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China's Organization and Governance of Innovation

– *A Policy Foresight Perspective*

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Abstract: We study China's organization and governance of innovation in this paper from a policy foresight perspective. With its experience of planning systems, China resorts to state intervention in economic and social activities, which profoundly includes research and innovation. The government organizes and governs a vast national science and technology system, most of which is in the state sector, demonstrating the importance and relevance of its research and innovation policy. In this study, 343 innovation policy items, collected in our sample for the period 1990 and 2013, have been scrutinized in a three dimension analytical framework for policy instruments, objectives and implementation. We then abstract and conceptualize the results and findings arrived at the study. Targeted and general purpose policy instruments are categorized. Patterns have emerged revealing the linkages between the targeted policy instruments and the policy objectives. The results and findings based conceptualization contributes to innovate the thinking in innovation policy configuration to advance national innovation constructs.

Key words: S&T, STI, R&D, innovation policy, policy instruments, policy objectives, policy implementation

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1. Introduction and background of study

Technological advance and innovative application of science is pivotal to economic growth. 'Science and technology (S&T) give capital a power of expansion independent of the given magnitude of the capital actually functioning', Marx maintained (Marx, 1867, p418). Schumpeter (1942) conceived creative destruction from exploring Marx's analysis of bourgeois society, its relations of production and means of production and of exchange. The process of creative destruction 'incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one (Schumpeter, 1942, p83). Henceforth one of the major driving forces for economic development is innovation and the associated research and development (R&D), while innovation policy fosters R&D[1]. We pay attention to China's innovation policy that is instrumental to implementing medium to long-term S&T planning frameworks specifically in this study, given its status as the largest emerging economy and the second largest economy in the world. Moreover, with its experience of planning systems, China resorts to state intervention in research and innovation. The government organizes and governs a vast national science and technology system, most of which is in the state sector. Nonetheless, national planning in science, technology and innovation (STI) fields is not unique to China; it's not unique to the former planning economies either. As early as in the 1980s, Roessner (1985) examined the efforts in the US to initiate and implement a national innovation policy, though his assessment of the prospects for a national innovation policy was rather negative at the time. Sokolov and Chulok (2016) studied Russia's priorities for future innovation, and claimed that after the crisis of late 1990s, the government declared S&T as one of national priorities and started increasingly investing in this sector. A number of policy instruments have been introduced to increase the efficiency of STI policies. One of them is S&T

[1] Science and Technology (S&T) and Research and Development (R&D) are associated closely by international organizations. S&T policy, science, technology and innovation (STI) policy and innovation policy are adopted interchangeably by them (*cf.* OECD, 2012, 2014; EC, 2012).

Foresight. Li *et al.* (2017) specifically presented technology foresight in China, which was claimed to have received increasing attention in China among academic scholars and leopolicy makers. '… this large emerging country requires science and technology strategies to realize advancing development based on innovation' (ibid, p246). In general, innovation policies of the European Union (EU) and its assessment of, and influence, on national innovation systems, policies and performance are pervasive.

China was the largest emerging economy included in the Bloomberg top 30 most innovative countries in 2015, where China was ranked 22 overall, up from 25 in 2014 (Bloomberg, 2015). Moreover, China was ranked number one in Manufacturing Capability among the Bloomberg top 30 most innovative countries in 2014 (Bloomberg, 2014). In seven contributing factors[2] to global innovators, China was ranked top ten in other three factors, in addition to Manufacturing Capability. Coupled with its size, the impact and influence of China on the world economy and global innovative capacity are considerable. Now, not fast but sustainable economic growth and development in China is more crucial, not only for China but also for the world in an interwoven global economy. China cannot achieve sustainable economic growth and development by remaining the workshop of the world. Indeed, China's manufacturing capacity, which has turned into excess in many fields, is more a problem for, rather than a solution to, further development. China has to renovate its means of production, the way in which production is organized and products are developed. China has made every effort to transit to an economy modeled on the west at the early stage of transformation, typified by former planning economies and emerging economies. It endured a planning economic system for the large portion of its post revolution period; and the tradition and practice under the planning system remain deeply in its institutions and governance protocols. This is in stark contrast to the west represented by US, Western Europe and Japan who have dominated the world's innovation

[2] They are R&D Intensity, Manufacturing Capability, Productivity, High-Tech Density, Tertiary Efficiency, Research Concentration, and Patent Activity.

landscape, which is compounded by the imparity in the innovation literature between emerging economies and the west and a time lag in research. China has transformed into a market-oriented economy to a certain extent but 'intervened so systematically and invasively in their innovation system' (Liu *et al*., 2011, p918). Research on China's innovation and innovation policy is rare and needs to be bridged by the dominant western literature. Thus Huang *et al.* (2004) have utilized policy practices in the OECD countries as a guideline to examine China's innovation policy in five categories: reform in the public S&T institutions, financial policy, business innovation support structure, human resource policy and legislative actions. Indeed, OECD is one of the major sources for documenting China's innovation and innovation policy, and OECD (2008) has detailed China's R&D and innovation in state research institutes and higher education institutions and presented the evolution of China's S&T systems. The present paper is a focused study on China's innovation policy, the examination of which fills a gap in the literature, producing comparable corroborated evidence for China to contrast with the practice and corroborated evidence of the west readily available in the literature. Being the largest, most powerful emerging economy and R&D engine, China has been proactively integrating the rest of the world at this stage of development, which has become increasingly assertive. Specifically, our study maps innovation policy objectives with innovation policy instruments and implementation in a three dimensional analytical framework, which enriches general innovation studies and general policy studies. It is a timely study of China's innovation policy while its innovation activity is making impact beyond the national borders.

The rest of the paper proceeds as follows. The next section reviews the prior studies, which is centered on research design for the present study in a three policy dimension analytical framework, substantiated with the analysis of reviewed studies. It is followed by research design for the execution of the empirical work, introducing our samples and variables, together with their sources, features and coding. The paper then proceeds to implement the empirical work in conformity to the theoretical framework, analyzing the results that across the three policy dimensions. The final section concludes this study.

2. Theoretical framework – policy instruments, objectives and implementation for innovation

A policy in general is a set of principles to guide decisions and direct actions to achieve rational outcomes. Policy and policy studies, concerned with the pursuit of goals and objectives, take on matters from foresight or futures perspectives; whereas policy makers set to achieve policy goals and objectives by implementing policy instruments. 'That is, when an instrument is selected to achieve a particular public purpose, what implementation problems are presented?' (Peters, 2000, p41). While it has always been the case that policy instruments have to be implemented to achieve policy objectives, recent studies such as Peters (2000) and Nill and Kemp (2009) make policy implementations explicit. This is particularly valuable for assessing the effectiveness of policy instruments, because 'discussions about the relative merits of policy instruments are often conducted as if they were self-implementing and administration was irrelevant to their success or failure' (Peters, 2000, p36). The additional two dimensions of 'problem – constraints' in Nill and Kemp (2009) can be fittingly considered to be the implementation problem in Peters (2000). Therefore, this study is carried out with a three-dimension framework for policy objectives, policy instruments and policy implementation.

Policy instruments are the most concrete among three policy dimensions; they are the carrier of policy. 'The choice of policy instruments constitutes a part of the formulation of the policy, and the instruments themselves form part of the actual implementation of the policy' (Borrás and Edquist, 2013, p1513). Bemelmans-Videc *et al.* (1998) offer a comprehensive analysis of categories and typologies of policy instruments. It presents examples of studies of the three categories of policy instruments: regulation (sticks), economic means or subsidies (carrots), and information campaigns (sermons) (ibid, pp10-12). Rothwell and Zegveld (1981) classify policy instruments into three types, namely, supply side, environmental side, and demand side instruments. With regard to innovation policy, the typology of Edler *et al.* (2013) distinguishes between supply side instruments and demand side instruments, the former influences innovation generation and the latter influences those requesting, buying or applying innovations (p1). 'There is strong theoretical reasoning and empirical evidence that demand is crucial for innovation activities' (Edler, 2013, p2). The EU has stressed the role of demand side measures, policies and measures to foster the market uptake of innovations, in recent years. The Communication of the European Commission (EC) on 'Europe 2020 Flagship Initiative Innovation Union' highlights that: 'The potential of the single market should also be activated through policies that stimulate the demand for innovation, starting with an effective competition policy' (EC, 2010, P15). It points out: 'Whereas most previous EU policy initiatives have focused on supply side measures which tried to push innovation, demand side measures give markets a greater role in "pulling" EU innovation by providing market opportunities' (ibid). Demand side innovation policy tools and measures complement supply side innovation policy tools; therefore, effective links between them should be established, maintained and developed. The Organization for Economic Co-operation and Development (OECD) and the World Bank take the similar stance. 'In recent years, OECD countries from Finland to Australia and emerging economies such as China and Brazil have used more targeted demand side innovation policies such as public procurement, regulation, standards, consumer policies and user led innovation initiatives, as well as "lead market" initiatives, to address market and system failures in areas in which social needs are pressing' (OECD, 2011, p9). 'This interest in demand side innovation policy has emerged as part of a greater awareness of the importance of feedback linkages between supply and demand in the innovation process' (ibid).

It seems that the recent emphasis on demand side instruments has over reacted to 'correct' the traditional reliance on supply side policy instruments, which makes the boundary between demand side and supply side instruments more blurred, as some policy instruments can't be simply 'pushing' or 'pulling'. In this sense, the three-category classification by Rothwell and Zegveld (1981) prevails in accommodating the tributes and features of various policy instruments. Therefore, we adopt demand side, supply side, and environmental side policy instruments as the three major policy instrument categories in this paper. Accommodating both 'pushing' and 'pulling' ingredients to varied degrees, environmental side instruments campaign to foster innovation by providing a regulative and infrastructural environment for all kinds of innovation activities and, among them, innovation diffusion which bridges innovation generation and innovation adoption. While supply side instruments attempt to push innovation by supporting innovators for innovation generation and outwards diffusion, demand side instruments aim at pulling innovation by creating market opportunities for innovation adoption and inwards diffusion. Based on the above deliberation, this categorization is generic and applicable generally to the developed and developing economies, with some economies paying more attention to demand side policy instruments while some others relying more on supply side instruments or valuing environmental side instruments specifically. It is expected that planned economies resort to supply side policy instruments primarily, while there is a greater role for the market to play in capitalist economies.

