is done online through the CAAC website. The first step in this undertaking is opening an account with the CAAC in which a drone owner supplies their personal details. One then adds the drone to the inventory by keying in its serial number. After that, the drone owner then receives a QR code via email (Friedewald 2017). One is required to print the code and stick it on the drone for ease of identification. It also serves as proof of registration. It is worth noting that China has a significant problem with unregistered drones. Estimates have it that the country has about 20,000 unregistered drones and that is something of concern to the authorities (Schulzke 2017).

***(2) Codes of conduct***

Several codes of conduct are put forward for civilian drone users to control their behaviours. For example, the maximum allowable height is 120m or the 400 feet, beyond which one would require a license to fly (Elliott 2016). Failure to adhere to these disincentives leads to fines from the relevant governmental authorities in a bid to regulate the sector (Boyle, 2017). Noteworthy, most of the drones have the maximum attitude automatically set. Users will be warned if they tried to manually alter the settings to allow for a higher maximum. The height limit is an important consideration that is aimed at preventing cases of drones straying into designated aircraft flight paths. One of the biggest concerns with drones is their being flown into restricted areas. Safe flying of drones is a priority for authorities

[77] Original document is available at:
http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170517409761154678.pdf.
English summary of the document is available at: http://www.caac.gov.cn/en/XWZX/201705/t20170524_44222.html.

not just in China but worldwide. There is no doubting the benefits of drones from uses in areas such as photography and agriculture. However, it is also important to ensure that their use does not cause harm. Several drone incidences have been reported in China. Statistics indicate that the years 2016 saw 23 incidents of drones affecting airport service, and that was a sharp spike from the 5 recorded in 2016 (Chandler 2017).

There are more limitations for commercial drones than that for personal drones. When operating for commercial purposes, companies must ensure that their drones remain detectable to aviation authorities particularly when they approach restricted boundaries (Custers 2016). High-security areas like government buildings and airports will be able to manage drone traffic and avoid accidents more efficiently. Nevertheless, the information that the authorities can access should be restricted to the serial number of the device, its speed, location and altitude so that they remain safe, while at the same time not compromising on the integrity of data (Gynnild and Uskali 2018).

The CAAC has developed two cloud-based programs which it hopes to use in regulating the operation of drones in the country. The U-Care and U-Cloud systems are to be used for the registration and monitoring of drones in the country. The U-Care system is accessible to all drones that are equipped with a chip of over 100 grams. By having a drone registered on the U-Care, the system can track its movements provide warnings in good time to the operator about details such as flight zones and speed limits. Provision of such useful information can help in preventing cases of drones straying into designated no-fly zones.

Apart from nationally implemented regulations, many local governments have also issued documents on civilian drones. Some cities have delineated the "no-fly zone", for example, flights within the sixth ring of Beijing[78] are prohibited, which basically covers all living area of the city. Many other provinces and stipulated the "limited flight area" or “no-fly zone” of drones. Incidences like the one in Chengdu Airport have led to the CAAC developing guidelines on No-Fly Zones where drones are not allowed to fly. All drones are subject to these guidelines. Generally, the areas listed under this category include areas surrounding airports and military installations which are sensitive facilities. The government also

[78] *Beijing Public Security Bureau’s Notice on Regulating UAV in Beijing* required that from March 1 to March 16, 2017, drones flying within a 200-kilometer radius around the Tiananmen Square must be approved by the relevant departments. On February 17, 2017, Beijing Capital International Airport announced a "head-on air reserve" covering an area of 1,058 square kilometers.

places restrictions on the flying of drones in some of the country's big cities such as Beijing and Shanghai which are densely populated areas (La Bella 2017). Leading manufacturer DJI has tried to deal with the problem by programming its drones not to take off in the restricted zones. Still, the problem is that some people hack the system and manage to bypass the restrictions. Anyone intending to fly a drone in an area that has been designated as a no-fly zone would need to obtain special permission from the CAAC to do that. However, it might make more sense for the authorities to regulate the manufacturers so that they can follow DJI's lead in preventing drones from taking off in restricted areas.

# 3 Discussion

## 3.1 The role of governmental interventions for innovation in the field of civilian drones

***(1) A favorable business environment***

The Wenchuan earthquake in 2008 has brought the rise of civilian drone applications. And Former President Hu's statement on the 'civil-military integration' in 2009 played a key role in the R&D in the private sector. This has lowered the entry barrier of civil UAV industry and attracted many players. Many key giants, even manufacturers of smartphones have developed their own drones with the hope of increasing the number of consumers purchasing their products (Schaefer 2015). Since then, China has expanded the drone market in regards to integrating technology for various enterprises and consumers (Custers 2016). On the other hand, tax incentives encouraged high-tech SMEs to engage in R&D activities. With various supportive means, a growing number of patents in UAV technologies has provided business opportunities in developing better products. Regardless of the fact that the drone industry is still in its early stages, various businesses within the main trades have already adopted the technology and are willing to change. These businesses are focused on ensuring the technology becomes more accurate in order to assist them in achieving noticeable results for their consumers (Springer 2013). An expert also pointed out that the threshold for civil UAVs will be reduced in the

future as the government has published several documents encouraging the research in civil aviation[79]. He believes that in the long run, drones will become a part of people's lives like a mobile phone and this will bring business opportunities not only to the manufacturing of the drone itself but also various types of application services based on drones.

However, challenges still exist. The regulatory environment is still under development and may be limiting for particular kinds of usage. Although most high-tech start-ups in China managed to get financial support from various programmes, the number of start-up companies dropped (Love and Roper, 2015). It's hard to say whether this has resulted from a less favorable business environment established by the public sector, or the severe competition in seeking investors with larger funds. Researchers also argued that the research capability in China is seen weak as an alarming percentage of companies do not engage in research, and though over 50% of corporations engage in collaborations with universities their work research costs are relatively low (Liang and Chuan-Jing 2017). Moreover, the historical Chinese political culture of suppressing free social association also has a direct impact on the foundation and grow of business-related associations (Yang 2008). A gradual compromise is needed for knowledge sharing and resource integration for a better business environment.

