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THE CHINESE SYSTEM OF ECO-INNOVATION:
STRUCTURES, ACTORS, PERFORMANCE

Zeting LIU

THE CHINESE SYSTEM OF ECO-INNOVATION: STRUCTURES, ACTORS, PERFORMANCE

Zeting LIU[1]

Abstract: This study proposes a new approach to analyze the innovation system based on the concept of the "filed" of innovation. A field is composed of sectors with different technological trajectories tied up by a socio-economic function toward which they evolve. In our case, the socio-economic objective is the protection and the preservation of the natural environment. Thus, the environment represents a filed composed of different sectors such as energy, microelectronic, petrochemicals, transport, biotechnology, pharmaceutical, eco-building, etc. How to define the Chinese environmental field? The Chinese innovation system of the environmental field, how does it organized? Who are the actors of eco-innovations? What is their capacity of innovation? To answer these questions, we will investigate the literature, reports, archives and official documents, and statistics to draw the outline of the environmental field in China and analyze the performance and limitations of public policies for the development of eco-innovations. To answer these questions, we will investigate the literature, reports, archives and official documents, and statistics to draw the outline of the environmental field in China. By analyzing the patent filing activities of three key industries – photovoltaic, wind turbine, electric car –, we show the trajectory of technological development of Chinese eco-industries and the performance and limitations of public policies for the development of eco-innovations. The study will show that 1) Chinese interventionist industrial policy creates favorable conditions that facilitate the emergence of new industries in the energy sector, and through its pragmatism adapts to structural changes in the market to support industrial transformation. 2) The performance of the Chinese public policy faces the problems of coordination due to its dual political system and the failure of its innovation system. 3) New orientation on policy making is trying to remedy the deficiencies on coordination.

Key Words: Field of Innovation, Innovation System, Eco-Innovation, Industrial Policy, Innovation Policy, China

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TABLE

INTRODUCTION

Since the structural reforms launched in 1978, China has seen its business evolves around 10% on average per year. However, the rapid economic growth, industrialization and accelerated urbanization have created very quickly and social imbalances aggravated the environmental situation. According to the World Bank, sixteen cities of the twenty most polluting cities in the world are in China. The cost of pollution and resource depletion is estimated at 5.8% of GDP (World Bank, 2007).

After nearly thirty years of spectacular economic growth, China is at a crossroad of economic development and actively searching for a new growth model in order to assert its global superpower status and to achieve a better balance of economic and social development. Faced with an environmental impasse, and as China enters a new era known as "new normal" with lower growth rate, the Chinese government seeks a new model of development based on the "green development" toward an environmental friendly, more efficient and competitive economy. Recent policy orientation focuses on optimizing and upgrading its industrial structure and promoting innovation in particular eco-innovations.

Eco-innovations are "innovations that results in a reduction of environmental impact, no matter whether or not that effect is intended" (OECD, 2009: 15). This is a large definition that includes all technological, commercial, organizational or institutional innovations introduced by different actors in society with the aim of preventing or reducing risks to the environment, pollution or other damaging effects of the use of resources (OECD, 2010, Boutillier et al., 2012). Indeed, the solutions to tackle environmental challenges bypass a single industrial branch, sector or a specific technology system. It involves various subsectors to evolve toward comprehensive business innovation process (Janicke, 2012).

This study proposes a new approach to analyze the innovation system based on the concept of a field of innovation. We define the field of innovation as a system composed of technological subsystems that are linked together by the socio-economic function toward which they evolve together. In our case, the socio-economic objective is the protection and the preservation of the natural environment. Thus, the environment represents a filed composed of different sectors such as energy, microelectronic, petrochemicals, transport, biotechnology, pharmaceutical, eco-building, etc. How to define the Chinese environmental field? How is it organized? Who are the actors of eco-innovations? What is their capacity of innovation? To answer these questions, we will investigate the literature, reports, archives and official documents, and statistics to draw the outline of the environmental field in China and analyze the performance and limitations of public policies for the development of eco-innovations.

1. THE FIELD OF ECO-INNOVATIONS: CONCEPT AND ANALYTICAL FRAMEWORK

1.1. System of innovation and the field of eco-innovations

Innovation is seen as an effective tool to improve national competitiveness to maintain jobs. Innovation process implies the exploration and exploitation of knowledge and information that become available thanks to the constant interactions between different actors (firms, universities, public research centers, government, etc.). Innovation studies use system approach to understand the dynamic relations between actors, institutions and market which translate technology and other opportunities into innovation. The systems of innovation concept relates to a general systems concept, where the term "systems" refers to "complexes of elements or components, which mutually condition and constrain one another, so that the whole complex works together with some reasonably clearly defined overall function" (Fleck, 1992: 5, cited in Edquist, 1997: 13).

An innovation system can be identified by the proximity of its actors, which can be spatial or geographical (national or regional innovation system), technological proximity (sectoral system of innovation, technological system and socio-technical system), and in terms of activities (Edquist, 2005). The basis of system approach is to define the boundaries of the system, its actors, attributes and the dynamic relations that it maintains. The attributes of an innovation system are characterized by the dynamic interactions between its actors and institutions based on the level of analysis. Based on the different level of analysis, the concept can be broken down into national (Freeman, Nelson, et al.), sectoral (Pavitt, 1984; Malerba, 2002), regional (Cooke et al., 1997; Cooke, 2001; Bison, 2006), industrial branch, technological systems (Carlsson et al., 1992), or Socio-technical system (for example Geels, 2004; Dolata, 2009).

Table 1. Different approaches of innovation systems analysis

Approach of innovation system analysis	**Main authors**	**Level of analysis and highlights**
National innovation system (NIS)	Freeman, 1987; Lundvall, 1992; Nelson, 1993	Marco level Innovation capacity of the country as a whole
Regional system of innovation	Cooke et al., 1997; Cooke, 2001; Bison, 2006	Meso level Spatial proximity of actors facilitating interactions and flows of information
Sectoral system of innovation	Pavitt, 1984; Breschi and Malerba, 1997; Malerba, 2002; and others	Meso level Sectoral evolution alone a technological trajectory
Technological systems	Carlsson and Stankiewicz, 1991; Carlsson et al., 1992; 2002	Meso level Co-existence of many technological systems in a country Technological systems defined by problem-solving networks are embedded in international knowledge pool
Socio-technical systems	Geels, 2004; Dolata, 2009	Meso level The functionality of technology, production and diffusion of products Co-evolution of technology and institutions
Filière / industrial branch	Bélis-Bergouignan et Levy, 2010; Laperche et al., 2016; Liu, 2016	Meso level A system composed of various technological subsectors that develop integrating solutions to satisfy a specific user group along a value chain

Source: Author

A national system of innovation includes "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist, 1997: 14). The nation system of innovation approach emphasizes the interactions between different actors in a country to generate, diffuse and translate knowledge into economic outcome not only R&D but also learning process (learning by doing, learning by using, learning by interacting) (Lundvall, 1992). A regional system of innovation can be sub-national but also supra-national, depending on the geographical proximity of its actors and their interactions.

The sectoral system of innovation approach focuses on the sectoral characteristics of knowledge, actors, networks and institutions in the innovation process (Pavitt, 1984; Malerba, 2002). The learning process and innovation activities of a sector are influenced by its technological regime and the conditions for access to internal and external knowledge. The source of technological opportunities differs significantly across sectors. Some sectors depend on scientific discoveries, while in other sectors collaborative innovation between suppliers and consumers is more common. Thus, the innovative performance of a sector is based on the configuration of the collective system of producers, distributors and users of knowledge necessary for innovation (Malerba, 2002).

The sectoral approach highlights the path-dependency of the mutation of an industrial sector. Nevertheless, this analysis has its limits on analyzing large technical systems (Dolota, 2009). Carlsson et al., (2002) argue that there are several technological systems in each country and the composition and attributes of these technological systems evolve over time. The boundary of a technological system is not necessarily defined by national borders. As defined by the problem-solving networks, the technological systems are part of global knowledge networks. Moreover, the long-term dynamics generated by the transformative capacity (Dolato, 2009) of new technologies will lead to the co-evolution of technology and society (Geels, 204). The system of innovation approach can also combine a structural and an actor-oriented approach (Edquist and Johnson, 1997). Built on the complementarity of the subsectors in the industry value train, the development of a *filière*, or an industrial branch, depends on the dynamic relations between actors from different industries to generate synergies and to develop new solutions to satisfy a specific user group or social need (for example the wood industrial branch in France studied by Bélis-Bergouignan et Levy, 2010 and the analysis on gerontinnovation by Laperche et al., 2015; Liu, 2016).