We elaborate further on the categorization of policy instruments with examples and in the above analytical framework. Tax incentives scheme is accordingly environmental, incentivizing innovation creation and helps innovation diffusion to benefit innovation adoption which is broader than the demand side measure of 'market uptake of innovation'. These include reduced corporate income tax rate for new and high technology enterprises, deduction of R&D expenses for corporate income tax purpose, corporate income tax exemption or reduction on income derived from qualified technology transfer, different corporate income tax holidays for software and integrated circuit enterprises. Enterprises gain from operating in such environments, to speed up innovation diffusion and pass certain benefit onto innovation adoption through lowering product prices. The latter achieves the similar effect of a demand side measure for reducing tax payment on innovation products, but it is indeed originated on the supply side and fostered in such a pro innovation environment. Collaboration mechanisms are demand side as if an internal market is created to pull innovation by providing market opportunities, which is the measure promoted by the EC (Suriñach *et al.*, 2011). For instance, collaboration between industry, HE institution and R&D institution is to promote commercialization of innovation and R&D products and to make it easy for innovation adoption by the industry and business firms.

Policy objectives are specific and measurable while policy goals are broad and general. To organize innovation policies into typologies, Edler *et al.* (2013) have reviewed a total of 1402 reference items, including 197 evaluation reports, 584 academic analyses with evaluation evidence, and 621 other documents. They have identified seven major innovation policy goals through synthesizing the key findings and insights in these reports and documents. These goals are: (1) increasing research and development investment; (2) augmenting skills; (3) enabling access to expertise; (4) strengthening system-wide capabilities and exploiting complementarities; (5) enhancing innovation demand; (6) improving frameworks for innovation, including regulation and standards; and (7) facilitating exchange and dialogue about innovation (p1). They present the goals and their degrees of relevance to a range of demand side and supply side instruments (ibid, p7). With specific reference to innovation voucher schemes, the stated policy goals in Flanagan *et al.* (2011) are: (1) stimulating/raising level of demand for R&D in firms; (2) supporting R&D performing institutions; (3) promoting collaboration; (4) making public R&D more responsive to demand signals; and (5) matching supply of and demand for knowledge in the same region. Suriñach *et al.* (2011) point out: 'It is important to notice, in fact, that the IM (Internal Market) regulations designed by the European Commission are generally aimed at achieving specific objectives which usually abstract from the direct goal of fostering innovation adoption or creation' (p99). There is the vast literature on diffusion of technology, innovation and/or R&D, and Suriñach *et al.* (2009) provide a comprehensive review of the diffusion/adoption literature, as well as empirical evidence. They reveal that: 'Generation of innovation would be mainly driven by some sectors and then adopted in other sectors' (ibid, p44). Pierce and Delbecq (1977) define 'innovation is a process including three stages: generation, acceptance, and implementation' (p29). Synthesizing the above goal of fostering innovation adoption or creation with the diffusion literature and the stages conjecture of innovation, (fostering) generation of innovation, diffusion of innovation, and adoption of innovation are adopted as the three broad innovation policy goals in this study, into which specific policy objectives are categorized.

Policy implementation 'is what develops between the establishment of an apparent intention on the part of government to do something, or to stop doing something, and the ultimate impact in the world of action' (O'Toole, 2000, p264). 'Policy implementation as a field of scholarly inquiry and practical recognition has come and gone like an elusive sprit' (deLeon and deLeon, 2002, p467), because 'it was either too difficult to study or, conversely, too simple (ibid, p469). Thus, the implementation issue or dimension is either circumvented – being too difficult, or ignored – being too simple, in much of actual policy research. deLeon and deLeon (2002) examine three generations of policy implementation theory research. The first generation of implementation studies usually consisted of case study analyses that considered the immense vale of troubles that lay between the definition of a policy and its execution (ibid, 469). The second generation '… assumed a command and control orientation, … known as a top-down perspective', … and 'an alternative approach … claimed to be bottom-up orientation' (ibid, p470). Top-down and bottom-up models are mostly recognized but have met much criticisms; now they have rarely been adopted in practice and only mentioned as a theory in textbook materials. The third generation 'sought to explain "why behavior varies across time, across policies, and across units of government and by predicting the type of implementation behavior that is likely to occur in the future"' (ibid, p471). Contingency theories are typical of the third generation of implementation research. Matland (1995) has proposed a kind of contingency model with two dimensions of ambiguity and conflict. 'Four implementation perspectives are developed in the ambiguity/conflict model, based on a policy's ambiguity and conflict level' (ibid, p155). His model draws extensively on the work of organizational theorists and decision-making scholars, along the line of Sorg (1983) who has recognized 'the contributions of institutional and policy characteristics to the success, failure, or modification of policies' (p391). Developing further the two by two general typology of Sorg (1983) for policy implementation, Matland (1995) exhibits the four implementation processes or perspectives in the four cells in the conflict-ambiguity matrix. The first is named 'administrative implementation' with low policy ambiguity and low policy conflict. 'The central principle in administrative implementation is outcomes are determined by resources' (ibid, p160). The second is 'political implementation' with low policy ambiguity and high policy conflict. 'The central principle in political implementation is that implementation outcomes are decided by power' (ibid, p163). The third is 'experimental implementation' with high policy ambiguity and low policy conflict. 'The central principle driving this type of implementation is that contextual conditions dominate the process' (ibid, pp165-166). Lastly, there is 'symbolic implementation' where both levels of policy ambiguity and policy conflict are high. 'The central principle is that local level coalition strength determines the outcome' (ibid, p168). Reviewing the OECD science policy-making model, Henriques and Larédoc (2013) suggest that 'OECD science policy reviews in the 1960s addressed the issue of how, with whom and in which format policy-making in S&T policy should be implemented by national governments to favour knowledge production and exploitation linked to economic growth' (p804). They stress that the OECD model 'is centred on the creation of structures, actors and functions that enable the policy cycle to deploy in the field' (ibid). It is revealed that, given the complexity in policy implementation and the need for reducing ambiguity and conflict in policy implementation, the institutional and policy characteristics have been considered to be paramount in theory and practice, with which we examine policy implementation in this study.

{Figure 1 about here}

We summarize the three dimensional theoretical and analytical framework with the help of Figure 1. It shows that the three policy dimensions are not identical; there is an expected causal relationship from policy instruments to policy objectives, and mediating effects of policy implementation for the fulfilment of policy objectives of policy instruments. Policies are issued and implemented to achieve policy objectives/goals. Therefore, a causal relationship is expected from policy instruments to policy objectives/goals for effective policies, as demonstrated in Figure 1. Meanwhile, policy issues' characteristics and policy characteristics are expected to play a role in facilitating the fulfilment of policy objectives/goals of policy instruments in successful policy implementation. Broadly and conceptually, it is to mediate the fulfilment of policy objectives/goals of policy instruments, which is also illustrated by Figure 1. Studies of mediation effects of/in policy implementation at macro levels are rare, much of which has to be learned from institutional level research and case studies, usually with the former involving statistical inferences and the latter no statistical estimation. In this regard, Feiock *et al.* (2003) investigate the mediating role of governance institutions in US municipal reform – mayor-council government versus council-manager government. They remark that 'the form of government is often included as a variable in explanatory model' (ibid, p619). One of the reasons is that 'most research treats institutional effects as additive rather than interactive' (ibid, p619); thereby they advocate the examination of interactive, mediating effects of governance institutions. Saleth and Dinar (2009) point out that 'there is a clear value in developing a generic framework that can formally handle both the impact synergies and the development mediation roles of institutions within the same analytical framework' (p924). In Wong and Li (2011), the benefits of information and communication technology on student learning is mediated by pedagogical and organizational factors, among others, in a school setting. Bearing the scarcity and difference in mind, we attempt to pursue a new line of inquiry into the mediation effect in policy implementation with the three dimensional analytical framework.

3. Research design, samples and variables

There were 343 policy items collected in our sample for the period 1990 and 2013. They were issued by the Standing Committee of the People's Congress, the legislature; the State Council, the executive; the Ministry of Science and Technology, the Ministry of Commerce, the Ministry of Finance, the Ministry of Education and other ministries that form the State Council; and non-cabinet departments and agencies. The policy variables describe policies in three dimensions of policy instruments, policy objectives/goals and policy implementation. Table 1 lists these policy variables with their narratives. The demand side policy instruments include three elements: public procurement, industry-HE institution-R&D institution collaboration, and international collaboration. There are four items included in the supply side: support for medium and small enterprises (MSEs) and small and micro enterprises (SMEs), fiscal support and subsidies, financial support, and human resources. The environmental side instruments consist of five items: administrative support, infrastructure support, enhancement in intellectual property protection, tax incentives, and standards setting. With regard to policy objectives, there is one policy objective of S&T development for the innovation generation goal. There are two policy objectives of technological transformation and technical exports for the diffusion goal. The adoption goal includes two objectives: technical absorption and technical imports. On the policy implementation dimension, institutional characteristics are featured by legislature, which is the National People's Congress of China; the executive is the State Council, and the ministries and departments that form the State Council; bureaus or agencies are non-cabinet government agencies and departments. Policy characteristics are reflected by the degrees of enforcement at five levels: laws, administrative regulations, measures, notifications and provisos.

The coding of the policies and their representative variables is as follows. Dummy variables are adopted for all policy instruments and policy objectives. For example, ID1 is 1 when a policy instrument is concerned with public procurement, 0 otherwise; GD2 is 1 when a policy instrument addresses technical exports, 0 otherwise. For institutions, IC1, IC2 and IC3 are also dummy variables; IC1 is 1 when the policy is issued by the legislature, 0 otherwise; the same coding is adopted for IC2 and IC3. The value of IC4, joint issue, is the number of entities who have jointly issued the policy. Policy characteristics are measured by degrees of enforcement of policies. PC1 is coded 5 when a policy is passed into law, 4 when a policy is administrative regulation, 3 for measures, 2 for notifications and 1 for provisos. Policy instruments are not mutually exclusive; e.g., a policy item for financial support can, at the same time, be on infrastructure support within the supply side. A policy item can also contain two or more instruments on different sides; e.g., a policy item for infrastructure on the supply side can also involve administrative support on the environmental side. The sum of percentages can therefore be over 100 percent. So are policy objectives; e.g., a policy item can be issued to achieve both objectives of technical imports and technical absorption. Since every policy item has three dimensions, it must be represented by at least three dummy variables, e.g., it is a supply side instrument of financial support (IS3 = 1), its policy objective is technical exports (GD2 = 1) and it is issued by the executive (IC2 = 1). In addition, a policy item is reflected by two non-dummies, IC4 for the number of entities involved and PC1 for the degree of policy enforcement.

