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Evaluation of China's policy for wind power development from the new structural economics perspective

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ABSTRACT

The Chinese energy transition, as a shift from fossil fuels to renewable energy sources, involves the dynamic growth of wind power's importance in a national energy mix. The development of the wind power industry in this country is intertwined with the implemented policies that translated to the significant increase in energy generation from this power source and the growth of trade volumes of wind power products. This research aims to review and analyse the China's policy that impacted wind power development in 2000-2019. The author aims to evaluate the efficiency of implemented policies and strategies from the perspective of the new structural economics assumptions and the revealed comparative advantage of the Chinese wind energy products. In addition to the review of scientific literature and policy documents, as well as analysis of the relevant trade and energy indicators, the method applied in this research is a calculation of the Revealed Comparative Advantage (RCA) index. The results provide pieces of evidence that despite the substantial development of the Chinese wind power industry on a national scale, this country still has not revealed a comparative advantage globally. However, the results also suggest that the Chinese wind power industry is on the right track to achieve export specialisation soon. Furthermore, the China's policy for wind power development matches the new structural economics assumptions. The presented insight into studied industry blazes the trail for other countries, which consider following the Chinese development path by shaping the growth of *leading-edge industries* and the energy transition process throughout various state interventions.

Keywords

China;
Wind power;
Revealed comparative advantage;
New structural economics;
Energy policy;

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1. Introduction

As a shift from energy generation from fossil fuels to renewable sources, the energy transition is an effortful process for every government, society and economy worldwide. Numerous countries have already implemented substantial policies and strategies to transform the national and regional energy sectors. These actions involve the changes in various areas like, for instance, investments in infrastructure and related facilities and the development of a national renewable energy industry that includes enterprises producing goods and those offering services related to renewable energy utilisation in energy generation. Diversifying a country's energy mix to increase the share of renewable energy sources at the cost of energy from conventional fossil fuels is a very capital-intensive and time-consuming process. However, after technical and economic analysis, some researchers, like Conolly and Mathiesen [1], have already demonstrated a feasible pathway to transform a national energy system entirely dependent on renewable energy sources.

As a multidimensional issue, energy transition requires substantial changes in national policies in diverse aspects and on every level – from municipalities and regions to central authorities [2]. Since the energy sector is an essential and critical part of a national econ-

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omy, less or more significant state involvement is required to shape the energy transition process. Moreover, the increase in the utilisation of renewable energy sources is linked to a country's economic growth, so the energy policies should be considered a vital part of national economic development and economic growth policies. The current analysis of the impact of renewable energy consumption on the selected economic conditions provides evidence that a 1% increase in renewable energy consumption will increase GDP by 0.105% and GDP *per capita* by 0.100%. In comparison, a 1% increase in the share of renewable energy to the energy mix of the countries will increase GDP by 0.089% and GDP *per capita* by 0.090% [3].

A recent study shows a dynamic relationship and causality of China's financial development, economic growth and renewable energy consumption. Besides, the study proved that Chinese economic growth and financial development impact renewable energy consumption in the long run, but with a diverse significance at national and regional (eastern, central and western) levels [4]. On the other hand, over the last two decades, the Chinese energy transition has been strictly linked with the growing energy consumption resulting from the rapidly growing economic development. The transformation of the energy sector in this country is shaped by numerous policies and strategies that aim to promote the reduction of carbon dioxide (CO_2) emissions by increasing the role of the renewable energy sector and adjusting its industrial structure [5]. Among other renewable energy sources, wind power is one of China's most essential one in mitigating climate change (together with hydro and solar power). Furthermore, the development of the wind power sector in this country has become one of the critical components of the national comprehensive policy system for energy transition [6].

The energy transition process can also be driven by other factors, including increasing energy cost, raising awareness of the harmful impact of human development on climate change and depletion of traditional energy sources – fossil fuels [7]. In this context, China presents an example of an economy under intensive pressure to remodel its energy system and rely on fossil fuels to a lesser extent. For instance, just in 2019, this country emitted over 10,175 Mt of CO_2 and was an absolute global leader among other emitters. However, it is worth emphasising that, over the last years, China has flattened and slowed down the growth dynamics of CO_2 emissions [8].

Nevertheless, this economy utilises half of the world's annual coal consumption (primarily for district heating purposes in urban areas, directly translating to air pollution and poisonous smog formation, especially in the northern districts) [9]. The inclusion of renewable energy sources in the Chinese energy mix has become an essential objective for the Chinese authorities from the beginning of the 21st century. From that time, this process significantly and irreversibly increased the role of renewables [10,11]. It is important to acknowledge that among the non-hydroelectric renewable energy sources (like sun, biomass and geothermal power), wind power continuously gains its importance in the Chinese energy sector. So far, it is a leading source in this particular group of renewables, which will be discussed in the following parts of this research article.

For those reasons, this research paper aims to provide broad information and evaluate state policies that translated the most to the Chinese wind power sector's impressive development in 2000-2019. The author aims to study and illustrate the theoretical background and efficiency of implemented policy instruments from the perspective of the new structural economics (NSE) assumptions. NSE is a modern economic doctrine that combines the postulates of neoclassical economics and twentieth-century structuralism [12-14]. This approach requires a specific state-controlled industrial policy that either turns comparative advantages into competitive advantages of selected sectors or shapes a country's economic development to gain the comparative advantages from the ground up. Moreover, NSE recommends applying detailed state actions suitable for advancing catching-up sectors and their distance to foreign competitors [15,16]. For this reason, the author broadens the scope of the research with the calculations of the Revealed Comparative Advantage (RCA) index, which allows to find out if a country holds an export specialisation in a given category of products [17].

Regarding the author's best knowledge, a similar analysis has not been conducted in recent years yet (especially in the context of the globally revealed comparative advantage of the Chinese wind power industry). The results contribute to a better understanding of the role of central authorities in shaping the Chinese wind power sector development and export specialisation in wind turbines. To comprehensively present research findings, this paper is organised as follows: the second part provides a literature review, while the third part presents the new structural economics assumptions,

especially in the context of the *leading-edge industries*. They are followed by the overview of China's wind power industry development in 2000 – 2019. The next section presents a revealed comparative advantage index calculations together with suitable analysis. The last section studies the Chinese wind power development policy from the new structural economics perspective. Conclusions and a summary are placed in the final part of the paper.

2. Literature review

The research focused on the Chinese industrial policy for wind power development was the subject of numerous studies in the past. However, because this industry has undergone significant and dynamic changes over the last two decades and the Chinese regional and central authorities constantly change relevant policy assumptions, it is crucial to review the most up-to-date literature.

The recent studies of the Chinese industrial policy for wind power development evaluate its overall assumptions and present detailed recommendations that may improve the functioning and efficiency of implemented policy instruments. Li *et al.* [18] tracked and studied the evolution of China's wind power development policy. They presented several pieces of advice, including improving the governmental performance assessment system, strengthening overall planning, improving the wind trading system, financial incentives and the level of wind power-related technologies. Moreover, the researchers were proposing strengthening relevant technical standards, testing and certification system construction, as well as improving the supervision and evaluation system.

