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# Эмпирический анализ и исследование путей развития низкоуглеродной экономики Китая, Японии и Южной Кореи

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**Аннотация.** Интенсивность выбросов углерода, измеряющая количество выделяемого диоксида углерода на единицу ВВП, выступает одним из ключевых показателей оценки уровня экономического развития той или иной страны или региона и охраны окружающей среды. Снижение интенсивности выбросов углерода имеет важное значение для таких стран, как Китай (КНР), Япония и Республика Корея (РК), для достижения целей низкоуглеродной политики, что показано в стратегических планах этих государств. Авторами выявлено, что ряд переменных (энергетическая структура, промышленная структура, технологический уровень и методы производства) оказывают влияние на интенсивность выбросов углерода. В статье, на основе данных статистики КНР, Японии и РК за период 2011–2020 гг. (доэпидемический период), проводится корреляционный регрессионный анализ состояния низкоуглеродной экономики трех стран на основе таких показателей, как интенсивность выбросов углекислого газа, количество патентов, доля накопления капитала в ВВП, доля вторичной промышленности в ВВП, а также компенсационная константа. На основе проведенного регрессионного анализа можно увидеть предпосылки для корректировки государственной политики рассмотренных стран, ориентированные на эффективность проводимой политики, динамику энергопотребления, воздействие финансовых стимулов при внедрении низкоуглеродных технологий и процедур и др. Так, было показано, что для Японии существует отрицательная корреляция между урбанизацией и патентной составляющей, но положительная корреляция между накоплением капитала, вторичными отраслями промышленности и низкоуглеродной экономикой. В РК существуют как положительные, так и отрицательные корреляции между урбанизацией и накоплением капитала. Скорость урбанизации в Японии достигла точки насыщения, поэтому ее ускорение не пойдет на пользу низкоуглеродной экономике. Положительная корреляция между патентной составляющей и низкоуглеродной экономикой КНР и обратная корреляция между вторичными отраслями промышленности, приростом капитала и урбанизацией позволяют предположить, что ситуация с патентами в стране находится в лучшем положении, чем в других странах.

С учетом полученных результатов, на базе рассмотренных трехсторонних нормативных инициатив, авторами составлен перечень мер и рекомендаций, стимулирующих развитие и рост низкоуглеродных экономик в Китае, Японии и РК. Так, среди наиболее важных мер, направленных на снижение интенсивности углекислого газа, для Японии и РК выделяется трансформация сферы энергетики, в т.ч. продвижение технологий энергоэффективного использования, новых видов

транспортных средств, водородной энергетики, формирование механизма торговли выбросами углерода (углеродного рынка); поддержка правительствами трех стран развития таких источников, как энергия ветра, солнечная энергия, энергия биомассы. Для КНР и РК подчеркивается необходимость реализации стратегий по защите и управлению интеллектуальной собственностью, стимулированию по созданию и внедрению результатов интеллектуальной деятельности, в том числе посредством инвестиций в технологические исследования и разработки, развития малого инновационного предпринимательства, фондов научно-технологических инноваций, системы налоговых льгот и др. Для всех трёх стран актуально создание фондов зеленых инвестиций, предоставляющих финансовую поддержку предприятиям, ориентированным на охрану окружающей среды и чистые технологии; продвижение и поддержка зеленого финансирования. Актуальными для указанных стран являются и меры по повышению уровня безопасности ядерной энергетики, в том числе утилизация ядерных отходов. В работе показано, что реализация указанных мер возможна в связи с сокращением интенсивности выбросов углекислого газа, увеличением количества соответствующих патентов, ростом капиталовложений и изменением энергетических структур. В связи с этим авторы показывают тенденции трансформации энергетической сферы, ориентированной на реализацию чистых технологий, низкоуглеродную политику и энергетическую безопасность.

**Ключевые слова.** Низкоуглеродная экономика, низкоуглеродная политика, сокращение выбросов углерода, Китай, Япония, Южная Корея.

科学文章

# 中日韩低碳经济发展路径的实证分析与研究

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**摘要**：碳排放强度，衡量单位GDP排放的二氧化碳量，是评估一个国家或地区经济发展水平和环境保护的关键指标之一。 正如中国、日本和韩国等国家的战略计划所示，降低碳强度对于实现低碳政策目标非常重要。 作者发现，一些变量（能源结构、产业结构、技术水平和生产方式）影响碳排放强度。 本文基于中国、日本和韩国 2011 年至 2020 年期间（疫情前）的统计数据，根据二氧化碳排放强度、专利数量、资本积累占GDP比重等指标，第二产业占GDP的比重以及补偿常数，对三个国家的低碳经济状况进行相关回归分析。 通过回归分析，可以看出各国调整公共政策的前提条件，重点关注政策的有效性、能源消费的动态以及财政刺激对引进低碳技术的影响和程序。 考虑到所获得的结果，在考虑三方监管举措的基础上，作者编制了一系列刺激中日韩低碳经济发展和增长的措施和建议。