{Table 1 about here}

4. Mapping policy goals with policy instruments and implementation

4.1. Policy, planning and foresight

China's innovation policy is the instruments to implement the national medium to long-term planning for S&T, projecting the long-range prospects of S&T development, and setting guiding principles, development goals and overall deployments. Martin (2010) addressed the origins of the concept of 'foresight' in science and technology, originated in 1983 in the renowned Science Policy Research Unit (SPRU) at University of Sussex. '"Technology foresight" is a term now widely used by academic researchers, policy-makers, industrialists, consultants and others round the world' indicated the association between foresight and policy (ibid, p1438). Miles (2010) provided a review of the development of technology foresight, which 'took off in the 1990s, as European, and then other, countries sought new policy tools to deal with problems in their science, technology and innovation systems' (p1448). These studies stipulated the association between the original concept of technology foresight and the practice in China, and the evolution from practice to theory, and then to practice again albeit at a higher level.

After the establishment of the People's Republic of China (PRC) in 1949, China launched the first Five-Year Plan in 1953 (National Planning Commission, 1955), which was adjusted to match calendar decades from the third Five-Year Plan that covered 1966-1970. The Five-Year Plan evolved from being economic planning to economic and social planning over time. Its full title was the Five-Year Plan for Developing National Economy initially, and then changed to the Five-Year Plan for National Economic and Social Development from the Seventh Five-Year Plan in 1986 onwards (People's Net, 2017). Correspondingly there has been S&T planning since as early as 1955, because the attainment of economic goals is considered to be dependent on the development in S&T. The State Council set up a Science Planning Commission in 1955, assembling over six hundred scientists to compile the first such planning, *Planning Framework for Long-Range Prospects in S&T Development (1956-1967)*, or *The Twelve-Year S&T Planning* (Ministry of Science and Technology, 2017). The latest was *Planning Framework for National Medium to Long-Term S&T Development (2006-2020)* (State Council, 2006a). In between, there were several other documents of S&T planning: *Planning for S&T Development (1963-1972)* compiled and implemented in 1963, *Planning Framework for National S&T Development (1978-1985)* in 1978, *Planning for S&T Development (1986-2000)* in 1982, *Planning Framework for National Medium to Long-Term S&T Development* together with *Ten-Year Planning for S&T Development of People's Republic of China and the Eighth Five-Year Planning Framework (1991-2000)* implemented in 1992 (Ministry of Science and Technology, 2017). Since the Eleventh Five-Year Planning cycle in 2006, S&T planning has been aligned with economic and social planning. Such that *Eleventh Five-Year Planning for National S&T Development* was compiled and issued by Ministry of Science and Technology in 2006 and *Twelfth Five-Year Planning for National S&T Development* in 2011. Since *Planning Framework for National Medium to Long-Term S&T Development (2006-2020)* was issued in 2006 just before *Eleventh Five-Year Planning for National S&T Development*, the latter was more about the concrete implementation of the former in the first five years. So far, *Planning Framework for National Medium to Long-Term S&T Development (2006-2020)* or *S&T Planning Framework (2006-2020)* remains the latest S&T planning framework.

These plans and planning frameworks were aligned with the nation's strategic goals of Four Modernizations, set forth formally for the first time by the then Premier Zhou Enlai in 1964 which encompass industry, agriculture, defense and science and technology (Zhou, 1964), while its prototype was proposed 10 years before (Zhou, 1954). It was put forward in *Planning for S&T Development (1963-1972)* that 'the modernization of science and technology is the key to achieving the modernizations in industry, agriculture, defense and science and technology'. It has been stressed that S&T is the forces of production, which was first formally phrased in *Planning Framework for National S&T Development (1978-1985)*, though 'fully utilizing S&T achievements to raise social productive forces', 'utilizing daily upgrading technology to push rapid development in productive forces' and so on were documented in all the previous S&T plans since 1956. These expositions presented the profound views of technological determinism, albeit historical materialism and dialectical materialism were in theory the guiding principles in the formulation of planning frameworks for economic, social and S&T development, to project and plan future development stages and phases and deal with complex or dialectical relations and interactions between various economic and social elements and forces.

There have been several milestones in grand planning in foresight to realize Four Modernizations. The phrase 'two bombs and one satellite', i.e., the ability to make atomic bombs and hydrogen bombs and to launch artificial satellites into space orbits, had been grand future dreams since the 1950s, which became true on April 24, 1970 when China successfully launched its first artificial satellite 'The East is Red 1', following the successful nuclear weapon tests for an atomic bomb on October 16, 1964 and a hydrogen bomb on June 17, 1967. The next milestones were crewed spacecraft and the Lunar Exploration Program. Shenzhou 5 was successfully launched on October 15, 2003, carrying the astronaut Yang Liwei in orbit for 21 hours. Phase II of the Lunar Exploration Program for soft landing and deploying lunar rovers was completed successfully ahead of schedule when

Chang'e 3 landed on the Moon on December 14, 2013, carrying the lunar rover Yutu; whereas Phase III entailing a lunar sample return mission was planned to be accomplished by 2020. All of these have been accompanied and made possible by the development in missile and rocket technologies. Many of S&T endeavors have been closely associated with or identical to military technologies, which materially helped foster the commercialization of military technologies for research establishments to stay profitable, one of the aspects to be addressed later in the present paper. China deployed top personnel and key resources for the fulfilment of Four Modernizations, especially the modernizations of defense (technologies) and S&T, by setting up a wide range of government- or military-run research institutes. The most renowned such establishments were the academies of the Ministry of Defense, including the Fifth Academy, Sixth Academy, Seventh Academy and Tenth Academy of the Ministry of Defense. The Fifth Academy was for the development of space technology and astronautic engineering, as well as tactical or short to medium range missiles; the Sixth Academy was for the development of aeronautical technology; the Seventh Academy was for shipbuilding, naval radar electronic warfare, underwater acoustic electronic warfare, and communications and navigation systems; and the Tenth Academy was for the development of military communications equipment. They became a dominant part of, or formed, the Ministry of the Seventh Machinery Industry, the Ministry of the Third Machinery Industry, the Ministry of the Sixth Machinery Industry, and the Ministry of the Fourth Machinery Industry, respectively. These ministries later assumed their explicit names in 1982 as Ministry of Astronautics Industry, Ministry of Aeronautics Industry, Ministry of Shipbuilding Industry and Ministry of Electronics Industry.

The above contextual exploration has presented the grand roadmaps for S&T advancement and supremacy. It has demonstrated how the government planned, directed and fine-tuned S&T activities in pursuit of its long-term goals of Four Modernizations to become one of the leading powers in the world. Plans and Planning Frameworks, by setting guiding principles, development goals, key tasks and overall deployments, presented roadmaps for industries, sectors and fields, which became more comprehensive over time. For example the latest *S&T Planning Framework (2006-2020)* identified key areas and priority themes, decided key special projects, technology frontiers and supported disciplines in fundamental research. New to *Planning Framework (2006-2020)* was the second part of Section VIII 'Reform of the S&T Governance and the Assembly of National Innovation System', a shift towards and an emphasis on innovation, which was deliberated earlier while the present study is aligned with. Fundamental policy guidelines and measures were addressed, the implementation of which was stipulated in an additional, separate document *Supporting Policies for Implementing 'Planning Framework for National Medium to Long-Term S&T Development (2006-2020)'* (State Council, 2006b). Covered in *Supporting Policies* were S&T input, tax incentives, financial support, public procurement, technical absorption, intellectual property, human resources, S&T bases and platforms, coordination between government departments in supporting innovation activities. These policy areas, together with those in previous planning frameworks over decades, are synthesized into policy variables and concealed in the present study. Policy instruments are the carrier of policy, implemented to achieve the envisaged policy goals. The development goals set in the medium to long-term planning framework are the grand goals, which will be realized through the implementation of a series of policies rolling out in sequence in perceived future. Thus mapping policy instruments with policy goals is a concrete step to assess the extent to which planning has been effective, helping improve and adjust future policy design and planning.

4.2. Overview

The general innovation policy profile in China is summarized in Table 2, presenting the number of policies in each category across the three policy dimensions and the percentage of policies in that category, except the last two rows. The number of environmental side instruments was by far the largest, accounting for over 70 percent of total implemented policy instruments (62 percent after adjustments). Between supply side instruments and demand side instruments, the former were used predominantly relative to the latter. A very small number/percentage of demand side instruments were put forward, accounting for less than 5 percent of total implemented policy instruments (4 percent after adjustments); whereas supply side instruments comprised over 40 percent (34 percent after adjustments). Only recently demand side measures were considered and adopted to a modest extent that give markets a greater role in pulling innovation by providing market opportunities. Whereas supply side instruments still played a dominant role as they had traditionally done, pushing innovation by supporting innovators for innovation generation and outwards diffusion. China has been ambitious since 1949 so that innovation generation was always top on agenda of government policy, while innovation adoption was considered of secondary importance which was left with enterprises and markets.

Table 3 and Figure 2 detail the issuances of innovation policies by year between 1990 and 2013. It can be observed that policy issuances climaxed in the early 1990s and then in the second half of the first decade in the new millennium. The period 1990 – 2013 can be divided into three sub-periods or stages according to China's progress in reforms. The first stage was the structural reform of S&T systems from 1990 to 1994; the second was the deepening reform stage of S&T systems between 1995 and 2005; and the third was the creation of innovation systems since 2006. There were relatively fewer issuances of innovation policies in the second stage, which was to consolidate the fulfilments attained in the first stage with the old concept of S&T and R&D focusing on hardware build-ups. It was not until recently that innovation was put high on the agenda, which produced a new round of passion in innovation policy formulation and issuance. Thus new policies or policy measures rarely replaced the old ones; they opened up the new fields or augmented the old measures.

{Table 2 about here}

{Table 3 about here}

{Figure 2 about here}

China valued the importance of environmental side instruments. It resorted to the environmental side instrument of administrative support considerably, accounting for approximately 46 percent of total implemented policy instruments. Instruments with intellectual property protection and tax incentives characters were also commonly used, accounting for around 11 percent. The supply side instruments instigating human resources accounted for more than a fifth of instruments in China, being the largest percentage among supply side policy instruments. Financial support was the second most frequently used supply side instruments with approximately a one tenth share, followed by fiscal support and subsidies.