Most of the research focuses on onshore wind power since the offshore facilities are still marginal on a national scale. However, the Chinese authorities vigorously promote this type of wind power facility, which translates to its increasing share in the national energy mix. The evaluation of the price policy for the offshore power plants, carried by Wei *et al.* [19], presented a dynamically growing industry fueled by the constantly adjusted price policy. However, the critical challenge in shaping the policy assumptions for offshore wind power is a "capacity, price, subsidy trilemma". This issue results in an impossible simultaneous increase in installed capacity, decrease in electricity prices and reduction of the offshore wind power subsidies. The authors proposed detailed recommendations to overcome this trilemma, including implementing the market-oriented competition price policy and mechanism and higher participation of foreign investors in the new offshore wind projects.

In general, the wind power industry in China has undergone tremendous changes from the beginning of the 21st century. One of the key policy documents that substantially impacted wind power development was the Renewable Energy Law issued in 2006. Among numerous studies on the impact evaluation of these policy statements and legal regulations, the research carried by Liu *et al.* [20] was focused on the empirical evaluation of the wind power industry in the framework of that law and related policies. That study revealed the significance of the three policy instruments that had the most significant impact on the growth of the wind power industry in China from the perspective of electricity generation and installed capacity – total target mechanism, feed-in tariffs mechanism and special fund mechanism.

The other studies are also focused on the role of industrial policy in increasing the innovativeness of the Chinese enterprises from the wind power industry. For instance, the effectiveness of the implemented policy instruments in the context of the innovation performance of the different ownership enterprises was studied by Wang and Zou [21]. Their econometric study based on the 254 wind power industrial policies issued at the departmental and ministerial level and above in China from 1994 to 2016 indicated a significant positive effect on innovation performance, mainly for the core technological innovation. Furthermore, they provided an in-depth analysis of the differences between the effect of the supply-side and demand-side wind power development policies, as well as differentiated the impact of the policies between the state-owned and the private-owned enterprises.

Besides, the effectiveness of the implemented wind power policy can be studied from the perspective of the individual instruments. The exemplification of this approach was research proposed by Lin and Chen [22]. Their study revealed that the demand-pull policies through feed-in tariff policy stimulate innovation in this particular industry. More importantly, higher feed-in tariffs on wind power translated to the increasing number of patents related to wind power technology. The researchers also emphasised the vital role of technology-push policies through R&D investments in stimulating the technological innovativeness of Chinese enterprises.

Another critical aspect of evaluating the wind power policy in China is its effectiveness on the provincial (regional) level. For instance, the study carried by Song *et al.* [23] has uncovered that the price-oriented wind power policy has a more significant impact on promoting the new installation of wind turbines on the national level than a quantity-oriented wind power policy. On the other hand, the price-oriented policy is more influential on the provincial level in the eastern, central and western regions. Still, the quantity-oriented policy was more successful in the eastern regions than in the central and western regions in the long run.

Such multidimensional analysis of the wind power policy, both on the national and regional level, presents substantial heterogeneity of this power source development in China. Dong and Shi [24] evaluated the main factors that affect the performance of wind power in the Chinese provinces. Their research findings shed new light on the current wind curtailment in many Chinese regions. Furthermore, they proved that local power consumption capacity, level of economic development and the rate of wind abandonment are some of the critical factors that diversify the provinces in the context of wind power utilisation. Simultaneously, the researchers have proposed promoting wind power consumption by renewable energy policy reform, including the increase in feed-in tariffs and the renewable portfolio standards, which are the highly efficient policy instruments in this matter.

The policies for the wind power industry development in China can also be evaluated from the perspective of productive efficiency improvement. For instance, a study presented by Jiang and Liu [25], based on the micro-data of Chinese wind power enterprises from 2006-2019, demonstrated that the overall productive efficiency of this industry is relatively low. The presented results reveal that the studied efficiency of upstream enterprises was the highest, in contrast to the downstream enterprises that demonstrated the lowest productive efficiency. That research also proved that the implemented economic policy has substantially stimulated the growth of productive efficiency, which increased in the studied period. However, it was still far lower than, for instance, in the US wind power industry.

The effectiveness of the Chinese wind power development policy was also studied from the perspective of trade relations and international competitiveness. Leng *et al.* [26] conducted research aiming to evaluate the trade potential of wind energy products with the countries alongside the Belt and Road Initiative (BRI). The researchers, thanks to the gravity model approach, revealed that the Chinese trade of wind energy products had been dynamically growing in the past. Still, the market structure is concentrated among the neighbouring countries. Besides, the GDP of importing countries, national energy consumption, and the growing Chinese wind power installed capacity positively impacted the Chinese export. In contrast, the distance between the trade partners negatively impacted the export volumes.

The trade potential of the Chinese wind energy products in the context of the BRI was studied by the same researchers also from the perspective of the revealed comparative advantage [27]. That study considered a broad panel of Harmonised System (HS) codes (categories of products) from the UN COMTRADE database. It demonstrated a relatively low revealed comparative advantage (RCA) of the Chinese wind power products in the studied period. However, the results showed that the overall comparative advantage of the Chinese wind energy products increased in 2007-2016, but only in 2016, the RCA index exceeded 1.00. In other words, the Chinese wind energy products demonstrated a comparative disadvantage and lack of export specialisation in the relations with the Belt and Road Initiative countries (despite dynamically increasing export and import volumes).

In conclusion, the presented literature review characterises the changes and challenges the Chinese wind power sector faced in 2000-2019. The analysed studies provided a broad perspective on the implemented policies and strategies, which allowed the Chinese wind power sector to grow thanks to various instruments, such as subsidisation, feed-in tariffs and stimulating price and R&D policy. Interestingly, despite the dynamically growing wind power installed capacity and increasing volumes of wind turbine export, the studied sector presents low competitiveness and effectiveness. As a contribution to the existing literature, this research aims to evaluate the Chinese wind power development policy in the context of global export specialisation and revealed comparative advantage of the Chinese wind power products in the theoretical framework of the new structural economics assumptions. The following section presents a brief review of the NSE postulates to demonstrate a theoretical background for the deliberations included in the next parts of the article.

3. New structural economics assumptions

The rapid development of the wind power industry in China over the last two decades may be perceived from the perspective of new structural economics assumptions. As a combination of structuralism and neoclassical economics, NSE recommends a state-controlled industrial policy approach [28]. New structural economics is founded on the following main assumptions: (1) economic development is a result of perpetual technological and industrial innovation, (2) a country's economic structure is endogenous to the economy's endowment structure, (3) transformation of a country's economic structure stimulates economic development. Moreover, NSE postulates that the mentioned structural changes increase labour productivity and reduce transaction costs. Furthermore, new structural economics underlines the critical role of states in transforming a country's comparative advantages into competitive advantages by appropriate economic policies adjusted to selected sectors [15].