**关键词**：低碳经济，低碳政策，碳减排，中国，日本，韩国。

Original article

# Empirical Analysis and Research of Low-Carbon Economy Development Trends in China, Japan and South Korea

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**Abstract.** Carbon emission intensity, being one of the key indicators of the level of economic development and environmental protection in a particular territory, indicates the quantity of carbon dioxide emitted per unit of GDP. Reducing carbon emission intensity is essential for nations like China (PRC), Japan, and South Korea (ROK) to meet low-carbon policy objectives, which is reflected in the strategic plans of these states. A number of variables (energy structure, industrial structure, technological level and manufacturing techniques) have an impact on the intensity of carbon emissions. Basing on the statistics of the PRC, Japan and the ROK for the period 2011–2020 (pre-epidemic period), the authors carry out a regression analysis of the correlation between the factors influencing the low-carbon economies of the three countries. Taking into account the results obtained, the authors propose a list of policies and measures to enhance the development of low-carbon economies in China, Japan and South Korea.

**Keywords**. Low-carbon economy, low-carbon policy, reducing carbon emission, China, Japan, South Korea.

## Introduction

On November 24, 2022, the China, Japan, and South Korea the Presidents Meeting of Research Institutes of Environmental Sciences held its 19th video conference, during which «the three parties held in-depth discussions on issues like climate change, air pollution control, water environment control, and environmental concerns»[1]. The three parties agreed to establish an ongoing and extensive working relationship, offer advice on the creation of national environmental laws, and assist low-carbon and environmentally friendly development. Masahide Kimoto, head of the Japan National Institute for Environmental Research, emphasized that reducing greenhouse gas emissions should be done in conjunction with efforts to avoid and manage air pollution. Air quality is a significant environmental concern for China, Japan, and South Korea, according to Kim Dong-jin, president of the National Academy of Environmental Sciences of Korea. According to Li Haisheng, president of the Chinese Academy of Environmental Sciences, China's efforts to prevent and combat air pollution require the support of scientific and technical forces. The China-Japan-Korea Research Institute for Environmental Research (Institute) Directors Meeting Mechanism was established by the Chinese side in 2004 and has since aided in the sustainable growth of Northeast Asia and served as a role model for inter-regional environmental cooperation[2].

China's low-carbon policy has its roots in the early 2000s, when the country first realized how crucial it was to fight climate change and cut carbon emissions. The following significant turning points in China's low-carbon policy history are listed: China's National Climate Change Program[3], which was released in 2005 and addressed the need to cut carbon emissions and enhance energy efficiency, was the first policy document on climate change in the nation; The 2007 Medium and Long-Term Renewable Energy Development Plan[4] establishes objectives for the growth of renewable energy and creates policies to assist it, such as feed-in tariffs

[1] 中日韩三国环境科学研究院（所）长会议第19次会议召开 [The Nineteenth Tripartite Presidents Meeting among CRAES, NIES and NIER was Held Online] // Chinese Research Academy of Environmental Sciences. URL: www.craes.cn/xxgk/zhxw/202211/t20221125_1006119.shtml.

[2] 中日韩三国环境科学研究院（所）长会议第19次会议召开 [The Nineteenth Tripartite Presidents Meeting among CRAES, NIES and NIER was Held Online] // Chinese Research Academy of Environmental Sciences. URL: www.craes.cn/xxgk/zhxw/202211/t20221125_1006119.shtml.

[3] China's National Climate Change Program. URL: www.china.org.cn/english/environment/213624.htm.

[4] Medium and Long-Term Development Plan for Renewable Energy. URL: https://policy.asiapacificenergy.org/node/42.

and tax incentives [1]; China's National Climate Change Plan, 2014–2020[5]: this plan included targets to reduce carbon intensity, increase carbon sequestration, and develop low-carbon transportation systems. China's 12th Five-Year Plan (2011–2015)[6]: this plan implemented rules to support energy efficiency, renewable energy, and low-carbon transport. China's National Low Carbon Pilot Program was launched in 2009, testing low carbon policies and technologies such as carbon trading and low carbon transportation systems in five provinces and eight cities.

The Japanese government has been putting its «Low Carbon Society Action Plan»[7] into practice since 2016, with the goal of reducing greenhouse gas emissions to less than 80 % by 2050. Energy efficiency improvements, support for renewable energy sources, encouragement of energy conservation and emission reduction, and development of low-carbon mobility are just a few of the actions Japan has made to develop a low-carbon economy[8]. Japan has also created a number of laws and policies to encourage individuals and businesses to support the growth of a low-carbon economy.