It has been demonstrated that China paid great attention to S&T development for the fulfilment of the objective of innovation generation, accounting for nearly 43 percent among all policy objectives. Transited from a planning economy and system, fundamental research traditionally enjoyed higher priorities, being dominated by the state sector. In contrast, technical diffusion and adoption of innovation were regarded less important, at least from the point of view of policy formation. These objectives were largely left for enterprises and R&D establishments to achieve for themselves. Nonetheless, China was keen on the commercialization of military technologies – transforming military technologies for commercial utilization to generate earnings. As such, technical transformation accounted for more than 17 percent among all policy objectives in China.

Characteristically, China resorted to joint issues to strengthen policy implementation. There were 108 policies that were jointly issued by two or more entities, accounting for nearly one third of the total of 343 policies. The average number of government entities involved in joint issues of policies was 1.69. On the policy characteristics side, the degree of enforcement in China was low – many policies were measures, notifications and provisos, fewer were administrative regulation and laws passed by the National People's Congress were rare.

To provide an intuitive perspective on purposes of implemented policies, Table 4 provides the preliminary statistics in terms of correlation matrix that exhibits the relationships between policy goals (disaggregated into policy objectives) and policy instruments and implementation. Given the data types in this study, Spearman's rank correlation method is employed for the estimation of correlation coefficients. As to a relationship to exist between a policy objective and a policy instrument, only a positive significant correlation matters for dummy variables; a negative significant correlation has the same meaning as insignificant correlations in this context – not related to each other. The relationship between a policy objective and policy implementation is handled in the same way. Notwithstanding for IC4, number of departments involved in issuing the policy jointly, a significantly negative correlation indicates the fewer, the more likely. It is the same for PC1, degree of enforcement, where a significantly negative correlation indicates the lower the degree, the more likely.

{Table 4 about here}

S&T development, the objective belonging to the goal of innovation generation, was of paramount importance in China. The supply side instrument of fiscal support and subsidies was adopted for the fulfilment of innovation generation, the correlation coefficient being positively significant at the 5 percent level. China further adopted the supply side instrument of financial support to achieve the objective of innovation generation, with the correlation coefficient being positively significant at the 5 percent level. China also made use of two demand side instruments of industry-HE institution-R&D institution collaboration and public procurement for innovation generation, though the linkage was at a lower significance level of 10 percent. With regard to the policy goal of innovation diffusion, China was pro-active in fulfilling the objective of technological transformation – primarily to transform military technologies for commercial utilization; the coefficient of an environment side instrument of standards setting that fostered commercialization processes was positive and highly significant at the 1 percent level. China was keen on promoting technical exports and attempted to promote technical exports in a direct way by employing the supply side policy instruments of financial support and the environment side instrument of administrative support, with the coefficients being positively significant at the 1 percent and 10 percent respectively. China adopted two environment side instruments of administrative support and infrastructure support to promote technical absorption, with the correlation coefficients being positively significant at a modest level of 10 percent. China provided tax incentives for technical imports, with the coefficient of this environment side instrument being positively significant at the 1 percent level.

Policy implementation helped achieve policy objectives/goals of policy instruments. According to the correlation matrix, China attempted to augment the attainment of technical absorption, technical imports and technical exports by joint issuances of policies, with the coefficients of IC4 with GA1, GA2 and GD2 being positively significant at the 5 percent or 1 percent level. Given these preliminary statistics, we will test whether, how and the extents to which policy implementation variables mediate for the criterion of policy goals in the next sub-section.

4.3. Results, analysis and discussion

Analysis of the innovation policy profile and preliminary statistics provides a broad picture and certain clue about the relationships and interactions among the three policy dimensions. However, correlation matrixes are symmetric, treating the three policy dimensions identically. Thus, preliminary statistics and correlation coefficients cannot reveal the causal relationships from policy instruments to policy goals, which will be achieved by the means of regression analysis. Moreover, the discussion and analysis in the previous section indicate the need for examining the mediating role in policy implementation. We thereby carry out such research at this point.

Mediating variables are important not only for identifying an indirect causal path, but also for detecting a missing direct causal path that would otherwise have vanished unnoticed. Many have turned a blind eye to the practical phenomena in testing mediating effects, the outcome of which does not conform to the conventional definitions of mediation and is largely ignored. MacKinnon *et al.* (2000) provide an excellent review of mediation, confounding and suppression effects with insightful discussion. One of the important points is that the mediating effect does not necessarily reduce the magnitude/significance of the coefficient for the direct route from the independent variable to the dependent variable; it may increase the magnitude/significance of the coefficient for the direct route. MacKinnon *et al.* (2000) call the latter a 'suppressior variable' ('suppression effect') (p175). In Breslow and Day (1980), the former is 'positive confounding' and the latter 'negative confounding' (p95). Mediation and confounding are identical statistically and can be distinguished only on conceptual grounds (MacKinnon *et al.*, 2000, p173). For the sake of familiarity in the non-statistics community, we label the former straight mediation and the latter augmenting mediation in this study.

Logit binary choice models and Poisson count models are adopted for empirical estimations in this study, given the property of the data. Probit models have produced nearly identical results as Logit models, though the results from Poisson count models and Logit models are close too. So the results from Poisson count models and Logit models are provided, analyzed and discussed. In the following, Table 5 reports the regression results from estimating Logit models; whereas Table 6 presents the results of Poisson count models. Same as the correlation analysis in the previous sub-section, only positively significant coefficients count for the variables' contributions. Insignificant coefficients of instruments imply that they were not designed specifically for a single policy objective – generally encouraging or regulating innovation activities across a range of policy objectives. The two tables do not include the variables that are not applicable in estimation. Legislature (IC1) is excluded (as the base case for institutions), which is otherwise a function of complete linear combinations of executive (IC2) and non-cabinet departments (IC3).

{Table 5 about here}

{Table 6 about here}

Let us inspect the instrument – objective/goal relationships, focusing on the mediated model in Table 5 and Table 6. The results from the simple model are contrasted to show the pitfall in neglecting mediation effects. Administrative support (IE1), fiscal support and subsidies (IS2), financial support (IS3) and tax incentives (IE5) were the dominant instruments to achieve specific policy objectives. To a less extent, infrastructure support (IE2), public procurement (ID1) and international collaboration (ID3) played a similar role. The only issuer/policy characteristic to mediate the fulfilment of policy objectives of policy instruments was the number of departments jointly issued the policy (IC4). Fiscal support and subsidies (IS2) and financial support (IS3) were identified as instruments aiming at promoting S&T development (GG1), confirming the previous preliminary analysis. The coefficients for these two instruments are positively significant at the 5 percent level as reported in Table 5.1. Financial support (IS3) was found to contribute to the policy objective of technical exports (GD2), with the coefficient being positively significant at the 1 percent level in Table 5.3 and Table 6.3. The environmental side instruments were also implemented to assist technical exports, the coefficient for the administrative support variable (IE1) being positively significant at the conventional level. Standards setting (IE4) aimed at promoting transformation (GD1), the coefficients being positively significant at the 1 percent level for IE5 in Table 5.2 and Table 6.2. That is, the government primarily employed the environmental side and supply side instruments to promote innovation diffusion. While two environment side instruments of administrative support (IE1) and infrastructure support (IE2) aimed specifically at technical absorption (GA1), the environment side instrument of tax incentives (IE5) was used for promoting technical imports (GA2). The coefficients of IE1 and IE2 are positively significant at the 5 percent level in Table 5.4 and Table 6.4 for the former, and the coefficient of IE5 is positively significant at the 5 percent level in Table 5.5 and Table 6.5 for the latter. Additionally, two demand side instruments of public procurement (ID1) and international collaboration (ID3) were also implemented to assist technical imports, with the coefficients being positively significant at the modest level of 10 percent in Table 4.5 and Table 5.5. Such findings indicate that the government primarily employed the environment side and demand side instruments to encourage innovation adoption. It is interesting to note the augmenting mediating effect of the issuer/policy characteristic – joint issues (IC4). The coefficient of fiscal support and subsidies (IS2) becomes modestly significant after being mediated by joint issues. This evidence confirms the importance of mediating variables and effects for detecting a missing direct causal path from a policy instrument to a policy objective.

It is noted that augmenting mediation effects of issuer/policy characteristics in policy implementation were more palpable than straight mediation effects. The coefficient of the joint issue variable is statistically positively significant in the estimation for three out of five policy objectives. In the case of technical absorption (GA1), the coefficient of fiscal support and subsidies (IS) becomes positively significant following the mediation of this policy characteristic, while the magnitude of the coefficient has increased as well. To a lesser extent, the coefficient of infrastructure support (IE2) increases in both significance and magnitude, being mediated by the joint issue variable. This observed effect is clearly an augmenting mediation effect, i.e., suppression effect in MacKinnon *et al.* (2000, p175), or negative confounding in Breslow and Day (1980, p95). In the cases of technical imports (GA2) and technical exports (GD2), while the coefficient of one policy instrument increases in magnitude, the coefficient of one other policy instrument decreases in magnitude. Both augmenting mediation effect and straight mediation effect are modest for these two policy objectives.

5. Further discussion: implications, abstraction and conceptualization

We abstract and conceptualize the results and findings arrived at in the previous section. To this end, Figure 3 is drawn to help demonstrate the relationships in a more integrated way than the tables. Illustrated in Figure 3 are the continuum for policy instruments on the left hand side and the continuum for policy objectives/goals on the right hand side. The creation of the instrument continuum and the objectives continuum and their mapping go an extra mile beyond the statistical analysis based on the results reported in Table 5 and Table 6. They contribute additionally to reconciling the both sides of the debate on the classification of supply and demand side instruments and the carving up of environmental instruments, and reflecting the changing degrees of innovation generation, diffusion and adoption in the classification of policy objectives/goals. The policy instruments showing up on the left side of Figure 3 are the instruments that possess positively significant coefficients in Table 5 and Table 6. Each of them has a causal relationship with one or more policy objectives. These empirical results have enabled us to develop further theoretical conjectures yet to emerge in the literature. We create two categories of policy instruments in this paper: targeted instruments and general purpose instruments. A targeted instrument has a specific policy objective(s) to achieve. Whereas a general purpose instrument comes across several policy objectives; it does not target a specific policy objective. As such, the coefficients of a targeted instrument are statistically significant with one or more policy objectives in the former, whilst the coefficients of a general purpose instrument are significant with none of the policy objectives in the latter.