Simultaneously, the structural changes should be associated with state actions that translate to infrastructure investments. Lin [28] summarised the role of state interventions in new structural economics with this statement: *(...) the role of the state in industrial diversification and upgrading should be limited to the provision of information about the new industries, the coordination of related investments across different firms in the same industries, the compensation of information externalities for pioneer firms, and the nurturing of new industries through incubation and encouragement of foreign direct investments*. From the perspective of new structural economics assumptions, the Chinese economy holds great potential due to a highly effective combination of an efficient market and facilitating state.

In NSE, a country's national sectors are grouped considering their importance to the domestic economy, distance to foreign developed economies, competitiveness or hidden comparative advantage. The division of sectors into five categories allows the state to match the adequate, systematic and comprehensive industrial policy instruments to the economic necessities and business requirements. The ways of encouragement or economic incentives given by authorities to national enterprises operating within the industries can include special economic zones, direct subsidies, incubation programs, industrial parks, corporate income tax holidays, tariffs, preferential governmental spending or R&D grants. These stimulative state interventions aim to provide the most business-friendly environment for domestic companies to increase their competitiveness, innovativeness and development dynamics.

NSE recommends various fiscal, industrial or other policy tools towards specific recognised industries (which are synthetically summarised and presented in Table 1).

Table 1: New structural economics recommendations towards industrial policy instruments for individual categories of sectors. Based on [15].

Catching-up industries	State authorities start with the identification of potential catching-up industries. A state should then attract companies' attention from more advanced economies to relocate to the country and strengthen its catching-up industries. Furthermore, the state should support successful businesses in new industries and attract domestic and foreign companies through 'special economic zones'. Finally, the state ought to compensate pioneering firms for the externalities they generate.
Leading-edge industries	The following instruments should support advanced modern technologies and product development: fiscal allocations to establish research funds, government subsidies for research institutions and R&D departments. Authorities can also force the pace of returns to scale increase by public procurements, legal regulations and standardisation.
Comparative advantage-losing industries	Companies should be fit with advanced, modern knowledge about design, R&D and marketing. The state authorities should also establish 'export processing zones' to strengthen firms' knowledge and higher volume of products transferred abroad.
'Corner-overtaking' industries	State authorities can support these industries by investing in the education of related human capital, setting up start-up incubators, reinforcement and protection of property rights, encouraging venture capital, providing preferential taxes, facilitating start-ups run by creative talents at home and abroad, and by using government procurement to support the production of new products.
Strategic industries	For instance, a defence industry. These crucial industries can be assisted with subsidies, R&D grants, or possibly strengthened with products' public procurement. Despite the circumstances, the number of supported companies should be minimal.

Catching-up industries are the businesses that have a lot of ground to cover, comparing to much more developed industries in other countries. Moreover, this category is in the new structural economics spotlight since the domestic enterprises already operate in these industries and possess good comparative advantages to gain on foreign leaders. Highly capital intensive businesses, categorised as *leading-edge industries,* typically operate in developed countries. Still, it is possible to enter this technologically advanced business by increasing a country's comparative advantage and competitiveness of individual enterprises operating in a national economy. The third category – *comparative advantage-losing industries* are an example of businesses that operate in developing countries, but due to economic growth and structural changes, they lose their comparative advantage (for instance, low labour costs in a particular sector). Some of the businesses included in the *corner-overtaking industries* section represent a potential field of competition with foreign competitors because it refers to only just established modern industries. Such a situation may occur when an innovative technology, commodity or service is introduced, and all competitors start at the same level. That last sector – *strategic industries* – refers to those businesses that are vital to a country's national defence. It involves companies (usually partially or wholly state-owned) whose comparative advantages have secondary importance, but they represent a great value from the perspective of national strategic security [15,29].

4. The Chinese wind power sector development in 2000 - 2019

Chinese territory holds much potential in electricity generation from wind power, estimated to be approximately 5500 GWh annually [30]. However, wind power resources are distributed unevenly among the regions. The richest in wind power resources are the northern and central districts, like Xinjiang, Gansu, Ningxia and Inner Mongolia, Tibet or Qinghai province, and the southern coastal area. Figure 1 presents the distribution of wind power density in the Chinese territory (in W/m^2 at 100 m above the ground level).

The utilisation of wind power resources, both onshore and offshore, began at the beginning of the 21st century. The state actions, and especially industrial policy instruments, significantly impacted the process of increasing the exploitation of this specific power source [32]. From 2000 it is observed that the Chinese wind power sector vitally increased its installed capacity, translating to the growing power generation from wind turbines. Figure 2 presents the growing annual total installed capacity of wind turbines year-to-year in MW.

The increasing volume of installed wind power capacity translated to the growing share of wind power

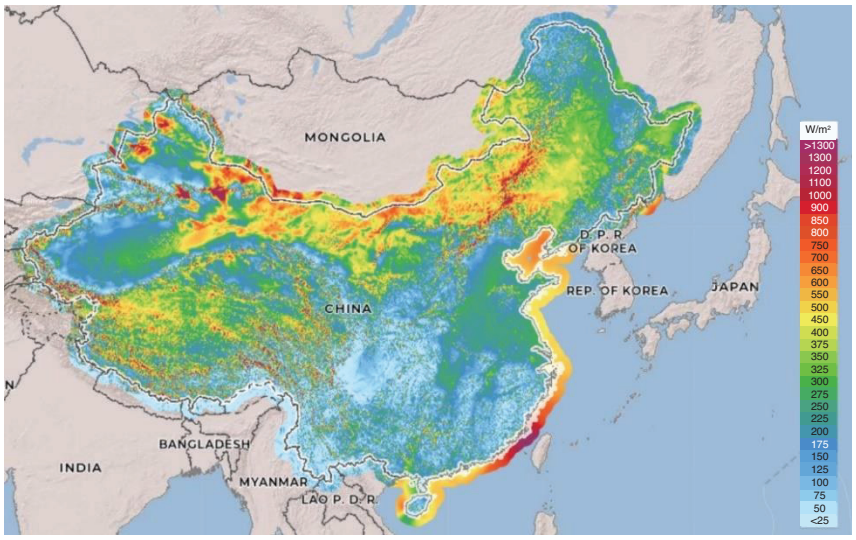

Figure 1: Wind power density distribution in China in W/m^2 at 100 meters height with a 100 km coastal and cross-border area. Figure from [31].

in the Chinese energy mix. It is substantial to acknowledge that over the last twenty years total annual energy supply increased from 10.467 MWh *per capita* to 26.749 MWh *per capita*, the annual total energy generation from coal increased from 7730.694 TWh to 23021.864 TWh and, last but not least, the electricity consumption increased from the 1 MWh *per capita* up to 4.9 MWh *per capita* annually [35]. These general energy sector indicators draw a clear picture of how this country's demand and energy supply has changed within two decades. Simultaneously, the share of wind power in the Chinese energy generation mix was continuously growing, which is presented in Figure 3.