However, the environmental challenges require solutions that bypass single technological systems or industrial sectors and national borders. Empirical study shows that international knowledge plays an important role as most countries are likely to exploit the renewable energy technologies that have been developed by other countries (Garrone et al., 2014). Eco-innovations include research, development or design of new products and services, new methods of commercialization, organization or institutions that aim at preventing or reducing risks to the environment, pollution or other damaging effects of the use of resources (OECD, 2010). It involves all technologies of which the use is less environmentally harmful than relevant alternatives including preventive or remediative pollution management, cleaner (integrated) technologies and products, and resource management (European Commission, 2002). These technologies generally known as eco-technologies (or green technologies, greentech or cleantech, environmental technology) can be found in activities and sectors such as energy, microelectronic, petrochemicals, transport, biotechnology, pharmaceutical, building, etc. and their adaptation requires integrated solutions to reconsider the whole production system. In this case, the boundary of the field of eco-innovations is defined by the socio-economic function of environment protection and preservation toward which the evolutions converge. The characteristics of the field is not only the evolution of individual subsector through the industrial value chain but also the transformative effect of interactions between them which may lead to a major social change.

1.2. Eco-innovations field and innovation policy mix

The dynamics of the innovation process are complex and subject to the risk of different failures: 1) Market failure related to the production, dissemination and use of new knowledge and technologies; 2) The systemic failure that blocks the interaction between the actors of an innovation system; 3) Institutional failure due to the asymmetry of information leading to the problem of coordination between institutions and various public policies (OECD, 2010). The defense of public support of R&D is mainly based on two arguments: 1) Innovation and technological change are central to generate growth and competitiveness of a nation. 2) Since firms are not able to fully capture the returns to their R&D investment, without public intervention, the reluctant of the private market would lead to too little private investment in R&D, especially the basic or fundamental research. Under this context, governments can use direct instruments (direct public R&D aid) and indirect measures (tax measures, venture capital promotion, incubator development, demand-side measures, regulatory measures, etc.) to improve the quality of information flows between actors and institutions and strengthen the innovative capacity of enterprises

Although the market is considered the best system of economic coordination by liberal economists, analyzes of the process of industrial transformation show that markets alone are not enough to initiate and sustain the process of industrial transformation. Industrial policy plays a facilitating role in industrial modernization and economic diversification in order to achieve rapid structural change (Lin and Monga, 2011; Lin, 2013). In contemporary economies, industrial policy often translates into innovation policies that aim to improve the quality of information flows between actors and institutions, and to strengthen the innovative capacity of firms (Niosi et al., 1992, Lundvall, 1992), in particular their ability to absorb knowledge specific to their sector of activity.

Industrial policy is considered as a means of directing the innovation activities of firms towards those areas where, without public intervention, market mechanisms alone are not enough to initiate and support the process of changing the innovation trajectory (Aghion et al., 2011). Comparative studies on experiences of different countries highlight the importance of public support (see Deutch and Steinfeld, 2013, Grau et al., 2012 for international comparison; and De la Tour et al., 2011, Wu and Mathews, 2012 on technology transfer in photovoltaic industry) in the development of new industries in the energy sector. On the other hand, studies on the capacity building of developing countries also highlight that During the catch-up phase, developing countries use industrial policy to support local 'infant industries' to take full advantage of the internal market and to develop their own know-how through a trial and error learning process that will be less costly and less risky (Krugman, 1979). In this context, the innovation system in developing countries can play a central role in increasing the learning capacities of economic actors (Lundvall et al., 2012) with the aim of creating an interactive and institutional framework that allows local actors to build its competence and specific learning techniques (Casadella, Tahi, 2014).

However, the existing policy arrangements or regimes are often the results of the accumulation of policy instruments developed incrementally over a relatively long period of time. The layering structures of policy instruments will increase not only the complexity and costs of governance but also the difficulty for changes (Howlett and Rayner, 2007). The policy mix approach proposes a new analytical framework emphasizing the interaction of specific innovation support instruments within the innovation system and the coherence of innovation policies in the overall public policies. A policy mix is the combination of policy instruments that are mechanisms or tools used by governments to achieve objectives and goals, which translate the strategies and accompanying objectives and goals into concrete interventions (Heide, 2011). It represents a synthesis of policies affecting the main domains influencing a country's innovation performance (Guy et al., 2009; OECD, 2010, 2011) or the integrated effect on a specific field. This approach is well suited to analyze policies in favor of emerging industries in a country like China where state coordination plays a decisive role in industrial development.

After nearly twenty years of spectacular economic growth, China is at a crossroad of economic development and actively searching for a new growth model in order to assert its global superpower status and to achieve a better balance of economic and social development. In 2006, Chinese government has set up its medium and long term plan aiming at transforming China into an innovative nation by 2020. In order to achieve its ambitions, the Chinese government uses well-structured and systemic industrial and innovation policies which is characterized as "pick winners" (Ken et al., 2014: p.137), to encourage the Chinese firms in particular the State-owned firms to absorb foreign advance technologies on the one hand and to carry out the indigenous innovation on the other hand (Liu, 2014). The high economic growth also leads to environmental problems. As the growth starts to slow down, China is looking for a new growth pattern supported by innovation, inclusive and coordinated green development.

2. CHINA'S ECO-INNOVATIONS FIELD: AN INTEGRATED ANALYSIS OF SOLAR, WIND AND ELECTRIC VEHICLE INDUSTRIES

There is no clear definition of eco-industries in China. The most used official term is the "energy conversion and environmental protection industries" which, under the 12th five-year plan (FYP), include environmental protection, energy conversion and resource recycling. By using the definition of the 2015 Green Bond Endorsed Project Catalogue issued by China's Green Finance Committee as guidance for green finance, the Chinese eco-innovations field includes 6 subsectors: energy conversion, pollution prevention, resource efficiency and recycling, clean transport, clean energy, protection of eco-system and climate resilient (GFC, 2015). Chinese eco-innovations fields has experienced strong growth over the past decade and reached 3 072 billion yuan in 2011, an increase of 660% compared to 2004 and 18 times the size in 2000 (MEP, 2014).

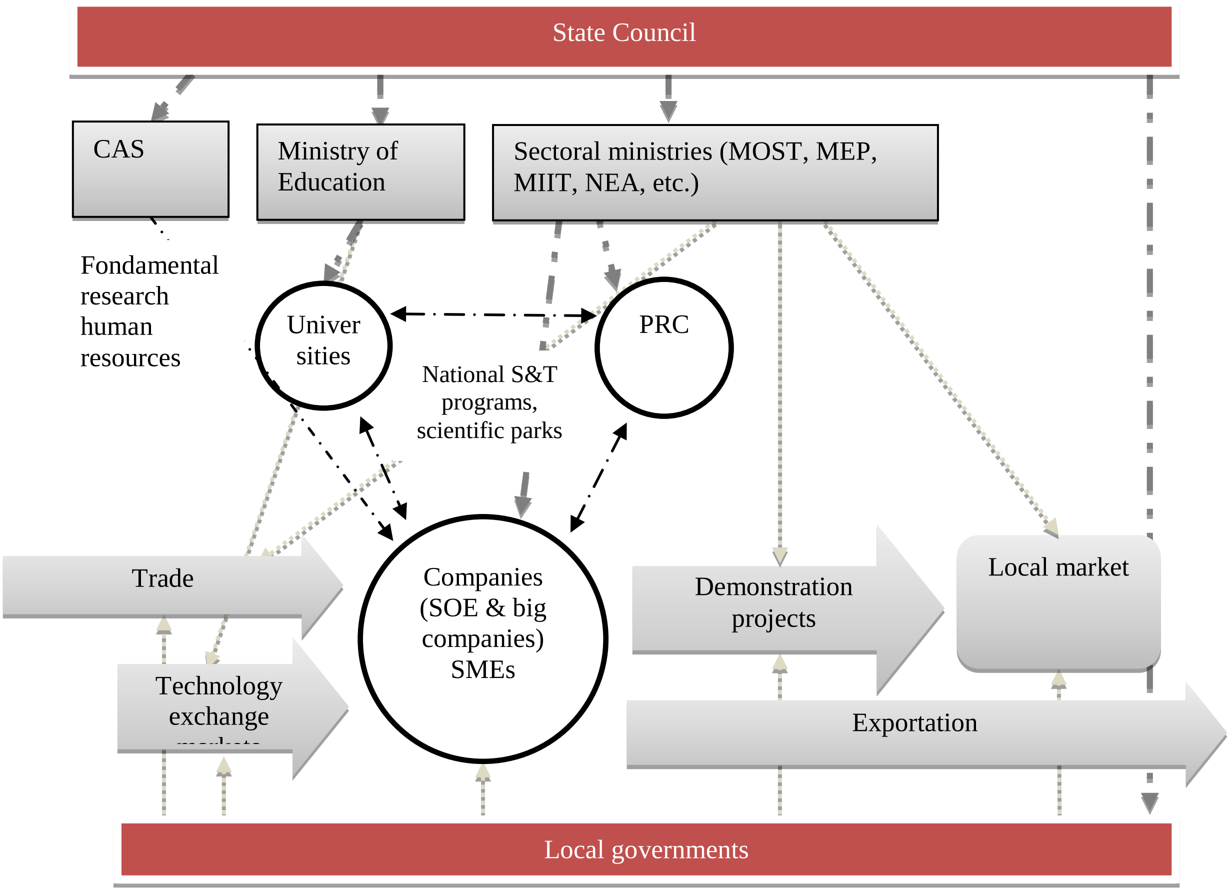
Among these subsectors, clean energy and clean transport are the most important sectors that account 39% of total Green Bonds proceeds in 2016 (21% of clean energy and 18% of clean transport). Of these two sectors, next-generation energy value chains (including renewable energy and electric power infrastructure) and electric vehicles are among the key strategic industries in which the Chinese government invests heavily for its capacity building and watches closely to ensure that they are primarily owned by Chinese firms, weather public or private (Hsueh, 2016). We choose to analyze the evolution of solar, wind and electric vehicle industries, which belong to energy and transport sectors, to show not only the trajectories of development of individual industries in China but more importantly how their evolution progressively is integrated into each other.