***(2) Capacity to change***

The Chinese government has determined to reform the management of low-altitude airspace (below a true altitude of 1000 meters) which is a big step forward in terms of developing infrastructures for civilian drones. Like roads to cars, low-altitude airspace is the playground for civilian drones which directly affected the development and diffusion of drone innovations. In the ICT paradigm, invisible elements such as frequency rules, tracking system and registration system can also be seen as infrastructures for the operation of drones. China has put lots of effort in the related fields in the past decade. However, the infrastructures for civilian drones in China still remain incomplete and there is a long way to go. Complaints about the complicated and confusing procedures of registration[80] can be heard sometimes. As one of the bases for innovation, such infrastructures have to be completed for the future development of drones.

[79] Director of UAV Application and Control Research Center, Chinese Academy of Sciences. Author's interview at China (Shanghai) International UAV Exhibition & Development Forum 2018. Notes of the interviewer. Shanghai. 3 April 2018.
[80] Former employee of a major civilian drone company in the south of China. Author's phone interview. Notes of the interviewer. 30 September 2017.

On the other hand, increasing investments in the industry, especially in terms of R&D, have led to more innovation, making the Chinese drone market one that cannot be overlooked. Various supportive programmes for the national level have brought great advantages to the research talents. Interestingly, attracting young talents and experts from overseas is one of the focus of these programmes. It seems that the government believes such diversity can generate more innovation and build a fine system of the quality workforce in R&Ds. An expert stated that this kind of policy actions have largely helped his research as it provided promising networks.[81] The fast-growing amounts of patents regarding UAVs also proved effective of current investment in scientific research. Interestingly, in recent years, the top assignees of UAV patents include not only SOEs and high-tech giants but also less well-known start-ups which indicates a promising future for the R&D of SMEs.

***(3) Stringent and focused innovation policy***

Regarding policy-making initiatives, drones are subjected to different regulations at varying stages. With the complexity of drone industry – various applications have made it integrated into many other industries; some technologies in civilian drones might be shared with the ones of military drones and it's hard to define the boundaries when generating innovations – that it's very difficult to say if the current innovation policy is stringent and focused in general. It remains unclear whether this confusion has affected the industry for the moment. Apart from following the regulations at the national level, companies that design and manufacture drones are also required to understand the regulations created at state and city levels, as they may have varying policies relative to those created at the national level. No regulation can be considered the most appropriate since every one of them varies from the other.

China has created airspace limitations and areas where drones are not permitted with safety recommendations for consumers. Nevertheless, the specifics still require further elaboration (Miguel Molina et al. 2018). And in some fields such as agriculture, the innovation policy is clearer for stakeholders within the process, however, it takes time to show whether these policies help develop the industry. It is important for policymakers to have close and regular deliberations with aviation authorities in different jurisdictions where drones operate in order to make sure that there is a balance and the skies remain safe, while they remain open to innovation.

[81] Professor of X University. Author's interview at China (Shanghai) International UAV Exhibition & Development Forum 2018. Notes of the interviewer. Shanghai. 3 April 2018.

## 3.2 The policy mix of safety rules vs. innovation

All in all, the past decade has seen concerted efforts by the government in China to regulate drones in the country. It is in contrast with the years before when the authorities did not put as much effort into regulating the sector. Different policy actions were conducted by various department (civil-aviation-related departments such as the CAAC and the CMC, business sectors like the MIIT and MOF, taxation administrations, S&T departments, and etc.), though targeting different goals they together complete the policy system of civilian drones from the national level, industry level and user level. Noteworthy, the regulations have largely come as a response to the numerous incidences of unsafe flying of drones and which threaten the safety of a lot of people (Yaun 2017). While the regulation of drones is going to drastically improve safety, it is also expected to impact their manufacture and innovation. Following the coming into force of the regulations, many manufacturers in China reported declines in their sales even though they were not too concerned about the initial decline. The sales decline can be up to 30% since the new rules are put into effect.[82] The numbers might pick up with time as users learn to live with the regulations. Also, specific commercial usage of drones can be restricted in China, like for corporations such as Alibaba that have been looking towards the use of drones for purposes of fulfilment and delivery. Such corporations experience challenges in the implementation of their drone delivery systems as a consequence of the regulations that restrict their usage in areas that have dense populations (Chamayou 2015).

However, the new rules could mean more innovations by the manufacturers as they look to be more compliant. For example, they could think of more robust ways which would ensure that the UAVs do not fly into restricted areas and cause safety concerns by straying into flight paths. Another thing would be having better mechanisms for identification and tracking of the owners of drones which would improve accountability and possibly reduce the misdemeanors associated with drones. The research on

[82] Former employee of a major civilian drone company in the south of China. Author's phone interview. Notes of the interviewer. 30 September 2017.

U-care and U-cloud systems are strong proofs that such situation can bring more opportunities for innovation. Another perspective is that the regulative rules will help enterprises minimize the risks from their products. One research personnel of civilian drones mentioned that although policies like the real-name registration and no-fly zones will to some extent affect the sales, the safety risks are controlled by the government, and the research team won't have to worry about the safety issues (since most safety accidents have resulted from wrong operations of users) or the responsibilities they take.[83] Consequently, the interactions bring a win-win situation for both the public sector and the private sector.

[83] Research personnel of a major civilian drone company in the south of China. Author's online live chat interview. Transcript. 2 May 2018.

# Conclusion

This thesis studied how government intervention has influenced the development of a particular innovative technological product. The aim was to discover the development of government interventions on civilian drones in China over the past decade (from 2009 to 2018) and to assess its impact on innovations. For this purpose, a theoretical framework interrelating element of TIS, three-fold typology of policy instruments, and policy mix were developed. Under the Chinese context, this case study relied on the use of published data and interviews with key stakeholders. Historical institutionalism was applied to analyze the past trend.