The growing importance of wind power in the national energy mix also involves other renewable sources. Wind power development is also related to the construction of offshore facilities and has already become an essential part of this country's energy supply system [36,37]. The success was also achieved in the field of photovoltaics, which accounted for 22 GWh in 2000 and 223 800 GWh in 2019 [35]. The change in the group of non-hydroelectric energy sources is presented

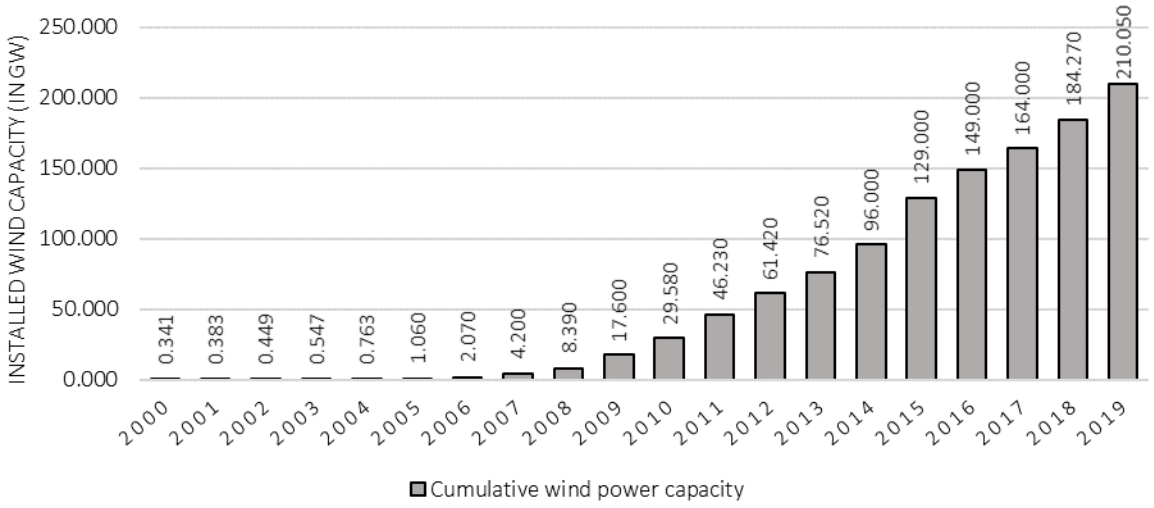

Figure 2: The cumulative wind power installed capacity in 2000 – 2019 (in a GW). Data from [33,34].

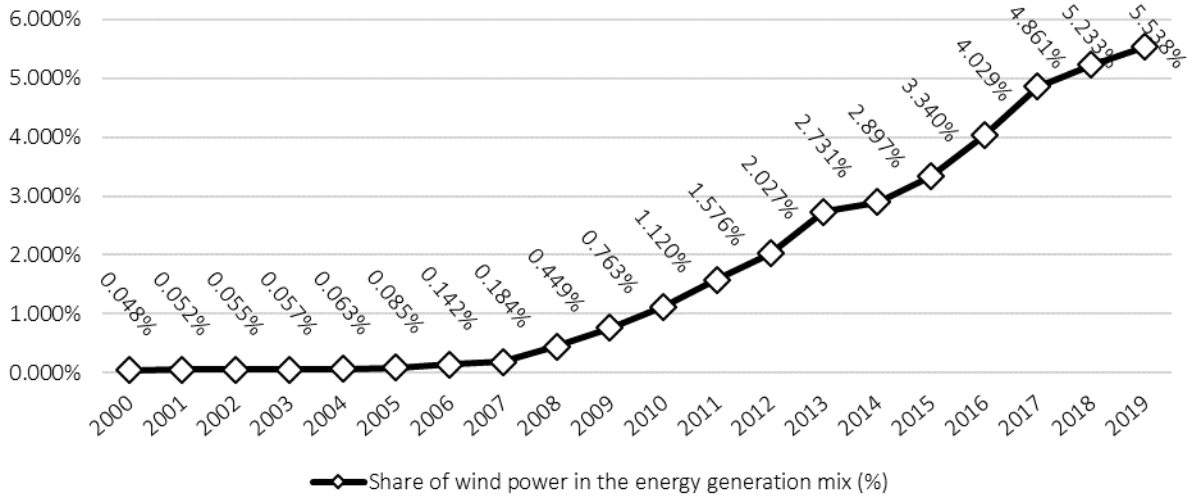

Figure 3: The share of energy generated from wind power in the total Chinese energy mix in 2000-2019 (in %). Data from [33,34].

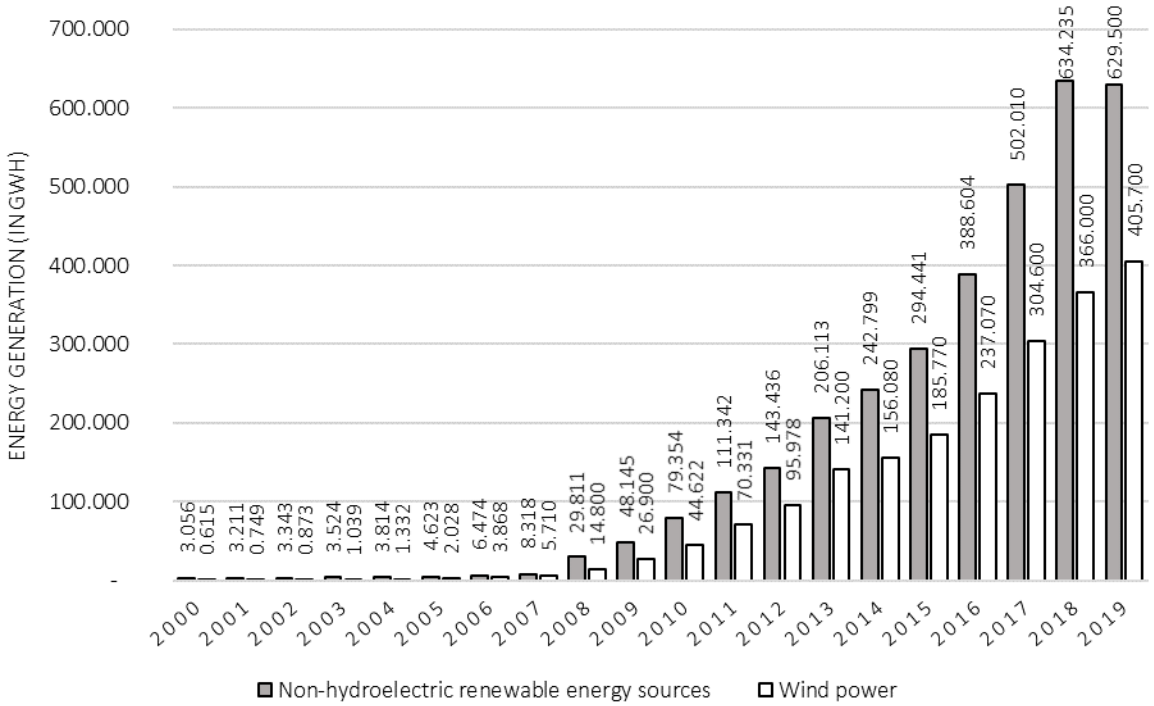

Figure 4: Energy generation from non-hydroelectric renewable sources and wind power in China in 2000-2019 (in GWh). Data from [33,34].

in Figure 4. The energy generated from wind power is continuously the leading energy source in this subcategory of renewable energy sources.