The supply side instruments are arranged on the top and the demand side instruments at the bottom, with the environmental instruments being in the middle. As indicated by the vertical arrow to the left of the policy instruments, the supply strength in the supply side instruments is the strongest on the top, diminishing downwards. Similarly, the demand strength in the demand side instruments is the most compelling at the bottom, diminishing upwards. Environmental instruments are carved and assigned to supply side and demand side instruments in a few prior studies, as some of them encompass the supply side elements and some others involve the demand side attributes to varied degrees. In this paper, the environmental instruments are ordered according to the extent to which they entail supply or demand side attributes. For example, administrative support (IE1) upholds the supply side attributes to the highest degree among all the environmental instruments in this study, followed by infrastructure support (IE2). On the other hand, the instrument of tax incentives (IE5) possesses much of demand side attributes and is sometimes assigned to demand side. Overall, the supply strength diminishes top down and the demand strength diminishes bottom up on such a continuum.

Policy objectives/goals are arranged in the same way. On the top is innovation generation and at the bottom is total innovation adoption – technical imports (GA2). There is certain innovation generation in diffusion processes, especially in technical transformation (GD1). As indicated by the vertical arrows to the right of the policy objectives, the degree of innovation generation recedes gradually top down, so does the degree of innovation diffusion. On the other hand, innovation adoption can involve diffusion, such as in the process of technical absorption (GA1). There is overlapping in different policy objectives and goals and the arrows show such overlapping and the changing degrees of innovation generation, diffusion and adoption on continuums.

Scrutinizing the linkages between the targeted policy instruments and policy objectives/goals, the following patterns emerge: a) innovation generation is typically targeted by the supply side instruments; b) innovation diffusion is typically targeted by the supply side instruments and environmental instruments; and c) innovation adoption is typically targeted by the environmental instruments and demand side instruments. Clearly, the supply strength is proportionate to the degree of innovation generation, and the demand strength is proportionate to the degree of innovation adoption. The environmental instruments augment both innovation diffusion and adoption but not innovation generation.

We further reflect on these results, findings and implications by briefly reviewing China's planning system and institutional evolution, with which China's economic legacy and administrative processes bear its hallmark. China started the nationalization of industries in the mid-1950s, which was almost completed just before the launch of the Cultural Revolution in 1966. One of the major reasons and purposes was to radically reform, if not to abandon, the orthodox Soviet planning system and approaches to economic management. Therefore, China did not possess a deep root in the planning economy and the root was shaken before it was planted firmed. In addition, with most people dwelling in rural areas, the reach of the planning system and state control in the economy had been limited and slack in China. The Cultural Revolution also influenced and predated the phenomenal transformation process since the 1990s, which was evident by a range of reformist ideas proposed in the '5.7 Instructions', a letter circulated in 1966 in the run-up to the Cultural Revolution (Mao, 1966). Mao suggested in the letter that workers in industrial corporations engage in agriculture and side-line production, and peasants set up and run small manufacturing factories collectively, whenever and wherever possible. The implications would be to take some economic activities out of the planning system and the state domain, setting to challenge state monopoly in the economy. The '5.7 Instructions' was not socialist utopia, being indeed implemented a few years later. Elaborating it further, Mao indicated in 1972 that 'Commune-brigade enterprises are the hope for rural economic development' and then commune-brigade enterprises mushroomed in the east and southeast of China (State of the Province Archives of Fujian, 2006). They were the predecessors to the vibrant private and non-state sectors, being more innovative that the state sector, especially the central state sector. A new government agency, Bureau of Commune-Brigade Enterprises, was created in the early 1970s, in response to the need to better manage this rapidly growing sector. It was renamed Bureau of Township Enterprises in the 1980s. According to National Bureau of Statistics (1999), the average annual growth in output by rural township enterprises was as high as 28.5% between 1974 and 1978, before the widely promulgated reform and opening up period. The above indicated that China started the economic reform, which not only actually watered down the planning system and centralization, but also encouraged and tolerated collective enterprises and commerce as early as in the early 1970s. The rural ventures continued to burgeon. In a recent study, Wu *et al.* (2017) documented the link between social entrepreneurship and rural economic growth in China, promoted by the national innovation system. 'Rural economic growth is associated with the adoption of new technology, and China's NIS facilitates that process' (ibid, p247).

Since Sino-Soviet split and the withdrawal of Soviet support and experts in late 1950s and early 1960s, the government emphasized self-reliance in realizing Four Modernizations, the expression of aspiration to become one of the leading players on the world stage. Self-reliance has to a great extent influenced the construct of the PRC national

S&T system and the pursuit of innovation generation and S&T supremacy, which seemed to be independent of and separate from the outside world. However, China, at the first opportunity, opened the door to the west, being symbolized by the visits to China of the US President Richard Nixon and Japan's Prime Minister Kakuei Tanaka in 1972, mediated by a series of seemingly non-governmental but robust and innovative diplomacies, including the Ping-Pong (table tennis) diplomacy. In the 1960s and 1970s, China devoted tremendously to the third world countries especially in Africa, leading to the triumphant return of the PRC to the seat in the United Nations in 1971. In building the Tanzania-Zambia railways soon after their independence in 1965, China deployed huge national capacities including its most advanced machinery, equipment and technologies recently developed and manufactured in China, which China could hardly afford to use at home at the time. It has been indicated that China started innovation generation and even exported innovation at the stage when China was acquiring innovation and engaging in technical imports. This shows that innovation is global and global innovation is interrelated in dynamic, two-directional traffic. China participated in globalization keenly since the 1970s, driving globalization in acceleration lately. Globalization brought about international convergence, which China involved in by adopting international standards and conventions passively in earlier decades, and then contributed to by influencing the making of international standards and conventions actively.

{Table 7 about here}

Indeed, China's economic legacy in general and its innovation capacity in particular have benefited from the implemented reforms and global involvements starting in the early 1970s. On the world stage and outside of China, all the visibles from China are the private enterprises, indicated in Wang (2016) who has reviewed China's national S&T systems and innovation comprehensively and contrasted state and private innovation. This is evident by the fact presented in Table 7 that lists global most innovative companies for 2015 with two rankings. One is the Most Innovative Companies 2015 of the BCG (2015) and the other is the 50 Smartest Companies 2015 from MIT Technology Review (2015). The BCG ranking covers all kinds of companies while MIT Technology Review focuses on technology companies. It can be observed in the table that the private sector in China has made significant inroads into R&D and dominant contribution to China's innovation capacity. There are three companies from China on the BCG list – Tencent, Huawei and Lenovo, ranked the 12th, 45th and 50th respectively. There are four companies from China on the MIT list – Xiaomi, Alibaba, Tencent and Baidu, ranked the 2nd, 4th, 7th and 21st respectively. All of them are private enterprises[3]. This fact points to the need of policy mapping and the study of policy mapping, given the prominence and supremacy of private sector innovation. The objectives of innovation, or any economic and business endeavor, won't be effectively achieved by the means of administrative directives and executive instructions in the private sector as in the state sector in a planning economy and system. While administrative directives and executive instructions used to be the common and widely adopted 'policy' tools directed at the state sector in a planning economy in a direct manner, their value and appeal have been voided by the failure of the planning system practised so far. Henceforth policy mapping and the study of policy mapping are beneficial to both state and private innovation. Nonetheless, the state enterprises may have to work harder to relieve themselves from the habitat of obeying administrative directives and executive instructions, which to a certain extent contributed to the fact and difference that state enterprises are less innovative than private enterprises.

[3] None on the BCG and MIT ranking lists in Table 6 are China's state enterprises, though Chinese Academy of Sciences Holdings (CAS Holdings or CASH) under the CAS currently has 34.85% shareholding in Lenovo (Legend Holdings, 2015). The state or the CAS is not involved in the running and strategic developments of Lenovo; they were not involved in Lenovo's business matters even in the past when CAS Holdings had a larger shareholding.

6. Conclusion

In this paper we have studied China's organization and governance of innovation from a policy perspective. In particular, we have examined China's innovation policy in a three dimension analytical framework for policy instruments, objectives and implementation. S&T and/or innovation are of paramount importance in China, so is the study of innovation policy. It has been found that administrative support, fiscal support and subsidies, financial support and tax incentives are the dominant instruments targeting at specific policy objectives. Overall two thirds of policy instruments target at specific policy objectives, spreading between supply, demand and environmental side instruments, with the rest being general purpose. Our empirical results have enabled us to develop further theoretical conjectures to make a contribution to the literature. Specifically, a number of thought provoking findings and new concepts are summarized in the following, some of which are case specific, some others are of universal implications.

Firstly, continuums for policy instruments and policy objectives/goals have been created in this study with universal implications. The creation of the instruments continuum contributes additionally to reconciling the both sides of the debate on the classification of supply and demand side instruments and the carving up of environmental instruments. Next, in mapping policy instruments and policy objectives/goals, patterns have emerged that in China, the supply side instruments target primarily innovation generation and then innovation diffusion, the demand side instruments typically target innovation adoption, and the environmental instruments augment both innovation diffusion and adoption. China has placed innovation generation top on agenda of government policy since 1949, while innovation adoption was considered of secondary importance which was left with enterprises and markets. Demand side measures were considered supplementary and adopted only recently to a modest extent. Thirdly, the state enterprises need to relieve themselves from the habitat of obeying administrative directives and executive instructions, and the policy makers need to rethink policy effectiveness in policy formulation and implementation, not only to reinvigorate state innovation but also to reinvent the national innovation system that integrate both the state and private sector. Last but not least, the importance of mediating variables and mediation is revealed from the perspectives of both statistical methodology and policy implementation. The case specific findings in this study may well impact the world in the near future if not now, given its sheer size of population and geography. How China and the rest of the world interact would have yet to be comprehended. While a piece of work on China's innovation and innovation policy, the present paper also provides a lens through which China' innovation policy formulation and implementation are observed.