2.1. Structure and actors of the field of eco-innovations in China

Although firms are main actors to carry out eco-innovations, planning plays an important role in China's economic life as it is both the main tool of government to mobilize resources to achieve economic and social objectives and the basis of assessment of local authorities. Structural reforms and decentralization since the 1970s have affected virtually all economic domains in China, including industrial structure, the science and technology (S&T) system and the energy system. Thus, we can find a sophisticated system of plans consisting of five-year plans, specific actions plans, guidance that regulates Chinese economic system.

The impact of planning in China's public policies for eco-innovations is reflected at two levels: at national level, national objectives (State Council) are adapted by ministries individually or jointly with their action plans and at the local level, the national plan will be transposed to each local administrative level. As the policy mix being more and more sophisticated, the public supports are designed to benefit the entire innovation process. Upstream, firms can benefit from support for the absorption of technologies either through the acquisition of foreign technologies supported by foreign investment policies or through technology exchange infrastructure. Downstream, they can benefit from industrial policies dedicated to developing new markets for eco-innovations locally or to export to global markets. At the heart of the systemic dynamics is the industrial-research-university triad, whose interactions are supported by different public policies through administrative plans and coordination (Graphic 1).

Graphic 1 The coordination of systems of innovation in environmental field in China



▬ ▶ Administrative relations
- · -▶ Interactions and flows of information and knowledge
⋯▶ Coordination of local and central policies

Source: Author

Chinese eco-innovations policies are highly structured in the way to support Chinese firms to develop their capacities and gradually to move up the value chain. The typical trajectory of Chinese industrial technological development is characterized by a learning process and the accumulation of knowledge to constitute the innovation capacity of Chinese enterprises: starting with the absorption of foreign technologies to imitation, re-invention and endogenous innovation. This process can separate into two steps. Initially, industrial policies support the import and absorption of foreign technologies. Then, measures are put in place to encourage industry-university-research collaboration in order to allow firms to carry out endogenous innovations.

As eco-innovations field covers several subsectors (energy conversion, pollution prevention, resource efficiency and recycling, clean transport, clean energy, protection of eco-system and climate resilient), it requires coordination of public policies at horizontal levels (between different ministries) and vertical levels (between public and local authorities). For example, although Ministry of Environmental Protection (MEP) oversees the overall environmental protection objectives and actions, it is the National Energy Administration (NEA) who is in charge of energy planning. Meanwhile Ministry of Science & Technology (MOST), Ministry of Industry and Information Technology (MIIT) and State Intellectual Property Office (SIPO) are all involving in the policies in favor of research and development of eco-technologies. And alone side, the Ministry of Education defines the objectives of human resources training. The initiatives such as green bonds are supported by the Ministry of Finance (MOF).

In the mid-2000s (during the period of the 11th FYP), Chinese government started proactive actions aiming at increasing innovation capacities and competitiveness of Chinese firms. Progressively, renewable energy and new-energy vehicle gain importance in the national industrial development strategies. Table 2 provides an example of interrelated policies and supported ministries to promote renewable energy and new-energy vehicle industries. Both industries are considered as strategic emerging industries of which Chinese government invests heavily in the support of capacity building of public and private actors while making sure that the local market will be mainly occupy by Chinese firms (Dent, 2015). General plans and legislations provide a general orientation of economic and social development such as the environmental protection law or the FYP (currently the 13th FYP covers the period from 2016- to 2020). Under the general guidelines, measures can be adapted according to specific objectives (S&T development, innovation and environmental protection) or subsectors (renewable energy, solar and wind energy, new-energy vehicle) with precisions on the methods and resources allocated to achieve the objectives. The subsector plans do not necessarily only concern the given sector. Renewables and new-energy vehicles (particularly electric vehicles) have gained increasing importance in the national strategies to promote eco-innovations, with measures increasingly overlapping to consider the whole industrial value chain (renewable network connection, smart grid, infrastructure for electric vehicle charging).

Table 2. Coordination of Chinese eco-innovations policies, with example of renewable and new-energy vehicle industries

<table>
<tr><td rowspan="2">General plans and legislations</td><td colspan="3">Environmental Protection Law, first issued in 1989, amended in 2014</td></tr>
<tr><td colspan="3">13th FYP (2016-2020): The plan highlights innovation, coordinated and inclusive development, green growth and further opening up</td></tr>
<tr><td>Individual objectives</td><td>Energy efficiency</td><td>Science & Technology</td><td>Innovation & industrial development</td></tr>
<tr><td>Renewable energy</td><td>- Renewable Energy Law, 2006
- Medium and Long-Term Development Plan for Renewable Energy in China, 2007
- Individual 13th FYPs for Renewable energy (State Council), solar, wind energy development (NEA)
- Action Plan for Power Distribution Network Reconstruction for 2015-2020, issued in 2015 (NEA): emphasizing the development of smart grid to support renewable energy, distributed energy and EV charging</td><td rowspan="2">- Medium and long term S&T development plan (2006-2020), issued in 2006 (MOST): focusing on technological catch-up & development of high-tech industries among which renewables and EV
- FYPs: started from the 10th FYP under an EV-specific 863 program, (MOST)
- During the 11th FYP, joint measures for MOST, MIIT and MOF have been tented to promote EVs in order to restructure and revitalize the auto-industry</td><td rowspan="2">Strategic emerging industries, issued in 2010: identifying 7 SEI which needs to push for “indigenous innovation” among which: 5) new energy; 7) new-energy vehicles

Made in China 2025, issued in 2015: emphasize the entire manufacturing process and industrial upgrading among which: 6) New-energy vehicles and equipment; 7) Power equipment</td></tr>
<tr><td>New-energy vehicle</td><td>- Energy-saving & new energy vehicle development plan (2012-2020), issued in 2012 (State Council)
- Guideline for accelerating the development of energy conversion and environmental protection industries, issued in 2013 (State Council)</td></tr>
</table>