Indeed, the development of this sector is also noticeable in the context of private enterprises. By 2019, the Chinese wind power industry became one of the global leaders in capacity, production and export. For instance, a Chinese-based company – Goldwind – was among the top-4 world wind turbine producers, together with Vestas (Denmark), Siemens Gamesa (Spain), and GE Renewable Energy (United States). In 2019, those four enterprises were responsible for nearly 55% of the wind power capacity installed worldwide [38].

Another example of the Chinese wind power sector growth is its export volume in 2013-2018. In that period, Chinese enterprises exported over 2882 MW of wind turbines abroad [39]. By 2019 the Chinese wind market of Original Equipment Manufacturers (OEMs) has been dominated and consolidated mainly by Goldwind, Envision and MYSE, which accounted for 62% of the national market share. Besides these three companies, the other leading Chinese-based OEMs are listed in Table 2.

The development of this particular sector can also be described from the perspective of the revealed comparative advantage.

Table 2: Top 10 Chinese Original Equipment Manufacturers and their share in the Chinese wind turbine market in 2019 (in %). Data from [40].

Ranking 2019	Original Equipment Manufacturers in China	Market Share
1	Goldwind	27.7%
2	Envision	18.8%
3	MYSE	15.6%
4	Windey	7.1%
5	Shanghai Electric	5.9%
6	CSIC Haizhuang	5.1%
7	Dongfang Electric	4.9%
8	United Power	3.7%
9	XEMC Wind	2.7%
10	CRRC	2.2%

5. The revealed comparative advantage of the Chinese wind power sector in 2000-2019

This part presents the Revealed Comparative Advantage (RCA) index calculations in the context of Chinese export specialisation in wind turbines and relevant components.

5.1. Methods and data

The concept to measure revealed comparative advantage was presented for the first time by Balassa in 1965 [17].

It is based on the Ricardian comparative advantage theorem, which states that an economy possesses the advantage when it can produce particular commodities or provide services at a lower opportunity (comparative) cost than its trading partners. From the first publication of the RCA index assumptions and formula, this approach has become one of the key indicators to measure export specialisation, resulting from a country's economy comparative advantages. However, there are many various alternatives to calculate the RCA index [41,42].

The classical approach used in this research and applied by the United Nations Conference on Trade and Development (UNCTAD) is founded on the concept that revealed comparative can be measure with Equation 1 presented below [43].

$$RCA_{Ai} = \frac{X_{Ai} / \sum_{j \in P} X_{Aj}}{X_{Wi} / \sum_{j \in P} X_{Wj}} \quad (1)$$

, where:
P – is the set of all exported products (with $i \in P$),
X_{Ai} – is the country A's exports of product *i*
X_{wi}– is the world's exports of product *i*
$\sum_{j \in P} X_{Aj}$ – is the country A's total exports (of all products *j* in *P*), and
$\sum_{j \in P} X_{wj}$ – is the world's total exports (of all products *j* in *P*).

The presented export specialisation index's interpretation is as follows: a country has revealed comparative advantage for a given product when the RCA index value exceeds 1.00. When such observation occurs, a country's economy becomes a competitive producer and strong exporter of the commodity's analysed category. In other words, the higher the RCA index above 1.00 is, the stronger the comparative advantage a studied economy has.

On the other hand, when the RCA index value is below 1.00, a country's economy has a comparative disadvantage in the analysed product category, meaning that this economy is producing and exporting that category of goods at or below the world average.

The data used in the following RCA index calculations are sourced from United Nations Comtrade Database using the Harmonized Commodity Description and Coding Systems (HS). The studied time covers the period between 2000 and 2019. The first category of considered goods is 730820 (HS) *Towers and lattice masts made of iron or steel*, and the second category of goods is 850231 (HS) *Electric generating sets; wind-powered* [44].

5.2. Results of RCA index calculations

Analysis of the Chinese export of wind power products shows that this sector achieved dynamic growth from the beginning of the 21st century until 2019. Table 3 presents the Chinese and world export of selected HS categories and total Chinese and global export in detail. The results of the RCA index calculations for the Chinse wind power industry are presented in Table 3.

In addition to Table 3 and in the context of revealed comparative advantage index calculations, it is worth presenting the dynamics of the share of the wind power products (HS codes 730820 and 850231) in the total value of the Chinese and world export.

Figure 5 demonstrates the fluctuating share of the wind power products export in the Chinese and the global export in the studied period. Regarding the RCA formula, the Chinese wind power industry could reveal an export specialisation if the national share of the wind power products in total Chinese export is higher than the global share. As presented in the mentioned figure, the increasing share of wind power products export in China has not reached the global share in 2000-2019.

Interestingly, in contrast to the dynamic growth of export (presented in Table 3) and the total installed capacity of wind turbines in China (demonstrated in the previous section), the RCA index calculations results have shown that, so far, the Chinese wind power industry has not revealed a comparative advantage on the global scale yet. Moreover, this sector has a comparative disadvantage, even though in 2013-2018, Chinese enterprises exported wind turbines whose capacity exceeded 2882 MW [45]. However, Figure 6 demonstrates something more substantial – it proves that the studied industry slowly minimises the comparative disadvantage and can potentially reveal comparative advantage and export specialisation just in a few years from now.

As shown in Figure 6, the growing linear trend suggests a noticeable improvement in the export specialisation of the Chinese wind power industry in 2000-2019. These research results are concurrent with the other researchers' evidence, especially Leng *et al.* [27]. This industry's visible revealed comparative disadvantage could be explained by low innovativeness (compared to the foreign partners), which results in moderate learning rates and a relatively low number of international patents. As Lam *et al.* [46] demonstrate, the Chinese wind power industry managed to reduce production costs, successfully transfer technology and conduct substantial capacity-building thanks to generous and sustained government

Table 3: Revealed comparative advantage index of the Chinese wind power sector and the values of the wind power products export in 2000-2019 (in USD). Values of export were sourced from the UN COMTRADE database.