The development of civilian drones in China can be divided into three stages: starting stage, the rising stage, and the expanding stage. From the perspective of TIS, institutions are the focus of this study. The earthquake in 2008 was a turning point for the industry, and since then the public sector has conducted several policy actions targeting the public level, the industry level and the user level. Firstly, the regulatory instruments mainly include standards for safety, standards to the completion of infrastructure and standards for manufacturers. Also, a patent analysis of civilian drones was taken to evaluate the innovation progress. Secondly, R&D grants, subsidies and preferential tax policies were prevalent economic and financial instruments. These incentives aimed to enable innovation capacities of high-tech enterprises. Lastly, several soft instruments were released as the complement of regulatory instruments and economic instruments, which are voluntary standardizations and codes of conduct.

Based on research data and interviews, the innovation policy mix of civilian drones in China was assessed. In its results, the Chinese government has put lots of effort in providing a favorable business environment for enterprises to change, with the determinations such as the civil-military integration and

various economic incentives for high-tech industries. Since the regulatory environment was still under development, limitation existed for particular issues including the safety. Also, SMEs collaborating with universities were relatively weak and research capacity of both sides need to be strengthened. Besides, the focus on attracting quality research personnel with R&D grants has shown its effectiveness as the number of patents regarding UAVs grew fast in recent years. Interestingly, the top assignees of UAV patents include not only SOEs and high-tech giants but also less well-known start-ups which indicates a promising future for the R&D of SMEs. The interactions between policies for safety and innovation cannot be overlooked. Although there was negative influence on the sales, more positive impact is taking place. The risk of public security will be largely decreased for the good of both users and manufacturers. Moreover, new rules can bring more innovations for the industry and potential business opportunities for enterprises. Consequently, this is mutually beneficial for the public sector and the private sector.

# List of References


2017 Annual Work Report. AOPA (2017), available at: http://www.aopa.org.cn/Content_Detail.asp?Column_ID=44848&C_ID=20012464.

"2018 Postdoctoral Innovation Talent Support Program Highlights". Mohrss (2018), available at: http://www.mohrss.gov.cn/SYrlzyhshbzb/dongtaixinwen/buneiyaowen/201803/t20180301_289072.html.

"A discussion on the development of airworthiness of civilian drones in China". Sohu.com (2015), available at: http://www.sohu.com/a/2112314_115926.

"A Notice on Frequency Usage of Unmanned Aerial Vehicle System". MIIT (2015), available at: http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057735/n3057748/n3057752/c3653837/content.html.

Abercrombie, N., Hill, S., & Turner, B.S. (1994). *Dictionary of sociology* (3rd ed.). Harmondsworth, UK: Penguin.

"About CAAC – departments". CAAC, available at: http://www.caac.gov.cn/en/GYMH/BMJS/.

"About CAAC – main functions of CAAC". CAAC, available at: http://www.caac.gov.cn/en/GYMH/ZYZN/.

"About Ehang". Ehang, available at: http://www.ehang.com/about/.

"Aerial data at your fingertips". 3D Robotics, available at: https://3dr.com/features/.

"Air Traffic Management Measures for Civil Unmanned Aircraft Systems". CAAC (2016), available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=4f8ae58a-7489-4fc9-8e6f-88737f3731ba&code=UAV#down.

"Alibaba's drones deliver packages to islands". The Economic Times (2017), available at: https://economictimes.indiatimes.com/news/international/business/alibabas-drones-deliver-packages-to-islands/articleshow/61545583.cms.

"Analysis of the airworthiness management status of China's civilian UAVs". Carnoc.com (2014), available at: http://news.carnoc.com/list/293/293102.html.

ANAO (2007). Administering regulation: better practice guide. Australian National Audit Office (2007), available at: http://www.anao.gov.au/~/media/Uploads/Documents/administering_regulation_.pdf.

"Announcement on issues concerning the preferential policies on NHTE Income Tax". State Administration of Taxation (2017), available at: http://www.chinatax.gov.cn/n810341/n810765/n2511651/n2511693/c2805187/content.html.

Armstrong, A.J. (2010). Development of a methodology for deriving safety metrics for UAV operational safety performance measurement. Report of Master of Science in Safety Critical Systems Engineering at the Department of Computer Science, the University of York.

Ashford, N. A. (2000). An innovation-based strategy for a sustainable environment. In J. Hemmelskamp, K. Rennings, & F. Leone (Eds.), Innovation-oriented environmental regulation: *Theoretical Approach and Empirical Analysis* (pp. 67–107). New York/Berlin: Springer-Verlag.

Ashford, N. A., Ayers, C. and Stone, R. (1985). Using regulation to change the market for innovation. *Harvard Environmental Law Review*, 9, 419–466. Harvard University Press, Cambridge/London.

Ballaster, R., Firman, A., & Clot, E. (2017). *A Practical Guide to Drone Law* (3rd ed.). Somerset: Law Brief Publishing, Minehead.

Bemelmans-Videc, M.L., Rist, R.C. and Vedung, E. (2003). *Carrots, Sticks & Sermons: Policy Instruments & Their Evaluations, Transaction*. Transaction Publishers, London.

Bergek, A., Hekkert, M., Jacobsson, S. (2008a). Functions in innovation systems: a framework for analysing energy system dynamics and identifying system building activities by entrepreneurs and policy makers. In: Foxon, T., Killhler, J., Oughton, C. (Eds.), *Innovations in Low-carbon Economy*: pp. 79e111. Edward Elgar, Cheltenham/Northampton.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy* (37), 3, 407-429. Elsevier, London.

Bergek, A., Jacobsson, S., Hekkert, M. (2007a). Functions in innovation systems: A framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policy makers, in Foxon, T., Köhler, J., Oughton, C. (Eds.), *Innovations for a Low Carbon Economy: Economic, Institutional and Management Approaches*. Edward Elgar, Cheltenham/Northampton.

Bissonnette, G. R., & Smith, R. E. (2017). Drone law. NBI, Inc, Eau Claire.

Blom, J.D. (2009). Unmanned aerial systems: a historical perspective (occasional paper 37). Combat Studies Institute (CSI) Press, Fort Leavenworth.