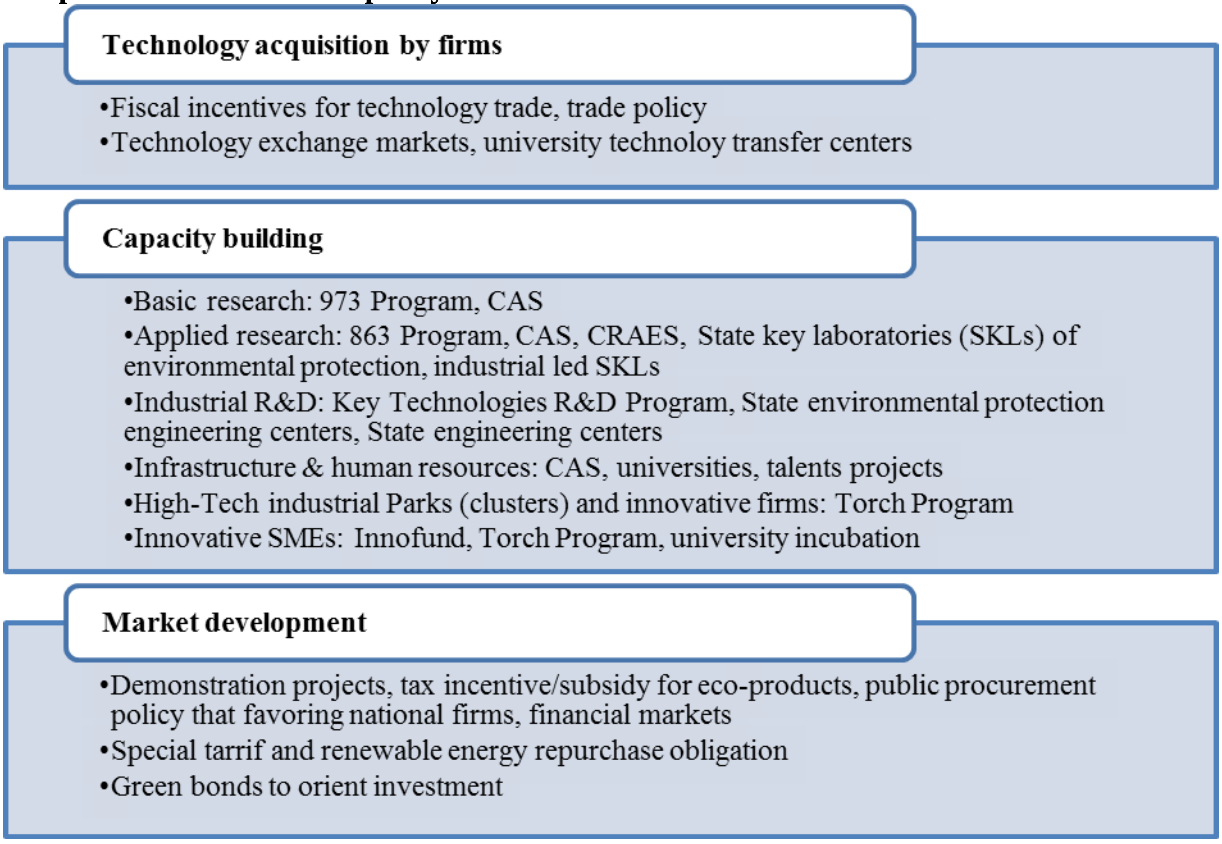
Source: Author

2.2. The policy mix to promote eco-innovations in China

The Chinese innovation mix policy for the environmental technologies sector consists of direct financial measures (financing of research programs, subsidies) and indirect financial measures (tax incentives for the import of foreign technologies or for innovative companies) as well as measures aimed at building the knowledge base (human resources) and the market (public procurement policy, demonstration projects, renewable energy repurchase obligations or export support for eco-products).

Direct funding for R&D is the most widely used instrument of the central government through major programs that are either run by public research centers (such as CAS, CRAES, universities) or by large enterprises, especially public enterprises . They are complemented by measures to facilitate access to credits for research and innovation projects (carried out by companies or research institutes). In 2011, renewable energy and environment projects accounted for 19% of the total funding from the central government. At the local government level, through fiscal decentralization, local governments can use the favorable tax regime to attract investment, particularly from abroad, to promote local economic growth. Local governments use traditional industrial policies such as tax relief, financing mechanism (the financing vehicle of local government and bank loans), loan guarantees, preferential property taxes or the provision of land at reduced cost, etc. to attract investment. Measures are deployed on three fronts: ensuring access to technological sources for companies, building the innovative capacity of companies and developing local and international markets for eco-products. The composition of this structured approach is illustrated in Graphic 2.

Graphic 2 The innovation policy mix for eco-innovations field in China



Source: Author

(1) Technology acquisition by enterprises can be achieved through the importation of foreign technologies during international or local exchanges. The import of foreign technologies can be done in the form of transfer of technology by license or joint venture, by the purchase of equipment and cooperation with foreign companies in design. Indeed, for developing countries, foreign direct investment (FDI) represents a major source of advanced technologies. Since the structural reforms initiated in the late 1970s, the Chinese government uses strange investment policies to both attract foreign capital and technology to accelerate the industrialization and modernization of the Chinese economy. This policy is aimed more at

the large public enterprises whose effectiveness can be demonstrated by the development of the Chinese wind industry. This policy has allowed Chinese firms to acquire the knowledge and know-how to build its technological base and its capacity for innovation (Liu and Liang, 2013). The upgrading of Chinese wind industries is a good example of this policy.

There are also technology markets or international university technology transfer centers to supply the local technology knowledge base that are more targeted at SMEs or traditional enterprises are the targets (Liu, 2014).

(2) Innovation capacity building consists of both the development of absorption capacity and of endogenous innovation capacity of Chinese firms. A country's ability to absorb "imported" knowledge depends on its previous level of knowledge and a country's conditions (for example infrastructure, market structure, training, etc.) to attract, assimilate and apply external knowledge (Cohen and Levinthal, 1990). Thus the measures are put in place to both build the scientific base in China and develop the technological capacity of the industrial sector and policies to create a stimulating condition to foster the development of innovative enterprises.

We identify three categories of actions in the policies of support for research and technological development: basic research to build the scientific base, applied research that encourages the transfer of knowledge to industry, and industrial research and development. The main actors and programs are:

- Basic research on environmental technologies is supported by the 973 program (National Basic Research Program), of which approximately 7.7% of funding in 2012 has been allocated to projects in the fields of eco-technologies (energy, natural resources and environment), and by the Chinese Academy of Sciences (CAS).
- Applied research is carried out in particular by the CAS, the CRAES, the 32 key state laboratories (SKLs) (including one industrial SKL) or financed by the 863 Program (National High- Tech R&D Program), of which 10.6% of the 2012 budgets have been allocated to eco-technologies projects notably in the field of energy.
- Industrial R&D is supported in particular by the Key Technologies R&D Program that devoted 6.2% of its budget to eco-technologies projects in 2012. At the same time, the state-owned engineering centers in particular the 35 state environmental protection engineering centers play an important role in the dynamics of industry-university-research collaboration to develop the competitiveness of enterprises. [2]

The flow of scientific knowledge is supported by measures dedicated to training research personnel and fostering mobility of researchers such as CAS' "Hundred Talents" program (for scientific training) and the "National Distinguished Young Scholars" Program, funded by the National Science Foundation of China (NSFC). The "Mille Talents" program for highly qualified Chinese returnees, and incentives for the recruitment of qualified personnel.

Industry-university-research collaboration is reinforced by high-tech industrial parks and university incubators are the places that, by their definition, stimulate the interactions between innovation actors and so are considered the fertile land for innovative companies notably innovative SMEs and spinoffs from public research. The development of innovative SMEs is supported by the Innovation Fund for Technology SMEs (Innofund) which supported 1 123

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[2] Les données sont collectées, compilées et calculées par auteure en base des rapports annuels sur les programmes d'Etat (MOST, 2005-2013) les annuaires statistiques de S&T (NBS, MOST, 2004-2013) et sur le site du MOST http://www.most.gov.cn .

eco-technologies projects in 2012. However, the share of SMEs in public funds remains marginal.

(3) The final component of the policy mix is measures to develop new markets for eco-innovations, either domestic or for export. In order to do so, measures are designed either to prepare the market through demonstration programs such as the wind, photovoltaic (Liu, 2014) and new energy (Zhang et al., 2011) and by demand measures.

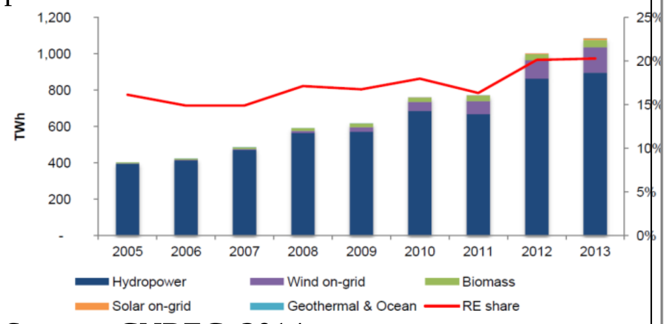
2.3. The rise of Chinese eco-innovations field and its limits: the case of solar, wind and electric vehicle industries

The structured and systemic approach of the innovation mix policy for eco-innovations has contributed to the development of the eco-technologies subsectors in China and enabled Chinese companies to build their capacity for innovation. However, they also have their weaknesses. To assess the innovation capacity of Chinese firms in these industries, we used R&D expenditures and patents as indicators. Our analysis is mainly based on the operation of the statistical yearbooks and the existing surveys and reports.