Year	Chinese export of the wind power products (HS 730820 and 850231)	Total Chinese export (all HS categories)	World export of the wind power products (HS 730820 and 850231)	Total world export (all HS categories)	Revealed Comparative Advantages index
2000	$14 382 176	$249 202 551 015	$888 153 095	$6 280 702 497 936	**0.40812435**
2001	$13 029 634	$266 098 208 590	$1 536 578 002	$6 056 245 373 170	**0.19299192**
2002	$31 506 646	$325 595 969 765	$1 467 974 700	$6 373 196 608 367	**0.42010892**
2003	$13 040 179	$438 227 767 355	$1 637 368 949	$7 446 351 958 163	**0.13532582**
2004	$32 721 422	$593 325 581 430	$1 876 781 411	$9 011 170 119 162	**0.26479306**
2005	$107 998 187	$761 953 409 531	$3 031 793 954	$10 146 669 036 616	**0.47436415**
2006	$161 900 373	$968 935 601 013	$4 510 368 910	$11 378 199 907 885	**0.42151636**
2007	$399 888 132	$1 220 059 668 452	$5 987 276 880	$13 578 167 325 447	**0.74330877**
2008	$761 015 109	$1 430 693 066 080	$9 441 296 888	$15 646 491 905 431	**0.88151992**
2009	$439 838 164	$1 201 646 758 080	$7 904 716 653	$12 224 297 419 127	**0.56604856**
2010	$376 901 764	$1 577 763 750 888	$8 822 769 020	$14 901 646 239 425	**0.40347398**
2011	$658 564 000	$1 898 388 434 783	$9 783 503 784	$17 899 100 380 183	**0.63467252**
2012	$851 237 289	$2 048 782 233 084	$11 677 016 185	$17 837 300 282 821	**0.63467601**
2013	$861 677 165	$2 209 007 280 259	$11 475 649 487	$18 549 757 678 847	**0.63053384**
2014	$908 677 211	$2 342 292 696 320	$12 009 724 574	$18 459 858 924 450	**0.59629862**
2015	$984 660 609	$2 273 468 224 113	$11 039 132 177	$16 134 265 693 596	**0.63301201**
2016	$1 194 919 380	$2 097 637 171 895	$10 988 859 853	$15 669 570 969 659	**0.81229299**
2017	$947 729 792	$2 263 370 504 301	$8 194 080 845	$17 259 263 734 074	**0.88196409**
2018	$1 039 527 226	$2 494 230 194 966	$9 321 111 333	$18 927 562 878 030	**0.84630389**
2019	$1 374 997 965	$2 498 569 865 637	$11 204 525 366	$18 188 024 605 841	**0.89331089**

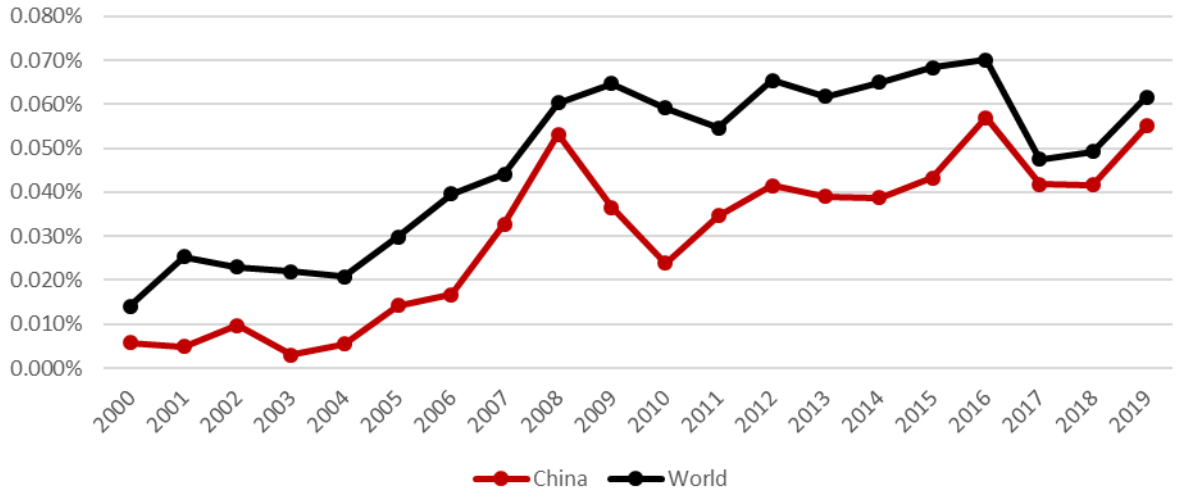

Figure 5: The share of the wind power products (HS codes 730820 and 850231) in the total value of the Chinese export and world export in 2000-2019.

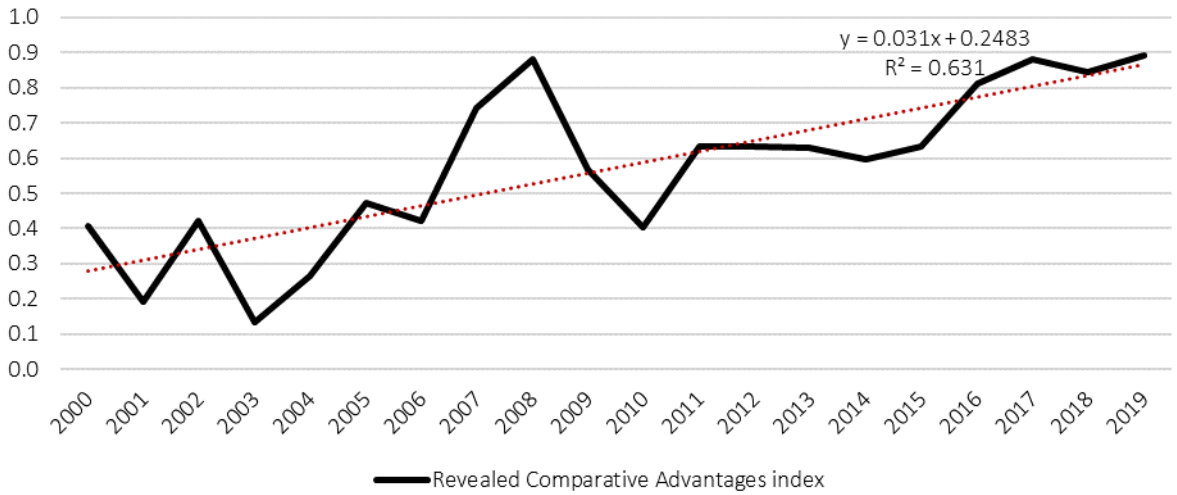

Figure 6: Presentation of the revealed comparative advantage (RCA) index of the Chinese wind power industry in 2000 – 2019 with the linear trend function.

support. The growth strategy adopted by the Chinese enterprises, based on undercutting the prices and increasing the wind turbine output, translated to the imbalance of supply and demand, together with the implementation of cost-reducing innovation. In addition, regarding the Jiang and Liu [25] results, the overall production efficiency of this industry is relatively low, for instance, comparing to the wind power industry in the USA. However, they also provided evidence that the implemented Chinese industrial policy has significantly impacted production efficiency growth in the studied period.