Bode (2016). "The judgement on DJI from UAV enthusiastic" Zhihu.com, available at: https://www.zhihu.com/question/27968317, retrieved on January 15, 2016.

Borrás, S. and Edquist C. (2013). The choice of innovation policy instruments. *Technological forecasting and social change,* 80.8: 1513-1522. Elsevier, New York.

Boyle, M. J. (2017). *Legal and ethical implications of drone warfare*. Routledge, London.

Bressers, H.A., O'Toole, L.J., (2005). Instrument selection and implementation in a networked context. In: Eliadis, P., Hill, M., Howlett, M. (Eds.), *Designing Government: From Instruments to Governance*. McGill-Queens University Press, Montreal.

Brownswood, R. (2008). *Rights, regulation and the technological revolution*. Oxford University Press, Oxford.

Bruijn, H.A. and Hufen, H.A.M. (1998). The traditional approach to policy instruments, in: G.B. Peters, F.K.M. nispen (Eds.), Public Policy Instruments. *Evaluating the Tools of Public Administration*: pp. 11-32. Edward Elgar, Cheltenham/Northampton.

Carlsson, B., Stankiewicz, R. (1991). On the nature, function, and composition of technological systems. *Journal of Evolutionary Economics*: 1, 93-118. Springer.

Chamberlain, P. (2017). *Drones and journalism: how the media is making use of unmanned aerial vehicles*. Routledge, Taylor & Francis Group, Abingdon.

Chamayou, G. (2015). *A theory of the drone*. The New Press, New York.

Chandler, M. (2017). *Recreational drones*. Capstone Press, North Mankato.

"Changjiang Scholars Program". China University of Mining an Technology, available at: http://eng.cumt.edu.cn/whangjiangwcholarswrogram/list.htm.

Chase, M.S., Gunness, K.A., Morris, L.J., Berkowitz, S.K. & Purser, B.S. (2015). Emerging trends in China's development of unmanned systems. RAND Corporation: RR-990-OSD 2015. RAND.org, Santa Monica.

"China fuels boom in domestic tech start-ups". FTtimes (2017), available at: https://www.ft.com/content/b63ee746-afc6-11e7-aab9-abaa44b1e130.

"China Launches First Operational Rules for Civil Unmanned Aircraft." HoganLovells (2016), available at: https://www.hlmediacomms.com/2016/01/21/china-launches-first-operational-rules-for-civil-unmanned-aircraft/.

"China Puts into Effect New Drone Registration Rules." Reuters (2017), available: http://www.reuters.com/article/us-china-drones/china-puts-into-effect-new-drone-registration-rules-idUSKBN18S3M3.

"China to support drone technology in transportation". ChinaDaily (2018), available at: http://www.chinadaily.com.cn/a/201802/08/WS5a7bf019a3106e7dcc13b932.html.

"China's Launching Drones to Fight back against Earthquakes". Wired.com (2017), available at: https://www.wired.com/2017/01/chinas-launching-drones-fight-back-earthquakes/.

Cho, G. (2012). Unmanned aerial vehicles: emerging policy and regulatory issues." *Journal of Law, Information & Science* 22 (2012): 201. Wm W Gaunt & Sons Inc, Holmes Beach.

Chong, J., & Sweeney, N. (2017). Civilian drone use in Canada. Parliamentary Information and Research Service, Ottawa.

"Civil Unmanned Aircraft Real Name Registration Regulations". CAAC (2017), available at: http://www.caac.gov.cn/XWZX/MHYW/201705/t20170517_44079.html.

Clarke, R. and Moses, L.B. (2014). The regulation of civilian drones' impacts on public safety. *Computer Law & Security Review*, 30 (2014) 263-285. Elsevier, London.

COGR (1998). University technology transfer: evolution and revolutions. COGR, New York, available at: http://www.cogr.edu/sites/default/files/University_Technology_Transfer-__Evolution_and_Revolutions.pdf.

"Commercial Drones are the Fastest-Growing Part of the Market". The Economist (2017), available: https://www.economist.com/news/technology-quarterly/21723003-most-drones-today-are-either-cheap-toys-or-expensive-weapons-interesting.

"Construction Guide of UAV Standard System (2017 – 2018 edition)". MIIT (2017), available at: http://www.miit.gov.cn/n1146290/n4388791/c5703886/content.html.

Coyne, A. (2014). "Drone almost collides with Westpac Rescue chopper". itNews (2014), available at: https://www.itnews.com.au/news/drone-almost-collides-with-westpac-rescue-chopper-380875.

Crozier, R. (2013) "CASA blasts 'irresponsible' drone bushfire flyover". itNews (2013), available at: http://www.itnews.com.au/News/361940,casa-blasts-irresponsible-drone-bushfire-flyover.aspx.

Culp, J. (2017). *Drones and the government*. Rosen Publishing, New York.

Custers, B. (2016). *The future of drone use: opportunities and threats from ethical and legal perspectives*. Asser Press, The Hague.

DeGarmo, M.T. (2004). "Issues concerning integration of unmanned aerial vehicles in civil airspace". Center for Advanced Aviation System Development (2004): 4.

"Discussion on the civilian UAV airworthiness development trend of China". Sohu.com (2015), available at: http://www.sohu.com/a/2112314_115926.

"DJI Store". DJI, available at: https://store.dji.com/?gclid=Cj0KCQjw1-fVBRC3ARIsAIifYOPTAZnDF5npECXvLAWk5V-3Kzj-_gyvmSt4t9TszJIgq8o41CF_58IaArFnEALw_wcB.

"Drone market shows positive outlook with strong industry growth and trends". Business Insider (2017), available at: http://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts-2017-7.

"Drone technology: patent landscape analysis" (2016). LexInnova (2016), available at: http://www.lex-innova.com/resources-reports/?id=68.

"Drone was shoot down during Chinese Air Force Missile Brigade training". Sina.com (2016), available at: http://mil.news.sina.com.cn/china/2016-12-01/doc-ifxyiayq1894734.shtml.