Renewable energy accounts for 20% of energy production in China and the share of on-grid wind and solar energy production increase constantly during the last ten years. Today, wind-generated electricity reaches 132 terawatt-hours in China in 2013, ten-fold compared to 2008, as the second largest wind-energy production country just after the United State (Graphic 3). From scratch, China became the leading producer and exporter of solar panels and wind turbines in ten years. Chinese new-energy vehicle sales are also more than tripled during the 12th FYP period (2010-2015) (Graphic 4).

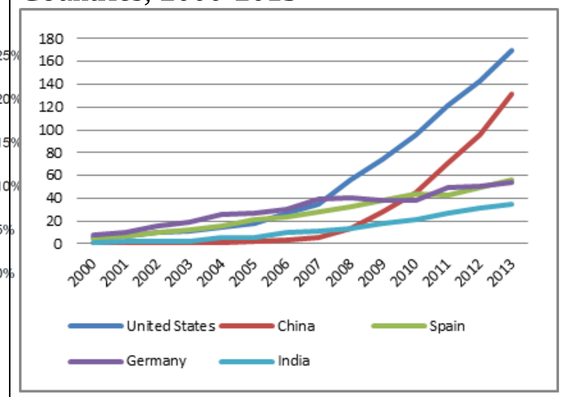
Graphic 3 Renewable energy production in China and compared to other countries

Evolution of energy production by renewable energy and its share in China's total energy production



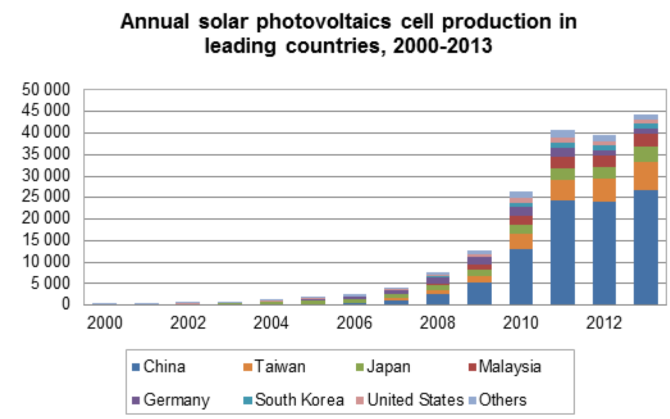
Source : CNREC, 2014

Wind-generated Electricity in Top Five Countries, 2000-2013

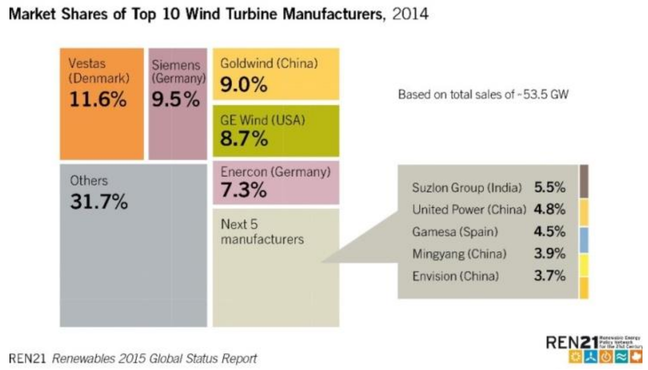


x

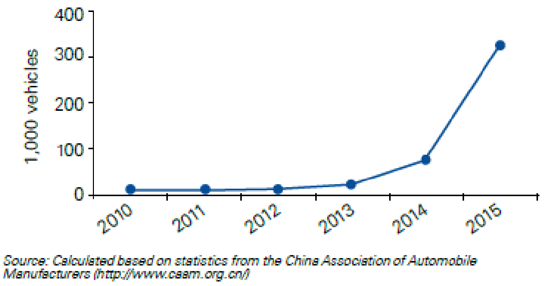
Graphic 4 Production and sales of Chinese solar, wind, new-energy vehicle industries



Source: www.earth-policy.org



New-energy vehicle sales in china

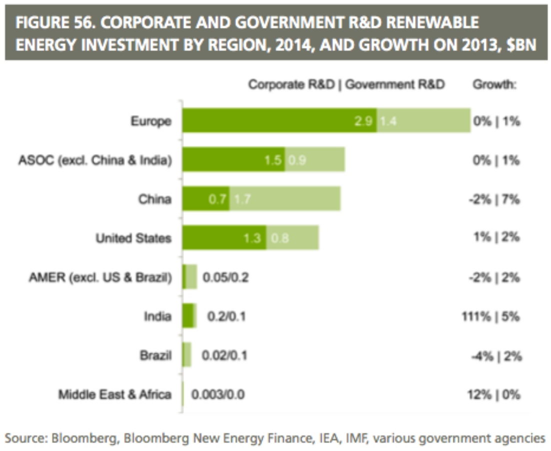


Source: KPMG, 2016

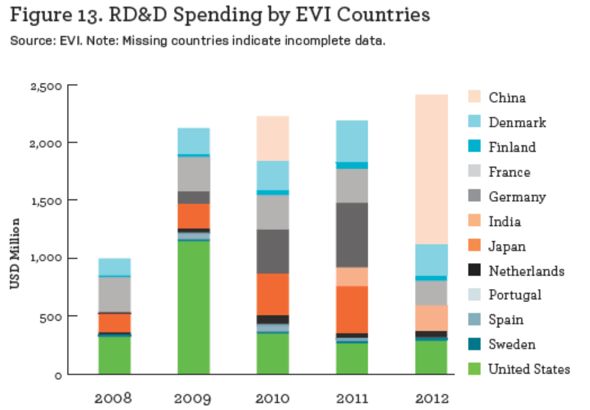
The rise of Chinese solar, wind and new-energy vehicle is supported by public policies. Since 1996, 69 measures have been implemented to support the development of renewable energy sector (IEA, 2015). The efforts have been intensified and become more and more integrated since 2004, with the introduction of the Renewable Energy Act and Renewable Energy Fund. By using 4 key instruments (Zhang et al., 2013, Liu, 2014) – mandatory market share by sector and technology, favorable tariff plan for renewable energies (feed-in tariff), financial support for RE projects, R&D programs in the field of materials and equipment, and recently in the management of smart grids, they help the Chinese RE industrial value to build up quickly. For new-energy vehicle sector, although since 2001 twenty-one measures have been taken (Shi et al., 2015), the kick-off of the NEV sector started in 2009, under the strategic plan to for the development of NEV focusing on standard and labeling, fiscal measures and subsidies for clean vehicles, R&D programs especially in battery. Both subsectors are also benefited from the "Made in China" measures which required up to 70% of new wind power installation must use local manufacturers (introduced in 2003 and amended in 2005, repealed in 2009) and new-energy vehicle tax exemption and subsidy applicable only to local manufacture.

Supported by proactive policies, Chinese new energy and new-energy vehicle industries have strongly increased their R&D investment and have rapidly realized technological catch-up and the construction of innovation capacity. The R&D expenditures of new energy industries increased on average 5% in 2013 and more than tripled for electric vehicle industry from 2010 to 2012 (Graphic 5-1, 5-2). In the Chinese market, the number of Chinese green patents held by Chinese companies tripled between 1999 and 2013. In 2012, the majority of Chinese patents in the fields of new energies are held by Chinese companies (Table 6).

Graphic 5-1. Corporate & government renewable investment R&D by region (2014, $bn) and growth (2013)

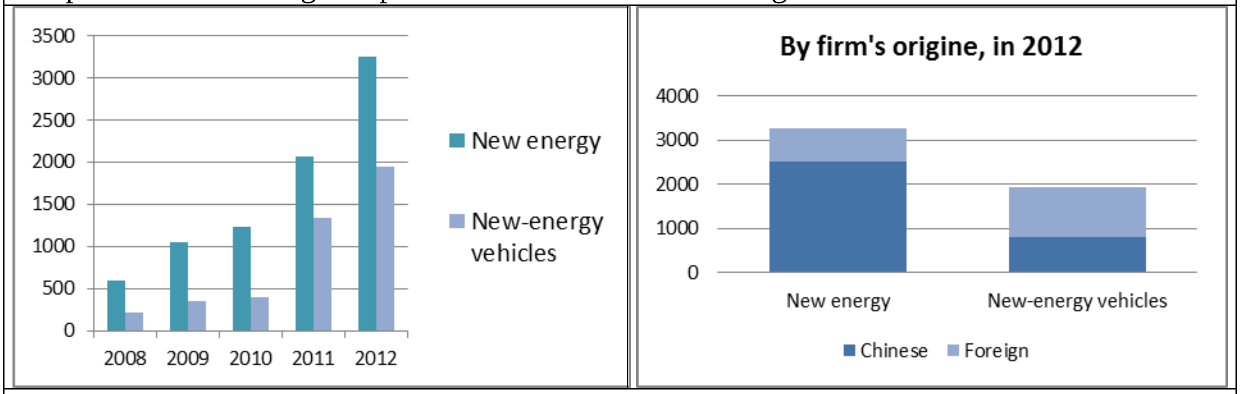


Graphic 5-2. RD&D Spending by EVI countries



Source : EVI, 2013

Graphic 6 Number of green patents of the 3 eco-industries granted in China



Source: Based on the report of State Intellectual Property Office (SIPO), 2013

Although the pragmatism of Chinese industrial policies has been successful, deficiencies are evident in the coordination between the State and the innovation system, which leads to unbalanced industrial development and raises the question of the innovation capacity of Chinese enterprises.