The explanation of the revealed comparative disadvantage can also be found in the research carried by Zhang *et al.* [47]. They proved that China is currently a global leader in installed wind power capacity, and its wind power industry has undergone tremendous development on a global scale. However, as their results show, the Chinese wind turbines have low international recognition. The Chinese wind power industry has, therefore, a limited impact on the global wind turbine market. The Chinese wind power industry presents a moderate competitive position because of the "quantity", not the "quality" of wind turbines. It is visible in the lower than average power generation from wind and a lower technology level of the Chinese wind turbines. As the researchers point out, the innovation and technological gap to the global producers are dynamically narrowing. The continuous development of the wind power industry in China may significantly improve the Chinese enterprises' global position. The shift from massive cost-reduction production of low-price wind turbines to the production of higher quality and more innovative wind turbines will likely increase the international recognition of Chinese wind turbines.

The previously presented literature review provided evidence that government measures and introduced policies shaped the Chinese wind power industry development in the last two decades. The increasing export specialisation and growth of the RCA index of wind power products are also intertwined with the implemented policies in 2000-2019.

6. Chinese policies towards the wind power sector from the NSE perspective.

This part reviews relevant policy statements, strategies and other crucial documents that translated to the changes in the Chinese wind power sector from the beginning of the 21st century in the context of the new structural assumptions.

6.1. Policies for wind power sector development in China in the 21st century

From the beginning of the 21st century, the Chinese central authorities have strived to develop the wind power sector through various policies and instruments. Considering the increasing values of the national energy sector indicators presented above and improvements in the private sector that translated to Chinese wind turbine producers' leading global position, these policies have the desired effects. Simultaneous sectoral development and

the progressive energy transition towards electricity generation from wind power and other renewables have been associated with at least 27 crucial policy documents [48].

Although the significant increase in electricity generation from wind power occurred around 2005, the governmental preparations already began with the first *demonstration phase* in 1986-2000. In 1986, the first wind farm was constructed in Rongcheng Shandong province. It was then followed by small projects mainly financed by foreign entities since the Chinese wind power sector was still in a very preliminary development stage.

The first targeted total wind power capacity of 1 GW was planned with the *Ride the Wind Power Programme* 1997-2001. As a result, for the first time, large wind power projects were accomplished with the involvement of foreign enterprises such as Nordex Balcke-Durr GmbH, Vestas and Micon. At the same time, the following projects were gradually increasing the Chinese enterprises' participation while the new ones were established [49].

The *demonstration phase* was followed by the next, substantially more advanced and prospective policies, strategies and statements that shaped the sector's growth and established the future energy transition process's goals. Table 4 presents the review of policies selected on the basis of their relevance to the wind power sectors development.

The mentioned documents, including policy statements, detailed strategies, and legal frameworks, set China's wind power sector development milestones. As shown in Table 4, the first decade of the 21st century was the *preliminary* and the *beginning phase*, when the Chinese central authorities laid the solid legal and economic foundations for the wind power sector's development. Among other crucial documents, the Renewable Energy Law of the People's Republic of China, Special Fund for the Industrialization of Wind Power Equipment, and Wind Power Concession Programme contributed the most to establish basics for future growth. Over the subsequent years, the authorities, including National Development and Reform Commission, the Chinese State Council, China National Renewable Energy Centre, China Electricity Council, together with respective ministerial and administrative institutions, were focused on the intensive industrial and market growth facilitation as well as on the wind power industry and market consolidation.

The improvements in terms of standardisation, implementation of more efficient measures, such as feed-in tariffs and subsidies, and the introduction of suitable regulatory actions blazed the wind power sector's trail in

Table 4: The review of selected Chinese policy statements, strategies, and notices concerning the wind power sector's development in 2000 – 2020. Review based on [48].

The 10th Five-year Plan for Economic and Social Development of the PRC (2001-2005)	**2001-2005**	One of the first policy statements underlining the importance of energy transition towards renewable sources of energy. This document set the objectives to promote sources like wind and solar power and introduced several instruments, including preferential tax policies for renewable energy – from 2003, foreign investments in wind energy production benefit from a reduced income tax rate of 15%, as opposed to 33%. Moreover, wind turbines and their main components were vatable with a reduced tax rate (8.5%, where standard VAT was 17%). The Plan set the targets to increase installed wind power capacity to 1.2 GW and wind turbines manufacturing capacity at 200 MW to meet domestic demand by 2005. These objectives were associated with public procurements to construct and develop wind farms across the country.
Wind Power Concession Programme	**2003 (ended)**	The programme was established to encourage foreign and national entities to invest in large-scale wind power projects (100-200 MW of installed capacity). The criteria included the share of domestically produced components and the estimated electricity price per kWh. The programme resulted in the construction, for instance, the two 100 MW wind farms in Rudong (Jiangsu province) and Huilai (Guangdong province), as well as opening a Vestas blade factory to increase the utilisation of their wind turbines in projects that they were given concessions.
Renewable Energy Law of the People's Republic of China	**2006 (in force)**	The policy framework and the milestone for the development and popularisation of all renewable energy sources in China. This document regulated the most significant aspects of the utilisation of renewables, including resources investigation and development, industrial guidance and technical support, popularisation and application of renewable energy sources, pricing and cost compensation, economic incentives and supervisory measures and legal responsibilities.