"Drones". AEE, available at: https://www.aeeusa.com/aee-drones.html.

"Drones, Reporting for Work". Goldman Sachs Research (2017), available at: http://www.goldmansachs.com/our-thinking/technology-driving-innovation/drones/.

Edquist, C. (2001). The systems of innovation approach and innovation policy: an account of the state of the art. DRUID Conference, Aalborg. 2001.

Edquist, C. (2011). Design of innovation policy through diagnostic analysis: identification of systemic problems (or failures). *Industrial and Corporate Change*: Volume 20, Number 6, pp. 1725-1753. Oxford University Press, Oxford.

Elias, B. (2012). Pilotless drones: background and considerations for congress regarding unmanned aircraft operations in the national airspace system. US Congressional Research Service 7-5700, available at: http://www.fas.org/sgp/crs/natsec/R42718.pdf.

Elliott, A. (2016). *Build your own drone manual: owners' workshop manual*. Haynes North America Inc, Newbury Park.

EPIC. (2005). "Unmanned planes offer new opportunities for clandestine government tracking". Electronic Privacy Information Center, available at: http://epic.org/privacy/surveillance/spotlight/0805.

EPIC. (2013). "Domestic unmanned aerial vehicles (UAVs) and drones". Electronic Privacy Information Center, available at: http://epic.org/privacy/drones/.

EVTank (2015). 2015 Annual Report of the Civilian UAV Market Research.

Faust, D. R. (2016). *Commercial drones* (2nd ed.). PowerKids Press, New York.

"Fence of Unmanned Aircraft System". CAAC (2017), available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=a070ac6b-5096-4de9-976f-000282f97036&code=UAV#down.

"First passenger drone makes its debut at CES". The Guardian (2016), available at: https://www.theguardian.com/technology/2016/jan/07/first-passenger-drone-makes-world-debut.

Fisher, R. (2011). "Maritime Employment of PLA Unmanned Aerial Vehicles," in *China's Aerospace Power: Evolving Maritime Role*, ed. Andrew Erickson and Lyle Goldstein. U.S. Naval Institute, Annapolis, MD.

Flanagan, K., Uyarra, E., Laranja, M. (2011). Reconceptualising the 'policy mix' for innovation. *Research Policy*: 40 (2011) 702-713. Elsevier, London.

"Flying drones/remotely piloted aircraft in Australia". CASA (2017), available at: https://www.casa.gov.au/aircraft/landing-page/flying-drones-australia, retrieved on Nov 26, 2017.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, 12(2), 219-245. SAGE Publications, Thousand Oaks.

Friedewald, M. (2017). *Surveillance, privacy and security : citizens' perspectives*. Taylor and Francis, London.

Gao, G.Z. (2017). On China's regulatory regime for civil Unmanned Aerial Vehicle [J]. *Journal of Beijing University of Aeronautics and Astronautics (Social Sciences Edition)* 2017, 30(5): 28-36. Beihang University Press, Beijing.

Gasiorowski-Denis, E. (2015). "Drone innovation reaches new heights". International Organization for Standardization (ISO) (2015), available at: https://www.iso.org/news/2015/05/Ref1954.html.

"Gartner says almost 3 million personal and commercial drones will be shipped in 2017". Gartner (2017), available at: https://www.gartner.com/newsroom/id/3602317.

"Global Recruitment of Pioneer 'Hundred Talents Program"of CAS'". Chinese Academy of Sciences (2015), available at: http://english.cas.cn/join_us/jobs/201512/t20151204_157107.shtml.

Goh, A. L. (2005). Promoting innovation in aid of industrial development: The Singaporean experience. *International Journal of Public Sector Management*, 18(3), 216–240. Emerald Insight, Bingley.

"Govt. White Papers – Intellectual Property Protection in China". China.org (1994), available at: http://www.china.org.cn/e-white/intellectual/index.htm.

"Govt. White Papers – New Progress in China's Protection of Intellectual Property Rights". China.org (2005), available at: http://www.china.org.cn/e-white/20050421/index.htm.

"Guideline on Deepening the Reforms on Low-Altitude Airspace Management". State Council (2010), available at: http://www.shenyang.gov.cn/zwgk/system/2010/11/02/000115034.shtml.

Gynnild, A. and Uskali, T. (2018). *Responsible drone journalism*. Routledge, an imprint of the Taylor & Francis Group, Milton Park, Abingdon, Oxon.

Hall, E. (2017). *The wonderful world of quadcopters and drones: 28 creative uses for recreation and business* (3rd ed.). Springer, Cham.

Hao, L., Qiu, B. and Cervantes, L., 2016. Does Firms' Innovation Promote Export Growth Sustainably?—Evidence from Chinese Manufacturing Firms. *Sustainability*, *8*(11), p.1173. MDPI, Basel.

Han, W. and Shi, J. (2012). A study on the reform of China's General Aviation Laws and Regulations. *Journal of Transportation Technologies*, 2012, 2, 189-192. Scientific Research, Wuhan.

Heller, M.A., Eisenberg, R.S. (1998). Can patents deter innovation? The anticommons in biomedical research. *Science* 280(5364), 698-701. American Association for the Advancement of Science (AAAS), Washington, DC.

Hepburn, G. (2006). Alternatives to traditional regulation. OECD Regulatory Policy Division; 2006. Undated, apparently of 2006, at: http://www.oecd.org/gov/regulatory-policy/42245468.pdf.

"Hobbyist drones vs. commercial/research drones: how to tell the difference". Robota.us, available at: http://www.robota.us/how-to/hobbyist-drones-vs-commercialresearch-drones-tell-difference/.

Hood, C.C. and Margetts, H.Z. (2007). *The Tools of Government in the Digital Age*. Palgrave, London.

Horowitz, M., Scharre, P., & FitzGerald, B. (2017). *Drone proliferation and the use of force : an experimental approach*. Center for a New American Security, Washington, DC.