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Tables

Table 1. Policy variables and their narratives

	Type	Name and symbol	Narrative
Policy instruments	Demand-side	Public procurement (ID1)	Regular and strategic public procurement, shaping innovation directly and indirectly
		Industry-HE institution-R&D institution collaboration (ID2)	Collaboration between industry, HE institution and R&D institution, promoting commercialization of R&D products
		International collaboration (ID3)	International collaboration and exchange programs, boosting R&D capabilities
	Supply-side	Support for MSEs and SMEs (IS1)	Technological training and consultancy for MSEs and SMEs, improving technological infrastructure in MSEs and SMEs
		Fiscal support and subsidies (IS2)	Funding and subsidies for R&D, depreciation subsidies
		Financial support (IS3)	More funding channels, loans on favorable terms, insurance and support for risk control
		Human resources (IS4)	Education and training, favored remuneration, welfare and bonus to attract and reward the talented domestically and overseas
	Environmental	Administrative support (IE1)	Streamlining procedures for approvals, easing restrictions on quotas and licensing, planning, organization, control and supervision of R&D activities
		Infrastructure support (IE2)	Provision of public infrastructure and facilities in the field, including the internet, libraries and databases for information sharing
		Enhancement in intellectual property protection (IE3)	Legislation and regulation for intellectual property protection, provision of legal services
		Standards setting (IE4)	Standardization, facilitating diffusion of innovations and market entry
		Tax incentives (IE5)	Tax exemption, tax reduction and other incentives
Policy objectives	Generation	S&T development (GG1)	R&D development, product development and design
	Diffusion	Transformation (GD1)	Application and promotion of new scientific and technological achievements, technicalization and commercialization of R&D
		Technical exports (GD2)	Exports of advanced technologies to foreign territories
	Adoption	Technical absorption (GA1)	Encouragement and promotion of absorption of new techniques
		Technical imports (GA2)	Imports of advanced technologies from foreign territories
Policy implementation	Institutional characteristics	Legislature (IC1)	National People's Congress of China and its Standing Committee
		Executive (IC2)	State Council of China, and are the constituents of, the state executive, or cabinet ministries/departments
		Bureau or agency (IC3)	Non-cabinet departments
		Joint issue (IC4)	Number of departments who jointly issued the policy
	Policy characteristics	Degree of enforcement (PC1)	Laws, administrative regulations, measures, notifications, provisos

Table 2. Summary of policy variables

<table>
<tr><th></th><th>Type</th><th>Name</th><th>No</th><th>%</th></tr>
<tr><td rowspan="12">Policy instruments</td><td rowspan="3">Demand-side</td><td>Public procurement (ID1)</td><td>5</td><td>1.46</td></tr>
<tr><td>Industry-HE institution-R&D institution collaboration (ID2)</td><td>5</td><td>1.46</td></tr>
<tr><td>International collaboration (ID3)</td><td>6</td><td>1.71</td></tr>
<tr><td rowspan="4">Supply-side</td><td>Support for MSEs and SMEs (IS1)</td><td>9</td><td>2.62</td></tr>
<tr><td>Fiscal support and subsidies (IS2)</td><td>28</td><td>8.16</td></tr>
<tr><td>Financial support (IS3)</td><td>34</td><td>9.91</td></tr>
<tr><td>Human resources (IS4)</td><td>71</td><td>20.70</td></tr>
<tr><td rowspan="5">Environmental</td><td>Administrative support (IE1)</td><td>157</td><td>45.77</td></tr>
<tr><td>Infrastructure support (IE2)</td><td>16</td><td>4.66</td></tr>
<tr><td>Enhancement in intellectual property protection (IE3)</td><td>29</td><td>8.45</td></tr>
<tr><td>Standards setting (IE4)</td><td>15</td><td>4.37</td></tr>
<tr><td>Tax incentives (IE5)</td><td>38</td><td>11.08</td></tr>
<tr><td rowspan="5">Policy objectives</td><td>Generation</td><td>S&T development (GG1)</td><td>146</td><td>42.57</td></tr>
<tr><td rowspan="2">Diffusion</td><td>Transformation (GD1)</td><td>60</td><td>17.49</td></tr>
<tr><td>Technical exports (GD2)</td><td>11</td><td>3.21</td></tr>
<tr><td rowspan="2">Adoption</td><td>Technical absorption (GA1)</td><td>13</td><td>3.79</td></tr>
<tr><td>Technical imports (GA2)</td><td>17</td><td>4.96</td></tr>
<tr><td rowspan="6">Policy implementation</td><td rowspan="5">Institutional characteristics</td><td>Legislature (IC1)</td><td>11</td><td>3.21</td></tr>
<tr><td>Executive (IC2)</td><td>294</td><td>85.71</td></tr>
<tr><td>Bureau or agency (IC3)</td><td>22</td><td>6.41</td></tr>
<tr><td>Joint issue (IC4)</td><td>108</td><td>31.49</td></tr>
<tr><td>Joint issue (average number of issuers)</td><td></td><td>1.69</td></tr>
<tr><td>Policy characteristics</td><td>Degree of enforcement (PC1) (weighted average)</td><td></td><td>2.45</td></tr>
</table>

Table 3. Policy issuances by year

Year	Total	Demand side	Supply side	Environmental
1990	2		1	1
1991	69	2	36	31
1992	57	5	22	30
1993	1			1
1994	4		1	3
1995	3	1	1	1
1996	4		1	3
1997	3	1		2
1998	0			
1999	15		9	6
2000	9		5	4
2001	6		2	4
2002	15	2	1	12
2003	4			4
2004	1			1
2005	10	2	5	4
2006	30	2	17	11
2007	39	5	16	18
2008	10	1	5	4
2009	24	3	10	11
2010	30	1	12	17
2011	2			2
2012	4		2	2
2013	2		1	1

Table 4. Correlation matrix for policy instruments, objectives and implementation

	GG1	GD1	GD2	GA1	GA2
ID1	0.0921*	-0.0560	-0.0221	-0.0024	0.0843
ID2	0.0921*	0.0080	-0.0221	-0.0241	-0.0278
ID3	-0.0699	0.0556	-0.0243	-0.0265	0.0720
IS1	-0.1044†	0.0684	0.0736	-0.0326	0.0466
IS2	0.1094†	0.0029	0.0062	0.0523	-0.0681
IS3	0.1091†	0.0270	0.1611‡	-0.0147	-0.0757
IS4	-0.1051*	-0.1216†	-0.0930*	0.0116	-0.0504
IE1	0.0020	0.0237	0.0985*	0.0935*	-0.0211
IE2	-0.0227	-0.0291	0.0382	0.1009*	-0.0505
IE3	-0.1980‡	-0.0020	0.0042	-0.0054	-0.0694
IE4	-0.0399	0.2393‡	-0.0389	-0.0424	-0.0488
IE5	0.0155	0.0331	-0.0115	-0.0701	0.1334‡
IC1	-0.0898*	-0.0403	0.0608	0.0505	0.0347
IC2	0.0481	0.0125	-0.0203	-0.0062	0.0932*
IC3	0.0394	0.0361	0.0874	0.0104	-0.0598
IC4	0.0571	-0.0498	0.1673‡	0.1249†	0.1097†
PC1	0.0406	0.0145	0.0280	-0.0410	-0.0178

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 5.1. Dependant variable GG1 (S&T development) with Logit model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-0.3740	0.2931	-1.2759	0.2020	-0.9125	0.5064	-1.8019	0.0716
IE1	0.3322	0.3216	1.0330	0.3016	0.2946	0.3275	0.8995	0.3684
IE2	-0.1198	0.5881	-0.2037	0.8386	-0.1098	0.5896	-0.1863	0.8522
IE3	-2.0711	0.6348	-3.2627	0.0011	-2.1871	0.6402	-3.4164	0.0006
IE4	-0.2544	0.6190	-0.4110	0.6810	-0.2141	0.6256	-0.3423	0.7321
IE5	0.1146	0.4089	0.2802	0.7793	0.1722	0.4258	0.4044	0.6859
ID1	1.7603	1.1558	1.5230	0.1278	1.5519	1.1649	1.3323	0.1828
ID2	1.5283	1.1388	1.3420	0.1796	1.4029	1.1421	1.2284	0.2193
ID3	-1.3645	1.1292	-1.2084	0.2269	-1.4523	1.1257	-1.2901	0.1970
IS1	-2.1716	1.0976	-1.9785	0.0479	-2.2714	1.1032	-2.0589	0.0395
IS2	0.8810†	0.4443	1.9830	0.0474	0.8072*	0.4541	1.7776	0.0755
IS3	0.8336*	0.4281	1.9474	0.0515	0.9643†	0.4665	2.0670	0.0387
IS4	-0.4241	0.3515	-1.2066	0.2276	-0.4291	0.3572	-1.2014	0.2296
IC2					0.4739	0.3812	1.2430	0.2139
IC3					0.3184	0.5599	0.5687	0.5695
IC4					-0.0694	0.0808	-0.8588	0.3904
PC1					0.1013	0.1119	0.9054	0.3653

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 6.1. Dependant variable GG1 (S&T development) with Poisson count model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-0.8715	0.1854	-4.6999	0.0000	-1.1528	0.3560	-3.2385	0.0012
IE1	0.1539	0.2059	0.7473	0.4549	0.12634	0.2079	0.6079	0.5433
IE2	-0.0562	0.4245	-0.1324	0.8946	-0.0519	0.4277	-0.1214	0.9033
IE3	-1.5230	0.5906	-2.5787	0.0099	-1.5800	0.5926	-2.6660	0.0077
IE4	-0.1846	0.4793	-0.3852	0.7001	-0.1702	0.4799	-0.3546	0.7229
IE5	0.0339	0.2724	0.1245	0.9009	0.0562	0.2804	0.2004	0.8412
ID1	0.6484	0.5333	1.2158	0.2240	0.5320	0.5429	0.9798	0.3272
ID2	0.5331	0.5164	1.0325	0.3019	0.4711	0.5218	0.9028	0.3666
ID3	-0.9471	1.0081	-0.9395	0.3475	-0.9941	1.0093	-0.9850	0.3246
IS1	-1.5038	1.0141	-1.4829	0.1381	-1.5448	1.0153	-1.5216	0.1281
IS2	0.4020	0.2702	1.4880	0.1367	0.3524	0.2753	1.2800	0.2005
IS3	0.3732	0.2577	1.4479	0.1476	0.4198	0.2790	1.5046	0.1324
IS4	-0.2863	0.2488	-1.1507	0.2498	-0.2960	0.2502	-1.1828	0.2369
IC2					0.2519	0.2821	0.8931	0.3718
IC3					0.1719	0.3785	0.4541	0.6498
IC4					-0.0369	0.0610	-0.6048	0.5453
PC1					0.0535	0.0809	0.6606	0.5089