One the one hand, the structural reform of the S&T system launched in 1985 aims to transform the old rigid S&T system, which did not allow any interaction between the various R&D actors and the productive apparatus to the model of the national innovation system where public R&D players and industry can collaborate to innovate according to market need. However, despite some twenty years of systemic reforms, the inconsistency in the definition and organization of the S&T system persists and has led to a separation between the various scientific actors (academies, research institutions, universities and some large companies) and an imbalance between basic research, applied research and industrial development. Graphic 5-4 above also shows that the main contribution of new energy R&D investments come from the government which increased 7% in 2013 while the private sector reduced 2% their efforts in R&D. This make Chines public sector occupies the highest share of renewable energy R&D investment.

Inside the country, technological development at national level is not equal between regions. Table 3 shows the concentration of the development of eco-technologies in six regions:

Beijing, Jiangsu, Guangdong, Zhejiang, Shandong and Shanghai[3]. These six regions account for one third of all Chinese green patents. This concentration in terms of the outputs of innovation activities is the result of the high R&D intensity in these six regions. Indeed, these regions have a much higher R&D and industrial R & D intensity at national level. They bring together one third of public research centers and two thirds of industrial research centers in China. They also specialize differently. Beijing and Shanghai focus their efforts in basic and applied research while Jiangsu, Guangdong, Zhejiang and Shandong focus on industrial research and development. In terms of the composition of R&D expenditures, most efforts are contributed to industrial development instead of basic and applied research. Amon the 6 regions, only Beijing and Shanghai have around 20% of their R&D efforts goes to basic and applied research. This trend mirrors the high concentration of scientific activities in these two regions (Graphic 7). However, the underinvestment in basic and applied research may impact the innovation capacities of Chinese firms in the long term.

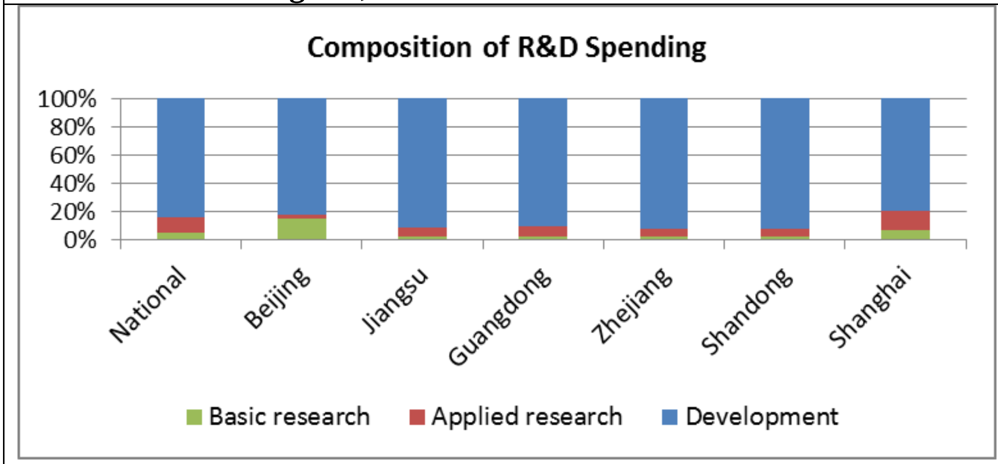
Tableau 3 The 6 most eco-innovative regions in terms of patents and R&D

	Patent		R&D expenditures		R&D centers (Nbr)	
	New energy	New-energy vehicle	R&D intensity	Industrial R&D (% of total local)	Public research	Firms
Beijing	469	84	5,95	18,6	379	747
Jiangsu	377	83	2,38	83,9	148	16417
Guangdong	269	124	2,17	87,2	186	3455
Zhejiang	192	65	2,08	81,5	101	7498
Shandong	142	28	2,04	88,8	225	3325
Shanghai	142	70	3,37	54,7	136	914
% national	44 %	20 %	1,39	70 %	32 %	70 %

* National average

Source: Compiled and calculated by author, based on the report of State Intellectual Property Office and S&T Statistics Yearbook, 2013

Graphic 7 Composition of R&D expenditures at national level and in the 6 most innovative regions, in 2012



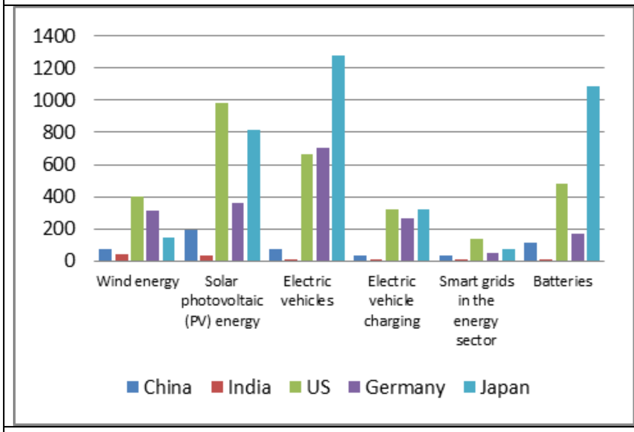
Source: Calculated based on the Chinese STS Yearbook, 2013

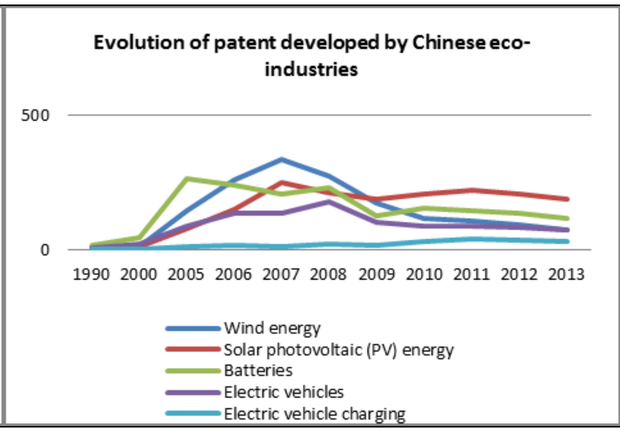
[3] Over 34 regions including Hong Kong, Taiwan and Macao (SIPO, 2013).

Systemic failures prevent good research-industry-market coordination and hence the development of an innovation system supported by market-based firms (see, for example, OECD, 2008, Lundvall, Gu, 2012). As a result, the ability of Chinese firms to achieve endogenous innovations in eco-innovations field remains low. In the area of energy, where there is a strong presence of Chinese companies, these are mostly downstream of the value chain (Eisen, 2011; Deutch and Steinfeld, 2013; Liu, 2014; Lam et al., 2017). A comparative study shows that Chinese photovoltaics are 30% less efficient than European products, while their carbon footprint is double that of European products (Yue et al., 2013). The strong presence of foreign companies in Chinese patents in the field of new energy vehicles (Graphic 6) shows the dependence of Chinese companies on foreign technologies. No Chinese actor is among the top 10 holders of Chinese patents in new energy vehicles. This industry is still "in the infancy" in China, innovation activities focus on building the scientific base where Chinese companies are in the phase of absorbing foreign technology to develop.

Moreover, while the number of green patents held by Chinese companies is increasing rapidly (SIPO, 2013), patent quotation rates and their share in patent triads (Lacour and Figuière, 2014) are low. OECD green patent also shows that although 37.7% of global environmental-related innovations are patented in China, only 3.9% of them are developed in the country. The evolution of Chinese eco-industries international patents has stagnated since the beginning of the 2010s. The "backwardness" of Chinese firms in climbing the value chain points to the weakness of the technological development path that prioritizes the absorption of imported technologies more than the creation of knowledge and know-how through the interactions between local actors.