Hsu, K. (2014). China's airspace management challenge. U.S.-China Economic and Security Review Commission, available at: https://www.uscc.gov/sites/default/files/Research/China%27s%20Airspace%20Management%20Challenge.pdf.

Hsu, K., Murray, C. and Cook, J. (2013). China's military Unmanned Aerial Vehicle industry. U.S.-China Economic and Security Review Commission, available at: https://www.uscc.gov/sites/default/files/Research/China%27s%20Military%20UAV%20Industry_14%20June%202013.pdf.

Huang, Y., Zhang, Y., Jan, Y., Porter, A.L., Wang, X. (2016). How does national scientific funding support emerging interdisciplinary research: a comparison study of big data research in the US and China. *PloS one*, *11*(5), p.e0154509. Public Library of Science, San Francisco.

"Innovation fund". ChinaTorch.org, available at: http://www.chinatorch.gov.cn/english/xhtml/fund.html.

"Interim Measures for the Management of Business Activities Using Civil Unmanned Aircraft Systems (Draft for Soliciting Opinions) (2018)". CAAC (2018), available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201804/t20180409_56265.html.

"Interim Provisions for Low Level Operation of Light and Small Unmanned Aircraft Systems". CAAC (2015), available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201601/t20160113_26519.html.

"Interim Provisions for Low Level Operation of Light and Small Unmanned Aircraft Systems". Global Drone Regulations Database (2015), available at: https://droneregulations.info/China/CN.html.

"Interim Provisions on the Administration of Civil UAV Pilots". CAAC (2015), available at: https://perma.cc/V4PT-9ER6.

Jaffer, J. (2016). *The drone memos : targeted killing, secrecy, and the law*. The New Press, New York.

"Japan's safety rules on Unmanned Aircraft (UA)/Drone". CAB (2015), available at: http://www.mlit.go.jp/en/koku/uas.html, retrieved on Oct 12, 2017.

Kan S.A. et al. (2001). China-US aircraft collision incident of April 2001: Assessments and policy implications. CRS report for Congress, 2001.

Keane, J.F. and Carr, S.S. (2013). A brief history of early Unmanned Aircraft. *Johns Hopkins APL Technical Digest*, Volume 32, Number 3 (2013).

Krishna, K. R. (2017). *Agricultural Drones : A Peaceful Pursuit*. CRC Press, Boca Ranton.

Krott, M. (2005). Regulatory Instruments. In*: Forest Policy Analysis*: Chapter 9 p219. Springer, Dordrecht.

La Bella, L. (2017). *Drones and entertainment*. Rosen Publishing, New York.

Leavitt, A. J. (2017). *Experimental drones*. Capstone Press, North Mankato.

Leiringer R. (2006). Technological innovation in PPPs: Incentives, opportunities, and actions. *Construction Management and Economics*: 24, 301-308. Taylor and Francis, London.

Levesque, G. and Stokes, M. (2016). Blurred lines: military-civil fusion and the "going out" of China's defense industry. Point Bello (2016), available at: https://static1.squarespace.com/static/569925bfe0327c837e2e9a94/t/593dad0320099e64e1ca92a5/1497214574912/062017_Pointe+Bello_Military+Civil+Fusion+Report.pdf.

Levush, R. (2016). Regulation of Drones. The Law Library of Congress, Global Legal Research Center (2016), available at: https://www.loc.gov/law/help/regulation-of-drones/regulation-of-drones.pdf.

Linder, S.H. and Peters, B.G. (1998). The study of policy instruments: four schools. of thought, in: B.G. Peters, F.K.M. Nispen (Eds.), Public Policy Instruments. *Evaluating the Tools of Public Administration*: pp. 33-45, Edward Elgar, Cheltenham.

Liu, Q., Ge, Z., Song, W. (2016). Research based on patent analysis about the present status and development trends of Unmanned Aerial Vehicle in China. *Open Journal of Social Sciences*, 2016: 4, 172-181. Scientific Research Publishing, Wuhan.

Liu, X., Peng, C. (2015). An evaluation of indigenous innovation policy of China. In: Shome P., Sharma P. (eds) *Emerging Economies*. Springer, New Delhi.

Love, J.H., and Roper, S., 2015. SME innovation, exporting and growth: A review of existing evidence. *International small business journal*, *33*(1), pp.28-48. SAGE Publications, Thousand Oaks.

"Low-altitude Airspace Regulations (Provisional)". State Council (2014), available at: http://news.carnoc.com/list/288/288814.html.

"Made in China 2025". State Council (2015), available at: http://www.cittadellascienza.it/cina/wp-content/uploads/2017/02/IoT-ONE-Made-in-China-2025.pdf.

"Man detained for illegally flying drone near airport in southwest China". China Plus (2017), available at: http://chinaplus.cri.cn/news/china/9/20170424/3527.html.

Miguel Molina, M. and Santamarina Campos, V. (2018). *Ethics and civil drones: European Policies and Proposals for the Industry*. Springer, Cham.

Miller, M. (2015). *The Internet of things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cities Are Changing the World*. Que, Indianapolis.

"Ministry of Agriculture Notice: Subsidizing Plant Protection Unmanned Aircraft". Xinhua.net (2017), available at: http://uav.xinhuanet.com/2017-09/25/c_129711879.htm.

"MOA, MOF and CAAC jointly issued notices - subsidy plant protection UAVs". MOF (2017), available at: http://www.mof.gov.cn/zhengwuxinxi/caizhengxinwen/201709/t20170928_2713895.htm.

Moses, L.B. (2007). Why have a theory of law and technological change? *Minnesota Journal of Law, Science & Technology*: Volume 8 Issue 2 Article 12. University of Minnesota Libraries Publishing, Minneapolis.

Nauwelaers, C., Wintjes, R., (2008). Conclusions and perspectives: adapting old policy institutions to new challenges. In: Nauwelaers, C., Wintjes, R. (Eds.), *Innovation Policy in Europe: Measurement and Strategy*. Edward Elgar, Cheltenham.