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 5.2. Dependant variable GD1 (transformation) with Logit model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-2.0852	0.3501	-5.9561	0.0000	-2.2832	0.6539	-3.4916	0.0005
IE1	0.5415	0.3872	1.3985	0.1620	0.5822	0.3928	1.4824	0.1382
IE2	-0.7321	0.8864	-0.8259	0.4089	-0.8129	0.9014	-0.9018	0.3672
IE3	0.0562	0.5440	0.1032	0.9178	-0.0485	0.5545	-0.0874	0.9303
IE4	2.4531‡	0.6246	3.9276	0.0001	2.5574‡	0.6326	4.0425	0.0001
IE5	0.5868	0.4855	1.2087	0.2268	0.7329	0.5022	1.4596	0.1444
ID2	0.3391	1.1546	0.2937	0.7690	0.2074	1.1684	0.1775	0.8591
ID3	1.4181	0.9197	1.5412	0.1231	1.3699	0.9263	1.4789	0.1392
IS1	0.7891	0.8052	0.9800	0.3271	0.7347	0.8171	0.8991	0.3686
IS2	0.3086	0.5507	0.5603	0.5752	0.3490	0.5588	0.6245	0.5323
IS3	0.5565	0.4971	1.1195	0.2629	0.3797	0.5480	0.6929	0.4883
IS4	-0.5936	0.4927	-1.2049	0.2282	-0.5844	0.4970	-1.1759	0.2396
IC2					0.2273	0.5061	0.4492	0.6533
IC3					0.9729	0.6924	1.4052	0.1600
IC4					-0.1249	0.1229	-1.0168	0.3093
PC1					0.0496	0.1429	0.3470	0.7286

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 6.2. Dependant variable GD1 (transformation) with Poisson count model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-2.1658	0.3036	-7.1334	0.0000	-2.2969	0.5538	-4.1474	0.0000
IE1	0.4181	0.3307	1.2640	0.2062	0.4522	0.3360	1.3459	0.1783
IE2	-0.6063	0.7807	-0.7766	0.4374	-0.6735	0.7883	-0.8544	0.3929
IE3	0.0549	0.4931	0.1114	0.9113	-0.0272	0.5004	-0.0544	0.9566
IE4	1.6205‡	0.4345	3.7293	0.0002	1.6947‡	0.4393	3.8574	0.0001
IE5	0.4602	0.4263	1.0797	0.2803	0.5808	0.4412	1.3162	0.1881
ID2	0.2754	1.0215	0.2696	0.7874	0.1750	1.0314	0.1696	0.8653
ID3	1.0760	0.7415	1.4505	0.1469	1.0375	0.7460	1.3907	0.1643
IS1	0.6122	0.6560	0.9333	0.3507	0.5749	0.6677	0.8611	0.3892
IS2	0.2328	0.4847	0.4803	0.6310	0.2743	0.4927	0.5567	0.5777
IS3	0.4336	0.4338	0.9995	0.3175	0.2780	0.4775	0.5821	0.5605
IS4	-0.5376	0.4544	-1.1831	0.2368	-0.5279	0.4575	-1.1540	0.2485
IC2					0.1591	0.4338	0.3667	0.7139
IC3					0.7779	0.6046	1.2865	0.1983
IC4					-0.1008	0.1108	-0.9098	0.3629
PC1					0.0357	0.1251	0.2857	0.7751

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 5.3. Dependant variable GD2 (technical exports) with Logit model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-5.6175	0.9739	-5.7679	0.0000	-7.3837	1.8904	-3.9058	0.0001
IE1	2.4196†	0.9553	2.5327	0.0113	2.1516†	0.9909	2.1714	0.0299
IE2	0.3196	1.2674	0.2522	0.8009	0.6673	1.3136	0.5080	0.6114
IE3	-0.0808	1.1106	-0.0727	0.9420	0.2887	1.1594	0.2490	0.8034
IE5	-1.2006	1.9512	-0.6153	0.5383	-1.4515	2.0444	-0.7100	0.4777
IS1	1.4116	1.3447	1.0497	0.2939	1.6008	1.4058	1.1387	0.2548
IS2	0.7816	1.7656	0.4427	0.6580	1.0200	1.7331	0.5885	0.5562
IS3	3.0337‡	0.9851	3.0796	0.0021	3.4435‡	1.2072	2.8525	0.0043
IC2					0.3638	1.1347	0.3206	0.7485
IC3					-0.5198	1.2195	-0.4263	0.6699
IC4					0.3280†	0.1307	2.5101	0.0121
PC1					0.2992	0.3658	0.8180	0.4134

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 6.3. Dependant variable GD2 (technical exports) with Poisson count model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-5.3731	0.8430	-6.3735	0.0000	-6.9812	1.7623	-3.9614	0.0001
IE1	2.1103‡	0.8107	2.6031	0.0092	1.7593†	0.8177	2.1516	0.0314
IE2	0.2934	1.2132	0.2419	0.8089	0.6685	1.2418	0.5383	0.5904
IE3	-0.0544	1.0892	-0.0500	0.9601	0.2864	1.1344	0.2525	0.8007
IE5	-1.0280	1.7586	-0.5846	0.5588	-1.1963	1.7955	-0.6663	0.5052
IS1	1.2823	1.2574	1.0198	0.3078	1.4656	1.3102	1.1186	0.2633
IS2	0.6148	1.6487	0.3729	0.7092	0.7600	1.5754	0.4824	0.6295
IS3	2.6350‡	0.7988	3.2988	0.0010	2.9891‡	1.0373	2.8815	0.0040
IC2					0.5191	1.0782	0.4815	0.6302
IC3					-0.6079	1.1671	-0.5209	0.6025
IC4					0.2860†	0.1176	2.4321	0.0150
PC1					0.2484	0.3382	0.7343	0.4628

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 5.4. Dependant variable GA1 (technical absorption) with Logit model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-4.6066	0.6987	-6.5935	0.0000	-4.1840	1.0850	-3.8562	0.0001
IE1	1.6169†	0.7204	2.2444	0.0248	1.6424†	0.7647	2.1477	0.0317
IE2	1.5167*	0.8383	1.8092	0.0704	1.9212†	0.8860	2.1683	0.0301
IE3	-0.4528	1.0907	-0.4151	0.6780	0.1120	1.1277	0.0993	0.9209
IS2	1.3708	0.9033	1.5175	0.1291	1.8297*	0.9628	1.9003	0.0574
IS3	-0.1366	1.1739	-0.1163	0.9074	-0.4731	1.2890	-0.3670	0.7136
IS4	0.9385	0.7836	1.1977	0.2310	1.1123	0.7962	1.3969	0.1624
IC2					-0.7212	0.9534	-0.7565	0.4494
IC3					-0.9641	1.4140	-0.6819	0.4953
IC4					0.3687‡	0.1270	2.9038	0.0037
PC1					-0.3105	0.2863	-1.0841	0.2783

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 6.4. Dependant variable GA1 (technical absorption) with Poisson count model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-4.5362	0.6539	-6.9368	0.0000	-4.1334	1.0453	-3.9542	0.0001
IE1	1.4880†	0.6722	2.2136	0.0269	1.4752†	0.7171	2.0570	0.0397
IE2	1.3861*	0.7786	1.7803	0.0750	1.7179†	0.8096	2.1219	0.0338
IE3	-0.4195	1.0636	-0.3944	0.6933	0.0955	1.0920	0.0875	0.9303
IS2	1.2334	0.8413	1.4662	0.1426	1.6651*	0.9010	1.8481	0.0646
IS3	-0.1579	1.1055	-0.1428	0.8864	-0.4822	1.2043	-0.4004	0.6889
IS4	0.8387	0.7377	1.1369	0.2556	1.0065	0.7522	1.3381	0.1809
IC2					-0.6535	0.9095	-0.7185	0.4724
IC3					-0.6748	1.2510	-0.5394	0.5896
IC4					0.2915‡	0.0950	3.0685	0.0022
PC1					-0.2528	0.2642	-0.9571	0.3385

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 5.5. Dependant variable GA2 (technical imports) with Logit model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-3.4780	0.5464	-6.3656	0.0000	-3.8291	0.8152	-4.6973	0.0000
IE1	0.3344	0.6319	0.5292	0.5967	0.3234	0.6518	0.4961	0.6198
IE5	1.5600†	0.6819	2.2879	0.0221	1.5341†	0.6990	2.1945	0.0282
ID1	2.0917*	1.2444	1.6809	0.0928	2.3542*	1.2928	1.8211	0.0686
ID3	1.9458*	1.1776	1.6523	0.0985	2.1542*	1.1890	1.8118	0.0700
IS1	0.6696	1.1309	0.5920	0.5538	0.8735	1.1528	0.7577	0.4486
IS4	-0.4839	0.8106	-0.5970	0.5505	-0.3787	0.8200	-0.4618	0.6442
IC4					0.2056*	0.1168	1.7606	0.0783
PC1					-0.0345	0.2431	-0.1418	0.8872

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 6.5. Dependant variable GA2 (technical imports) with Poisson count model

	Simple model				Mediated model			
	Coef	Std. error	*z*-stat	*p*-value	Coef	Std. error	*z*-stat	*p*-value
C	-3.5070	0.5310	-6.6047	0.0000	-3.8286	0.7845	-4.8803	0.0000
IE1	0.31978	0.6106	0.5236	0.6005	0.3057	0.6313	0.4843	0.6282
IE5	1.4483†	0.6507	2.2259	0.0260	1.4226†	0.6675	2.1312	0.0331
ID1	1.8975*	1.1322	1.6759	0.0938	2.1383*	1.1811	1.8104	0.0702
ID3	1.7764*	1.0754	1.6519	0.0986	1.9715*	1.0895	1.8096	0.0704
IS1	0.5980	1.0493	0.5699	0.5688	0.7944	1.0784	0.7367	0.4613
IS4	-0.4567	0.7837	-0.5827	0.5601	-0.3562	0.7943	-0.4485	0.6538
IC4					0.1860*	0.1061	1.7541	0.0794
PC1					-0.0310	0.2332	-0.1331	0.8941

* significant at the 10% level; † significant at the 5% level; ‡ significant at the 1% level.