Special Fund for the Industrialization of Wind Power Equipment	**2007 (ended)**	Example of an action designated to allocate funding for investments in wind power projects and related technology development, R&D, as well as the construction of pilot projects. More importantly, this action supported domestic companies in wind turbines production with the subsidies of 600 RMB/kWh (87.41 USD/kWh) for the first 50 new wind turbines with a minimum capacity of 1.5 MW.
Offshore Wind Development Plan	**2009 (in force)**	The agenda published by the Chinese National Development and Reform Commission (NDRC) was obliging the coastal provinces to establish regional offshore wind power strategies and set the regulations regarding the localisation of wind farms in the three categories based on the water depth: the Inter-tidal zone (0-5 m), the Offshore zone (5-50 m) and the Deep sea zone (50 m and more). This plan resulted in the construction, for instance, in Jiangsu province, two offshore projects of a 300 MW capacity each and two inter-tidal projects of a 200 MW capacity each.
Feed-in tariff for onshore and offshore wind	**2009 (in force)**	The feed-in-tariff policy was established by the Chinese National Development and Reform Commission (NDRC) and divided the country into four categories based on the natural regional wind power endowment, where the larger endowment is, the lower financial support was offered: Category 1: EUR 0.052/kWh, Category 2: EUR 0.055/kWh, Category 3: EUR 0.059/kWh, Category 4: EUR 0.062/kWh. It was the first feed-in-tariff mechanism introduced to the wind power in China.
Market entry standards for wind equipment manufacturing industry	**2010 (ended)**	This document introduced detailed regulations to improve the domestic wind power equipment manufacturing market's efficiency and competitiveness. Presented restrictions allowed manufacturing entities' function with at least five years of experience in large-scale mechanical production and a minimum production capacity of 2.5 MW. Besides, companies operating in this particular market were obliged to establish professional R&D teams that should develop the technologies meeting the highest standards described in the previously adopted Environmental Impact Assessment law.
China Energy White Paper and The 12th Five-Year Plan for National Strategic Emerging Industries for China	**2012 (ended)**	These two documents set objectives for the national energy sector to increase renewable energy utilisation in energy generation. For instance, the White Paper stressed the need to develop wind turbines projects in the northern provinces. To realise these expectations, the 12th Five-Year Plan set the objective to continue constructing wind power plants to achieve the 190 TWh goal by 2015. Moreover, it recommended establishing a national wind power quota system, scaling-up commercialisation of the wind offshore equipment products, increasing the product quality to meet the international standards, continuing the R&D investments in offshore and onshore wind power and, last but not least, establishing effective grid operation and energy management system for wind power.
China Offshore Wind Power Development Plan	**2014 – 2016 (ended)**	Another example of a plan focusing on the construction of the offshore wind projects. This document resulted in the construction of 44 offshore wind projects with a total capacity of 10.53 GW by 2016 with the cooperation between central authorities and provinces in the field of management, planning, construction, and standardisation of the required components' purchases.
Notice on Provisional Management Measures for Distributed Wind Power Project Development and Construction for all provinces	**2018 (in force)**	This document published by the Chinese National Energy Administration provided the Chinese manufactures and constructors with diverse technical and non-technical regulations to establish and develop wind projects covering the aspects such as technical requirements, grid connection models, land use and marketisation.
China 13th Wind Energy Development Five Year Plan (2016-2020)	**2016-2020 (ended)**	This agenda set the objective to increase the total targeted installed wind capacity to 210 GW (205 GW onshore and 5 GW offshore), accounting for 6% of total generated power in China by 2020.

this country to scale up and expand to the new markets. Moreover, wind power exploitation became more facilitated by adopting the Offshore Wind Development Plan and the other development agendas. Besides, it is worth emphasising that the Chinese authorities adopted several documents to increase administrative control and management standards over the developing wind power sector in the last few years. It resulted in legal regulations such as the notices on the Administrative Measures for the Development and Construction of Offshore Wind Power [50].

6.2. The Chinese wind power policies and new structural economics assumptions

Regarding the NSE assumptions, it is observed that the Chinese wind power sector could be categorised as a *leading-edge industry*. In this case, the most suitable recommended policy should support advanced modern technologies and product development throughout the measures such as fiscal allocations to establish research funds, government subsidies for research institutions or R&D departments, as well as direct or indirect fiscal incentives, such as feed-in tariffs for grid connection projects and preferential power pricing. Authorities can also force the pace of returns to scale increase by public procurements, legal regulations and wind power products standardisation.

Comparison of the postulated by NSE theoretical industrial policy measures with the historical evolution of the political documents, statements and legal regulations suggest that the actions taken by Chinese state authorities match this development path. One of the most critical aspects of the new structural economics is the comparative advantage of a country's industries and the entire economy in a broad sense. The analysis of the revealed comparative advantage has shown that the wind power sector is increasing its export specialisation. However, it is still producing and exporting wind turbines below the world average.

In the context of the new structural economics, to accelerate the export growth and increase the export specialisation, the Chinese authorities should continue the feed-in tariff policy for the wind power projects. As the previous studies show, this instrument was one of the most successful measures to stimulate the sector's growth and allowed the Chinese companies to dominate the national market and increase their share in the global market. The announced decrease and final cancellation of feed-in tariffs may potentially affect this sector's growth and slow down the process of achieving export specialisation in wind turbines. However, the review of the policies implemented in 2000-2019 provided numerous examples of the other measures that shaped the growth of this sector, including standardisation, legal regulations, grid connection models, institutional support, fiscal policy instruments and direct R&D subsidies. In conclusion, the course of action adopted by the Chinese authorities in recent years matches the new structural economics assumptions.

7. Conclusions

This study aimed to evaluate the role of Chinese state authorities in shaping wind power development from the new structural economics perspective. The results revealed the wide range of policies and measures that have already translated to this sector's dynamic growth in 2000-2019. Development of this sector has its reflections in the energy indicators such as the growing installed wind power capacity, the share of this source in the Chinese energy mix and the Chinese manufacturers' growing global position. However, the analysis of the RCA index provided evidence that this industry has revealed a comparative disadvantage in wind power products for the last two decades, despite the significant increase in export volumes and installed capacity.

The review of relevant literature proved that such low export specialisation could be caused by the relatively low innovativeness of this industry and production growth based on cost reduction. The reviewed literature has shown that the Chinese wind power industry has a relatively low international recognition and an impact on the international wind power market. Nowadays, a substantial challenge for this industry is a low production efficiency and decreasing support offered by the Chinese state authorities – both in the context of supply-side and demand-side policy, including a decrease in feed-in tariffs. Despite the demonstrated comparative disadvantage, this industry is on the right track to gain export specialisation in wind turbine manufacturing in a few years.

Despite circumstances, the Chinese state authorities continuously support the growth of international competitiveness and innovativeness of the national wind power industry. The approach towards this industry represented by the authorities is constantly changing, but still, it presents a persistent pursuit of growth and continuous improvements in the applied energy transition

policies. Furthermore, the Chinese wind power sector is at a new threshold since implementing the 13th Five-Year Plan for Energy (which demonstrated ambitious aims for 2016-2020). The potential chance for this sector is, among others, the pursuit of rapid development of offshore wind power plants. Still, thanks to the recently adopted policies and strategies, the Chinese wind power industry may increase its technological advancements in the wind turbines installed on the sea areas rich in wind power resources.

The Chinese wind power development policy, adopted at the beginning of the 21st century, went through dynamic changes that translated to its current global position for over twenty years. These policies were analysed from the new structural economics perspective. This study revealed that the state actions match the policy's assumptions towards the *leading-edge industries*. Additionally, the insight into the analysed policy-driven wind power industry blazes the trail for other countries, which consider following the Chinese policy and state interventions on a field of shaping the growth of *leading-edge industries* and the energy transition process in general.

Since the wind power sector in China is newly formed, this field of research should be continuously developed. Considering the simultaneous growth of the national wind power sector and the revealed comparative disadvantage of the Chinese wind turbines on a global scale, the future research must be focused on studying the individual factors that affect Chinese low export specialisation in this type of commodities and present the prognosis model of the future export specialisation in wind power products. In this context, the presented results contribute to a debate about the role of the Chinese development policy in shaping the wind power sector's growth by applying the new structural economics approach and the export specialisation perspective.

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