"No FLY Zones." DJI.com, available: https://www.dji.com/fly-safe/category-mc?www=v1.

"Notice of the MOST on 'Administrative Measures for the Spark Program'". MOST (2002), available at: http://www.most.gov.cn/fggw/zfwj/zfwj2002/200512/t20051214_54965.htm.

"Notice on Relevant Issues of Pilot Qualification Management for Civil UAVs" (2015). CAAC (2015), available at: http://www.caac.gov.cn/XXGK/XXGK/ZFGW/201606/t20160621_38593.html.

"Notice on the Launching of Reporting Mechanism of Civil UAV Manufacturers". MIIT (2017), available at: http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5653966/content.html.

"NSFC Guide to Programmes 2017". NSFC (2017), available at: http://www.nsfc.gov.cn/english/site_1/funding/E1/2017/12-18/14.html.

OECD (2006), OECD Main Science and Technology Indicators, 2006-I, OECD, Paris.

"Official Notice on Strengthening the Export Control on Certain Dual-Use Items". Mofcom (2015), available at: http://www.mofcom.gov.cn/article/b/c/201507/20150701067575.shtml.

Park, G.(2016). "DJI eye rapid growth with drones, robots". The Korea Herald (2016), available at: http://www.koreaherald.com/view.php?ud=20161206000782.

Park, S.H., Li, S., Tse, D.K. (2006). Market liberalization and firm performance during China's economic transition. *Journal of International Business Studies*: Vol. 37, No. 1 (Jan., 2006), pp. 127-147. Palgrave Macmillan, New Dehli.

Patanakul, P. and Pinto, J.K. (2014). Examining the roles of government policy on innovation. *The Journal of High Technology Management Research* 25.2: 97-107. Elsevier, London.

Pennsyvania Bar Institute. (2017). *What you need to know about drones*. Mechanicsburg: Pennsylvania.

Perez, C. (2012). Innovation systems and policy: not only for the rich? *The Other Canon Foundation*, Norway & *Tallinn University of Technology*, Tallinn. Working Papers in Technology Governance and Economic Dynamic no. 42, available at: http://technologygovernance.eu/files/main//2012071005451212.pdf.

Pollitt, C. (2008). *Time, Policy, Management: Governing with the Past*. Oxford University Press, Oxford.

"PowerVision Store". PowerVision, available at: https://store.us.powervision.me/.

"Product overview". Ascending Technologies, available at: http://wiki.asctec.de/display/AR/Product+Overview.

"Provisions on Managing Air Traffic of Unmanned Civil Aircraft". CAAC (2009), available at: https://perma.cc/UJ4F-N4L7.

"Qingdao is listed as a low-altitude open pilot city - Low-altitude aircraft will shake the trillion market". ChinaNews (2014), available at: http://www.chinanews.com/gn/2014/12-01/6832262.shtml.

"Regulations on Civil Unmanned Aircraft System Pilot". CAAC (2016), available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170527593445127625.pdf.

"Regulations on Real-name Registration of Civil Unmanned Aerial Vehicles". CAAC (2017), available at: http://www.caac.gov.cn/XXGK/XXGK/GFXWJ/201705/P020170517409761154678.pdf.

"Regulations on Real-name Registration of Civil Unmanned Aerial Vehicles Formally Issued by CAAC". CAAC (2017), available at: http://www.caac.gov.cn/en/XWZX/201705/t20170524_44222.html.

Ren, L., Castillo-Effen, M., Yu, H., Johnson, E., Yoon, Y., Takuma, N., Ippolito, C.A. (2017). Small Unmanned Aircraft System (sUAS) categorization framework for low altitude traffic services. NASA (2017), available at: https://utm.arc.nasa.gov/docs/2017-Ren_DASC17.pdf.

"S&T programmes", MOST (2006), available at: http://www.most.gov.cn/eng/programmes1/200610/t20061008_36199.htm.

Salamon, L.M. (2002). *The tools of government, A Guide to the New Governance*. Oxford University Press, Oxford.

Sandvik, K. B., & Jumbert, M. G. (2017). *The Good Drone*. Routledge/Taylor & Francis Group, London.

Schaefer, D. (2015). *China's drone air power and regional security*. K W Publishers, New Delhi.

Schulzke, M. (2017). *The morality of drone warfare and the politics of regulation*. Palgrave Macmillan, London.

Shen, G. (2017). A metrical survey of patents related to unmanned aerial vehicle for year 2015. *Defense Technology Review* (2017): (38) 01, 55-59 DOI: 10. 13943/j.issn 1671-4547. National University of Defense Research Department, Changsha.

Sloggett, D. (2015). *Drone Warfare : the Development of Unmanned Aerial Conflict.* Skyhorse Publishing, New York.

Song, L. and Liu, Z. (2016). National policy: the integration of technology and market economy – With the case of China's Civil UAV. *Journal of University of Science and Technology Beijing (Social Sciences Edition)*: Vol. 32, No. 5, 1008-2689 (2016) 05-0089-07, Oct. 2016. Beijing University of Science and Technology, Beijing.

"Spark Programme", Embassy of China in Ireland, http://ie.china-embassy.org/eng/ScienceTech/ScienceandTechnologyDevelopmentProgrammes/t112842.htm.

Springer, M. (2013). *Project and program management*. Purdue Univ. Press, West Lafayette.

Steinmo, S. (2008). What is Historical Institutionalism? (Chapter 7) in *Approaches in the Social Sciences*, Cambridge University Press, Cambridge.

Stöcker, C., Bennett, R., Nex, F., Gerke, M. and Zevenbergen, J. (2017). Review of the current state of UAV regulations. *Remote Sens*. 2017, 9, 459. MDPI, Basel.

"Taxation and Investment in China 2017". Deloitte (2017), available at: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Tax/dttl-tax-chinaguide-2017.pdf.

"The Future of Possible". DJI.com, available: http://www.dji.com/company.

"The National Special Support Program for High-level Talents", Rencai.com, available at: http://rencai.people.com.cn/GB/362597/370672/index.html.