Table 7. Most Innovative Companies 2015

Rank	BCG	MIT Technology Review
1	Apple	Tesla Motors
2	Google	Xiaomi
3	Tesla Motors	Illumina
4	Microsoft Corp.	Alibaba
5	Samsung Group	Counsyl
6	Toyota	SunEdison
7	BMW	Tencent
8	Gilead Sciences	Juno Therapeutics
9	Amazon	SolarCity
10	Daimler	Netflix
11	Bayer	OvaScience
12	Tencent	Google
13	IBM	Amazon
14	SoftBank	AliveCor
15	Fast Retailing	Gilead Sciences
16	Yahoo!	Apple
17	Blogen	Voxel8
18	The Walt Disney Company	IDE Technologies
19	Marriott International	Amgen
20	Johnson & Johnson	Aquion Energy
21	Netflix	Baidu
22	AXA	SpaceX
23	Hewlett-Packard	Sakti3
24	Amgen	Freescale Semiconductor
25	Allianz	Universal Robots
26	Tata Motors	Bristol-Myers Squibb
27	General Electric	Teladoc
28	Facebook	Nvidia
29	BASF	Facebook
30	Siemens	Alnylam
31	Cisco Systems	Rethink Robotics
32	Dow Chemical Company	Philips
33	Renault	Cellectis
34	Fidelity Investments	Bluebird Bio
35	Volkswagen	ThyssenKrupp
36	Visa	Slack
37	Dupont	Line
38	Hitachi	Improbable
39	Roche	Enlitic
40	3M	Coinbase
41	NEC	HaCon
42	Medtronic	3D Systems
43	JPMorgan Chase	Generali
44	Pfizer	Intrexon
45	Huawei	DNAnexus
46	Nike	IBM
47	BT Group	Snapchat
48	MasterCard	Microsoft
49	Salesforce.com	Imprint Energy
50	Lenovo	Uber

Sources: BCG, MIT Technology Review

Figures

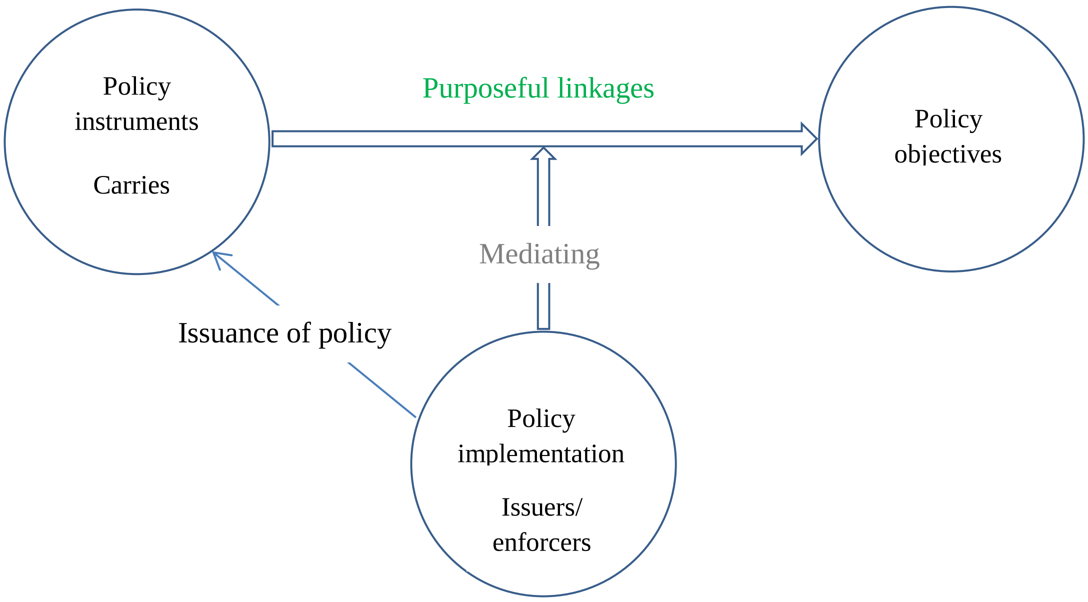


Figure 1. Three policy dimensions

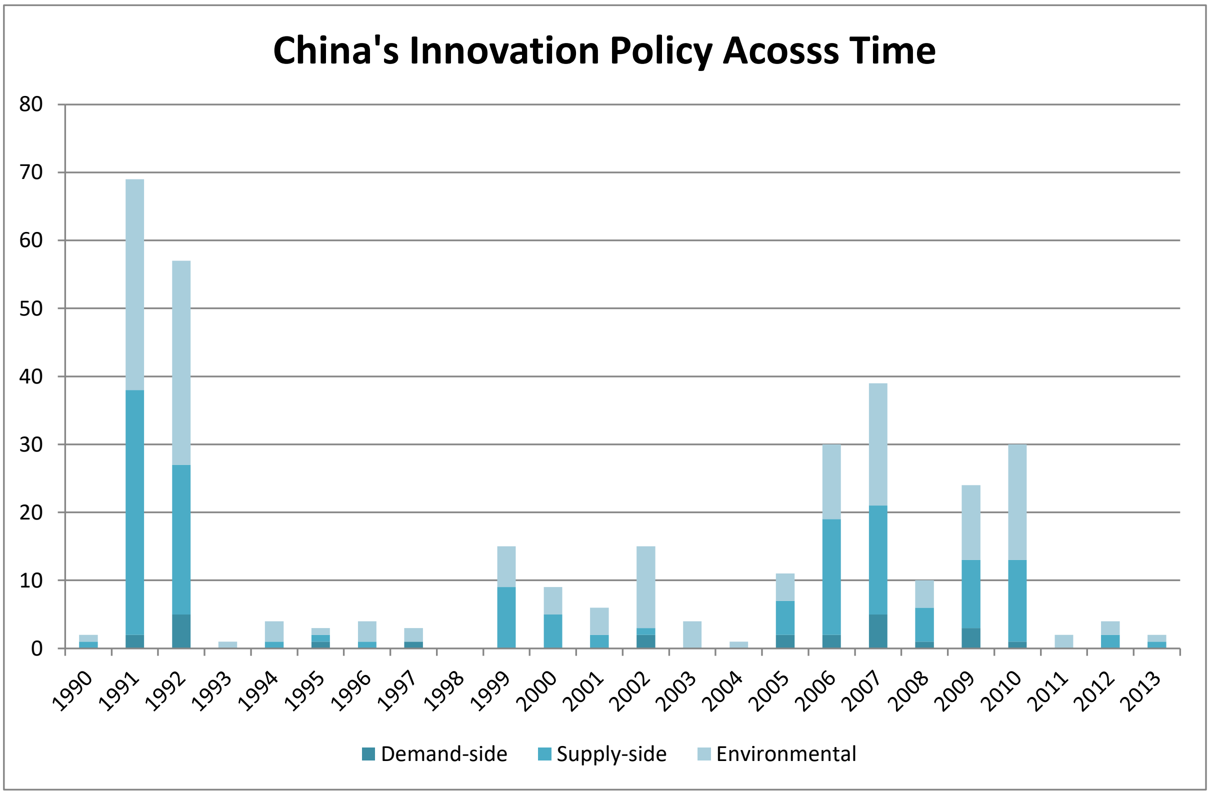
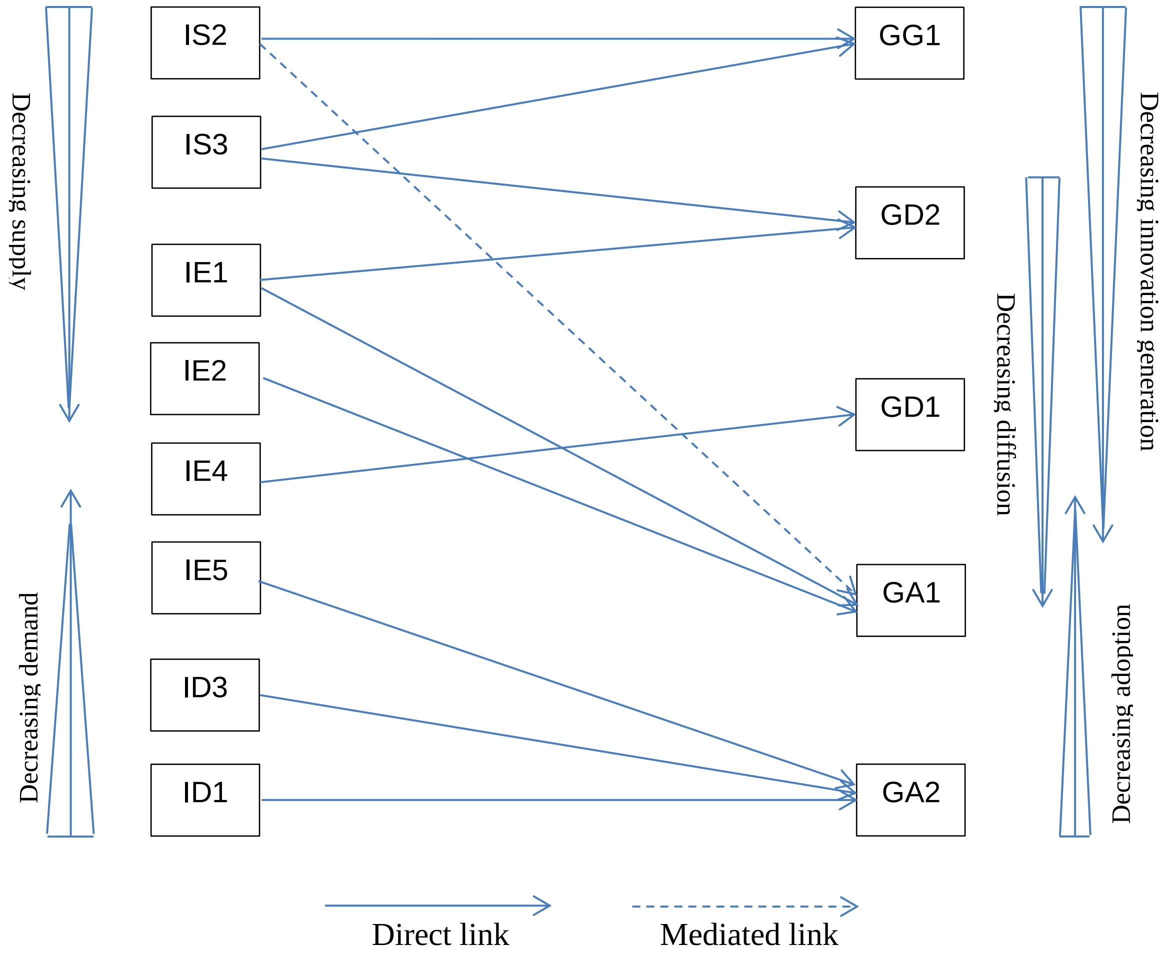


Figure 2. Policy issuances by year



IS2 - Fiscal support and subsidies
IS3 - Financial support
IE1 - Administrative support
IE2 - Infrastructure support
IE4 - Standards setting
IE5 - Tax incentives
ID3 - International collaboration
ID1 - Public procurement

S&T development - GG1
Technical exports - GD2
Transformation - GD1
Technical absorption - GA1
Technical imports - GA2

Figure 3. Policy instrument – goal links