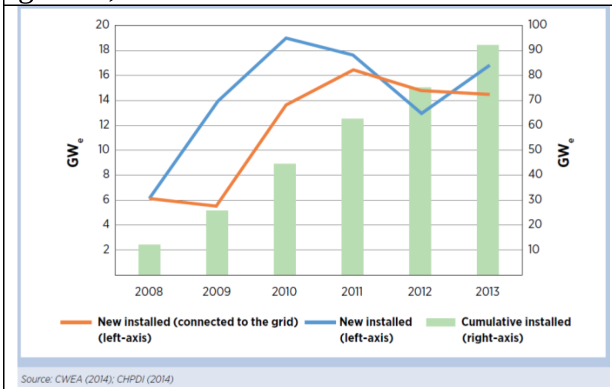
Table 5 Number of international green patents of the 3 eco-industries in different countries, in 2013

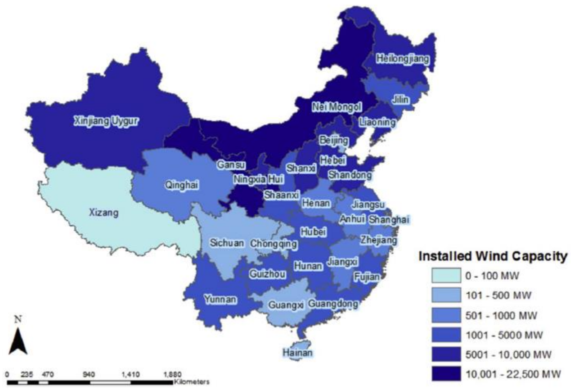




Source: OECD, Green Growth Indicators (data extracted from PATSTAT and EPO)

On the other hand, despite its structured and systemic configuration, the complexity of the billfold system makes it very difficult, if not impossible, to maintain dynamic flows between decision-makers and executors, which leads to the compartmentalization and inconsistency of the policies that constitute the innovation mix for environmental technologies. Moreover, the system of assessing local authorities based on their performance in achieving the objectives set in the plans entails inter-regional competition both to obtain public funds and private investment to develop the local economy (Fan, 1994). Institutional failure also creates market distortion. In the early years of 2010, the Chinese photovoltaic and wind energy industries are facing the crisis of overcapacity. This crisis is a reflection of the coordination between energy planning and network deployment (Luo et al., 2012, Yuan et al., 2012) and the problems of administrative coordination between the various public agencies that are responsible for their management. The rush on the renewable energy as new source of growth and job creation resulted in a fast growth installed wind power capacity. However, the connection to distribution network does not follow the speed of installation Graphic 8-1). The geographical distribution of installed wind power capacities shows that most installations are in North and Western regions with lower level of economic activities. This amplifies the problem of capacity waste, although since the 12th FYP, new measures are undertaken to limit new installation and to speed up the connection and repurchase of renewable energy. The distortion also appears in the new-energy vehicles. The demonstration projects of electric vehicles reveals the problems of lack of supporting infrastructure and industrial standards that hold back the diffusion of electric cars as consumers are anxious about the charging capacity and quality issues (Zhang et al., 2011; Li et al., 2016).

<table>
<tr><td>Graphic 8-1 China wind power capacity growth, 2008-2013</td><td>Graphic 8-2 China's wind power installation by province in 2014</td></tr>
<tr><td>


Source: CWEA, 2014; CHPID, 2014</td><td>


Source: Lam et al., 2017</td></tr>
</table>

A more serious consequence is the side effects of the development of environmental technologies in China that weigh heavily on the environment. Ecotechnologies aim to reduce the environmental impact of human activities by introducing new combinations of production methods. However, systemic failures result from the lack of control of pollution in the productive activities of the environmental technologies sector. Thus, paradoxically, Chinese eco-industries themselves become a source of pollution. Due to the excessive development of the photovoltaic industry and the lack of control of compliance with environmental standards in the production process, Chinese PV manufacturers today are themselves polluters (Greenpeace, CREIA, 2012; Yang et al ., 2014). Another example is the promotion of coal conversion technologies. Given the fact that, at present, the technologies are not mature enough to demonstrate their economic and environmental efficiency, the central government is reluctant to develop them on a large scale. Nevertheless, local governments, attracted by the potential for new jobs and new tax revenues, are rushing to promote these new activities on their ground (CGTI, 2012). This dysfunction of the system of coordination between the policies of central and local governments raises fears of a future environmental problem.

CONCLUSION

The development of environmental technology can benefit the economy by proposing new combinations of production that are less harmful to the environment and open up new market opportunities. The application of environmentally sound technologies is thus considered to be an integral part of economic growth while reducing environmental costs. However, while environmental technologies can introduce a creative destruction force into the current productive system, it requires public measures to ensure an institutional framework that is both stable and attractive to all stakeholders. In this perspective, industrial and innovation policies have the potential to promote the development of these industries.

Applied to the Chinese situation, they also enable local companies to achieve technological catch-up and to build their capacity for endogenous innovation to carry out eco-innovations. Since the 11th Plan (2005-2010), and especially the 13th Plan (2016-2020), the Chinese government has introduced a new innovation strategy characterized by a structured approach to industrial policies and innovation where Chinese companies are at the heart of the dynamics of interactions. Through the planning system, the Chinese state is mobilizing enormous means to guide and support the process of learning and accumulation of business knowledge in developing the innovative capacity of the environmental technology sector.

The analysis of the solar, wind and new-energy vehicle subsectors shows that in China, the public sector plays a key role in promoting eco-innovations and (incidentally) protecting and conserving the environment. The two key subsectors - renewable energy and clean transport - share a similar trajectory of catching up to endogenous innovation through the accumulation of knowledge despite existing problems.

Public support is essential for the emergence and development of new technology sectors, provided there is better coordination between the various policies. However, there is still little interaction between the two subsectors. In order to better asses the dynamic of Chinese eco-innovations field, it is necessary to study the subsystem of eco-innovations field to define more precisely their structure, the actors and their interactions.

REFERENCES

Aghion P., Boulanger J., Cohen E., 2011, Rethinking Industrial Policy, *Bruegel Policy Brief*, 2011/04, June.

Bélis-Bergouignan M.C., Lévy R., 2010, Sharing a common resource in a sustainable development context : The case of a wood innovation system, *Technological Forecasting & Social Change,* 77, 1126-1138.

Boutillier S., Djellal F., Gallouj F., Laperche B., Uzunidis D., 2012, *L'innovation verte,* Bruxelles, Peter Lang.

Breschi, S., Malerba, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In: Edquist, C. (Ed.), *Systems of Innovation: Technologies, Institutions and Organizations*. Pinter, London/ Washington, pp. 130–156.

Carlsson B., Jacobsson S., Holmen M., Rickne A., 2002, Innovation systems: analytical and methodological issues, *Research Policy,* 31, 233-245.

Carlsson, B., Stankiewicz, R., 1991. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics* 1, 93–118.

Casadella V., Tahi S. (2014), Système National d'Innovation, Capacités d'Apprentissage et Développement, in Boutillier S., Forest J., Gallaud D., Laperche B., Tanguy C., Temri L. (dir.), *Principes d'économie d'innovation,* Bruxelles : Peter Lang, 429-439.

China Greentech Initiative, 2012, *The China Greentech Report 2012: Faced with Challenges, China Accelerates Greentech Growth,* Beijing.