"The new Enterprise Income Tax law". Treasury Today (2008), available at: http://treasurytoday.com/2008/china/issue1/the-new-enterprise-income-tax-law.

"The thousand talents plan". 1000plan.org, available at: http://www.1000plan.org/en/plan.html.

"The Value of Military-Civil Fusion in this Age", PLA Daily (2010), available at http://news.163.com/10/0704/07/6ANU120R00014AED. html.

"Rural Industrial Technology (Spark) Project". The World Bank, available at: http://projects.worldbank.org/P003529/rural-industrial-technology-spark-project?lang=en.

"Unannounced appearance of mapping drone delays 10 flights at Beijing Airport – 4 drone operators detained by police". Personal Drones (2014), available at: http://www.personal-drones.net/unannounced-appearance-of-mapping-drone-delays-10-flights-at-beijing-airport-4-drone-operators-detained-by-police/, retrieved on Oct 15, 2017.

"Unmanned Aircraft and Cloud System". CAAC (2017), available at: http://pilot.caac.gov.cn/jsp/airmanNews/airmanNewsDetail.jsp?uuid=f3c12dcd-866b-4fe8-97b1-930e2a7d320c&code=UAV#down.

"Unmanned Aircraft Systems". FAA (2017), available at: https://www.faa.gov/uas/getting_started/.

"Unmanned applied solutions". Microdrones, available at: https://www.microdrones.com/en/industry-experts/.

Vasseur, V., Kamp, L.M. & Negro, S.O. (2013). A comparative analysis of photovoltaic technological innovation systems including international dimensions: the cases of Japan and The Netherlands. *Journal of Cleaner Production* 48 (2013) 200-210. Elsevier, London.

Vedung, E. (1998). Policy instruments: typologies and theories, in: M.L., Bemelmans-Videc, R.C. Rist, E. Vedung (Eds.), *Carrots, Sticks and Sermons. Policy Instruments and Their Evaluations, Transaction*. Transaction Publishers, London.

Von Tunzelmann, N. (2003). Historical coevolution of governance and technology in the industrial revolutions. *Structural Change and Economic Dynamics* 14 (2003) 365-384. Elsevier, London.

Wan, Q., Xu, Y. Dong, E. (2015). Diabetic nephropathy research in China: Data analysis and review from the National Natural Science Foundation of China. *Journal of Diabetes*. 2015;7(3):307–14. Peking University, Beijing.

Weber, K.M., Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change. Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy*: 41 (2012) 1037-1047. Elsevier, London.

"Wenchuan earthquake, 2008". DisasterHistory.org, available at: http://www.disasterhistory.org/wenchuan-earthquake-2008.

Whitehouse (2011). A strategy for American innovation. Securing our economic growth and prosperity. Washington DC: National Economic Council, Council of Economic Advisers, and Office of Science and Technology Policy.

Wright, D. (2014). Drones: regulatory challenges to an incipient industry. *Computer Law & Security Review*: The International Journal of Technology Law and Practice 3.30 (2014): 226-229. Elsevier, London.

Wu, T. (2016). "Ningbo: a drone "black fly" crashed and smashed". The Paper (2016), available at: http://www.thepaper.cn/newsDetail_forward_1546553, retrieved on Nov 18, 2017.

Xue, J. (2016). "'UAV night break prison': flights need to be legal and regulated". Opinion.Huanqiu.com (2016), available at: http://opinion.huanqiu.com/plrd/2016-04/8825114.html.

Yaun, K. (2017). *Drones in the classroom*. Rosen Publishing, New York.

Zhang, X. and Wu, J. (2004). Research on Effectiveness of the Government R&D Subsidies: Evidence from Large and Medium Enterprises in China. *American Journal of Industrial and Business Management*, 4, pp.503-513. Scientific Research Publishing, Wuhan.

# Appendix 1 The List of Interviewees

Interviewee 1: Head of Bureau of UAV Controls, Public Security Bureau of Guangzhou. Author's phone interview. Notes of the interviewer. 24 July 2017.

Interviewee 2: Former employee of a major civilian drone company in the south of China. Author's phone interview. Notes of the interviewer. 30 September 2017.

Interviewee 3: Drone flying coach of a UAV pilot training company in Beijing. Author's interview. Transcript. Beijing. 10 October 2017.

Interviewee 4: Professor (in robot automation and engineering, who participated in the R&D of first civilian drones in China) of X University. Author's interview at China (Shanghai) International UAV Exhibition & Development Forum 2018. Notes of the interviewer. Shanghai. 3 April 2018.

Interviewee 5: Director of UAV Application and Control Research Center, Chinese Academy of Sciences. Author's interview at China (Shanghai) International UAV Exhibition & Development Forum 2018. Notes of the interviewer. Shanghai. 3 April 2018.

Interviewee 6: Research personnel of a major civilian drone company in the south of China. Author's online live chat interview. Transcript. 2 May 2018.

# Appendix 2 The List of Interview Questions[84]

1. In what industries civilian drones have more applications?

2. How have civilian drones affected the public security?

3. What is the biggest safety risk of civilian drones?

4. What are effective ways to control and minimize these kinds of risks?

5. How do you evaluate the current regulations concerning the public security of civil UAVs?

6. Do you pay close attention to the government policy actions for civilian drones?

7. Do you think regulative rules will help develop the industry?

8. During the process of R&D, have you ever applied for the supportive programmes for research subsidies and funds?

9. Do you consider government interventions important to your research?

10. Do you believe that policies can promote innovations?

11. Will the contract in the cooperations largely limit your research directions and hinder innovation?

12. What's your interpretation of the recently released document of *Construction Guide of UAV Standard System* (2017 – 2018 edition)?

[84] All interviews were conducted in the Chinese language (the native language of all interviewees) and the transcript is later interpreted into English by the author.

13. Lately the amount of regulative policies for operating drones is increasing, such as the real-name registration, ‘no-fly’ zones. Has your business been affected? Do you think this is negative for the company’s sales and development?

14. Do you have any suggestion on the current regulation?