Cohen, W.M., Levinthal, D.A., 1990, Absorptive capacity: a new perspective on learning and Innovation, *Administrative Science quarterly*, 35(1), 128-152.
Commission Europeene (2002), *L'écotechnologie au service du développement durable,* Bruxelles.
Cooke P., 2001, Regional Innovation Systems, Clusters, and the Knowledge Economy, *Industrial and Corporate Change,* 10(4), 945-974.
Cooke P., Uranga M.G., Etxebarria G., 1997, Regional Innovation Systems: Institutional and Organizational Dimensions, *Research Policy,* 16(4-5), 475-491.
De La Tour A., Glachant M., Ménière Y., 2011, Innovation and international technology transfer: The case of the Chinese photovoltaic industry, *Energy Policy,* 39, 761-770.
Dent C.M., 2015, China's renewable energy development: policy, industry and business perspectives, *Asia Pacific Business Review,* 21(1), 26-43.
Deutch J., Steinfeld E. 2013, *A Duel in the Sun: The Solar Photovoltaics Technology Conflict between China and the United States*, A Report for the MIT, Future of Solar Energy. http://mitei.mit.edu/publications/reports-studies/future-solar
Dolata U., 2009, Technological innovations and sectoral change Transformative capacity, adaptability, patterns of change: An analytical framework, *Research Policy,* 38, 1066-1076.
Edquist C. (ed), 1997, *Systems of Innovation. Technologies, Institutions and Organizations,* Science, Technology and the International Political Economy Series, Pinter: London and Washington.
Edquist C., 2005, Systems of Innovations: Perspectives and Challenges, in Fagerberg J., Mowery D.C., Nelson R.R. (eds), *The Oxford Handbook of Innovation,* Oxford University Press: New York, 191-208.
Edquist C., Johnson B., 1997, Institutions and Organisations in Systems of Innovation, in Edquist C. (ed), 1997, *Systems of Innovation. Technologies, Institutions and Organizations,* Science, Technology and the International Political Economy Series, Pinter: London and Washington, 41-67.
Eisen J. B. (2011), China's Greentech Programs and the USTR Investigation, *Climate Law Reporter,* 11(2), Winter 2011, 3-8, 70-74.
Fan G. (1994), Incremental Changes and Dual-Track Transition: Understanding the Case of China, *Economic Policy*, Supplement: Lesson for Reform, 9(19), 99-122.
Freeman C. (1995), The National Innovation Systems in historical perspective, *Cambridge Journal of Economics*, 19(1), 5-24.
Garrone P., Piscitello L., Wang Y., 2014, Innovation Performance and International Knowledge Spillovers: Evidence from the Renewable Energy Sector in OECD Countries, *Industry and Innovation,* 21(7-8), 574-598.
Geels F.W., 2004, From sectoral systems of innovation to socio-technical systems. Insight about dynamics and change from sociology and institutional theory, *Research Policy,* 33, 897-920.
Grau T., Huo M., Neuhoff K. (2012), Survey of photovoltaic industry and policy in Germany and China, *Energy Policy*, 51, 20-37.
Green Finance Committee, 2015, *Green Bond Endorsed Project Catalogue*, Beijing.
Greenpeace, CREIA, 2012, *Clean Production of Solar PV in China,* Beijing, March 2013.
Guy, K., Boekholt P., Cunningham P., Hofer R., Nauwelaers C., Rammer C. (2009), Designing Policy Mixes: Enhancing Innovation System Performance and R&D Investment Levels, *The 'Policy Mix' Project,* Monitoring and Analysis of Policies and Public Financing Instruments Conducive to Higher Levels of R&D Investments, European Commission, Brussels.
Heide M. J.L. de, 2011, *R&D, Innovation and the Policy Mix*, Erasmus Universiteit Rotterdam: 168.

Howlett M. Rayner J., 2008, Design Principles for Policy Mixes: Cohesion and Coherence in New Governance Arrangements, *Policy and Society* 26(4): 1-18.
Hsueh R., 2016, Strategic and Nonstrategic Sectors, in Kennedy S. (ed), *State and Market in Contemporary China, Toward the 13th Five-Year Plan,* Report of the CSIS Freeman Chair in China Studies, March 2016, 24-26.
Janicke M., 2012, “Green Growth”: From a growing eco-industry to economic sustainability, *Energy Policy,* 48, 13-21.
KPMG, 2016, *The 13th Five-Year Plan – China’s transformation and integration with the world economy. Opportunities for Chinese and foreign businesses*, KPMG China, October 2016.
Krugman P., 1979, A Model of Innovation, Technology Transfer, and the World Distribution of Income, *Journal of Political Economy*, 87(2), 253-266.
Lacour P., Fuguiere C., 2014, Analyse de trois canaux de transfert de technologies vertes entre la Chine et le Japon : methodologies et resultats, *Marché et Organisations*, 21, 85-112.
Lam L.T., Branstetter L., Azevedo I.M.L., 2017, China’s wind industry: Leading in deployment, lagging in innovation, *Energy Policy,* 106, 588-599.
Laperche B. (ed), *Géront’innovations, Tragjectoires d’innovation dans une économie vieillisante*, Coll. Business & Innovation, Bruxelles, Peter Lang.
Li Y., Zhan C., de Jong M., Lukszo Z., 2016, Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China, *Journal of Cleaner Production*, 134, 371-383.
Lin J. Y.F., 2013, “La politique industrielle revisitée : une nouvelle perspective d’économie structurelle”, *Revue d’économie du développement,* 2013/2, vol.27, pp.55-78.
Lin J. Y.F., Monga C., 2011, Growth Identification and Facilitation: The Role of the State in the Process of Dynamic Growth, *Development Policy Review,* 29(3), pp.264-290.
Liu H., Liang D. 2013, A review of clean energy innovation and technology transfer in China, *Renewable and Sustainable Energy Reviews*, 18, 486-498.
Liu Z., 2014, Performances et limites de la politique industrielle et de l’innovation chinoises dans le secteur énergétique : le cas des industries photovoltaïque et éolienne, *Marché et Organisations*, 21, 57-84.
Liu Z., 2016, "Gerontechnology and Silver Industry: Is a new industrial filière emerging in China?”, in Laperche B. (ed), Géront’innovations, Tragjectoires d’innovation dans une économie vieillisante, Coll. Business & Innovation, Bruxelles, Peter Lang.
Lundvall B.A. (ed.), 1992, *National Systems of Innovation*, Londres, Francis Pinter.
Lundvall B.A., Gu S.L. (2012), Le cheminement de la Chine vers l’innovation endogène et la croissance économique, in BIRONNEAU R. (dirdir), *China Innovation Inc.,* 2012, SciencePo Les Presses, Paris.
Luo G.L., Zhi F., Zhang X.Y. (2012), Inconsistency between the wind power development and the grid planning and construction: an institutional perspective, *Renewable Energy*, 48, 52-56.
Malerba F. (2002), Les régimes technologiques et les systèmes sectoriels d’innovation en Europe, in Touffut J.P. (dir.), *Inistitutions et Innovation : De la recherche aux systèmes sociaux d’innovation,* Paris Albine Miche, 203-247.
Ministry of Environment Protection, 2014, *Report on environmental protection industries 2011*, Beijing, in Chinese
Ministry of Science & Technology, 2005-2013, *Annual Report of the State Programs of Science and Technology Development*, Beijing, in Chinese
Nelson R. R., Winter S. G., 1982, *An Evolutionary Theory of Economic Change*, Cambridge, MA: Harvard University Press.

Niosi J., Bellon B., Saviotti P., Crow M., 1992, Les systèmes nationaux d'innovation : à la recherche d'un concept utilisable, *Revue française d'économie*, vol.7, n°1, p. 215-250.
OECD, 2008, *Review of Innovation Policy. China,* Paris, OECD.
OECD, 2010, L'éco-innovation dans l'industrie : Favoriser la croissance verte, Paris, OECD.
OECD, 2011, *Towards Green Growth,* Paris, OCDE.
OECD, 2009, *Eco-Innovation in Industry. Enabling Green Growth,* OECD Publishing: Paris.
Pavitt K., 1984, Sectoral patterns of innovation: Toward a taxonomy and a theory, *Research Policy*, 13, p. 343-375.
Shao Ken, Feng Xiaoqing (eds), 2014, Innovation and Intellectual Property in China. Strategies, Contexts and Challenges, Cheltenham UK, Northampton USA, Edward Elgar.
SIPO, 2015, *Report on patents of strategic emerging industries,* Beijing.
State Statistics Bureau, 2004-2013, *Chinese S&T Statistical Yearbook*, Beijing, in Chinese.
World Bank, 2007, *Cost of Pollution in China: Economic Estimation of Physical Damages,* Conference edition, Washington D.C., The World Bank, February, 2007.
Wu C.Y., Mathews J.A., 2012, Knowledge flows in the solar photovoltaic industry: Insights from patenting by Taiwan, Korea, and China, *Research Policy*, 56, 524-540.
Yang H., Huang X.J., Thompson J. R., 2014, China tackle pollution from solar panels, *Nature,* correspondence, 509, p.563.
Yuan J.H., Yuan X., Hu Z., Yu Z.F., Liu J.Y., Hu Z.G., Xu M., 2012, Managing electric power system transition in China, *Renewable and Sustainable Energy Reviews,* 16, 5660-5677.
Yue D.J., You F.Q., Darling S. B., 2014, Domestic and overseas manufacturing scenarios of silicon-based photovoltaics: Life cycle energy and environmental comparative analysis, *Solar Energy,* 105, 669-678.
Zhang X.Y., Zhao H.B., Zhou X.K., 2011, The Development and Problems of China's New-Energy Auto Industry: Based on the Perspective of Sustainable Development of Auto Industry (en chinois), *Theory and Modernization,* 2(3), 60-66.