Following the Fukushima nuclear disaster in 2011, the Japanese government steadily decreased its reliance on nuclear energy and increased support for renewable energy. It consequently possesses a wealth of knowledge and expertise in the area of nuclear power. Several significant policy changes are suggested in the report Japan's Low Carbon Technology Plan[9]: building a Low Carbon Economy, including funding for research and development in the field of low-carbon technologies, tax incentives for businesses investing in low-carbon technologies, partnerships with international organizations and companies to promote knowledge sharing and collaboration, support for demonstration projects and pilot programs to test and scale new technologies, and more. In addition, academics from the University of Tokyo in Japan and Tsinghua University in China were requested to write a report titled «Japan and China's Low-Carbon Energy Policies»[10] that was released in 2016 and examined each of those measures reducing greenhouse gas emissions and promoting the use of renewable energy sources are the nation's goals and objectives. Feed-in tariffs, renewable energy certificates, and energy efficiency are some of the regulatory tools and measures that China and Japan have implemented to encourage the expansion of low-carbon energy sources. The study also points out areas where China and Japan can exchange knowledge and best practices for developing low-carbon energy. The report reveals, for instance, that China has made significant investments in the creation and application of clean energy technology, while Japan has successfully pushed for the adoption of energy efficiency and renewable energy through its tariff program.

In 2012, the Renewable Portfolio Standards (RPS)[11] were instituted in South Korea, mandating power companies to procure a specific proportion of their electricity from renewable sources.Twenty percent of electricity must come from renewable sources by 2025. South Korea introduced the Green New Deal in 2020 as a response to the COVID-19 pandemic, with the goal of fostering sustainable growth and job creation. Initiatives to increase the use of renewable energy, boost energy efficiency, and support low-carbon transportation are all part of the Green New Deal. South Korea introduced a Green New Deal in 2020 with the objectives of fostering sustainable growth and generating jobs. The Green New Deal includes initiatives to boost the use of renewable energy, increase energy efficiency, and support low-carbon transportation. To promote the use of renewable energy sources like solar and wind power, South Korea has also put in place the FIT system. The FIT program offers a set price for renewable energy generated by individuals or businesses. unveiled a carbon pricing plan in 2015 that includes a cap-and-trade system for major pollutants and a carbon tax on fossil fuels. In order to promote the use of electric vehicles, South Korea has developed a number of programs, such as tax rebates for electric vehicle owners, funding for charging infrastructure, and designating parking places only for electric vehicles. These policies and initiatives

[5] National Plan on Climate Change 2014-2020. URL: https://policy.asiapacificenergy.org/node/3011.

[6] 12th Five-Year Plan (2011-2015) for National Economic and Social Development. URL: https://policy.asiapacificenergy.org/node/37.

[7] Low Carbon Society Scenarios towards 2050. URL: https://2050.nies.go.jp.

[8] Eco Asia 2001 // Japan Environment Quarterly: News from the Ministry of the Environment. URL: www.env.go.jp/content/900452782.pdf.

[9] New Low Carbon Technology Plan. URL: https://policy.asiapacificenergy.org/node/2833.

[10] Energy Policies of IEA Countries: Japan 2016 Review // International Energy Agency. URL: www.iea.org/reports/energy-policies-of-iea-countries-japan-2016-review.

[11] Renewable Portfolio Standards (RPS). URL: https://policy.asiapacificenergy.org/node/4311.

demonstrate South Korea's dedication to creating a low-carbon economy and cutting greenhouse gas emissions.

## Methods

This study chooses relevant data for these three countries from 2011 to 2020 and does a correlation-regression analysis to investigate the current situation of the low-carbon economies of China, Japan, and South Korea. To accomplish low-carbon policy objectives, nations like the PRC, Japan, and the ROK must reduce the intensity of their carbon emissions [2–7]. Carbon emission intensity estimates the quantity of carbon dioxide emissions per unit of GDP and is one of the most important metrics for determining the degree of economic development of a nation or region and environmental protection [8–11]. The amount of carbon intensity is influenced by a wide range of factors, including energy mix, industrial structure, technology, and manufacturing techniques. The explanatory variable “carbon intensity (tonnes/10,000 USD)” as well as “patent”, “capital formation to GDP ratio”, “secondary industry as a proportion of GDP” and “urbanization” were ultimately picked due to the restrictions of the selection criteria for various components. The least squares method was used to build the model, which was a four-variable linear regression. To lessen the discrepancy between the sample values, the logarithm of each variable can be used to derive the following formula:

$$\ln Y = a\ln x1 + b\ln x2 + c\ln x3 + d\ln x4 + e,$$

where Y — carbon intensity (tonnes/10,000 USD); x1 — patents; x2 — capital formation to GDP ratio; x3 — secondary industry as a proportion of GDP; x4 — urbanization; e — compensation constant.

Thus, we get the following functions for countries.

Japanese function y = 3,7640x1 + 11,9153x2 + + 6,9866x3 – 152,9298x4 + 582,7164.

Korean function y = 1,9963x1 – 4,2550 x2 + + 3,1936x3 + 143,1362x4 – 648,9738.

Chinese function y = 0,0487x1 – 0,4374x2 – – 0,0209x3 – 2,7696x4 – 2,9554.

In the Japanese formula, the number of patents, capitalization, and industrialization of the low-carbon economy are positively correlated, and urbanization is negatively correlated. In South Korea, capitalization is negatively correlated. The positively correlated factors are capitalization, the number of patents, and urbanization in China. The carbon economy is only positively correlated with the number of patents, and the rest are negatively correlated.

In other words, urbanization has the greatest impact on China's low-carbon economy, followed by capitalization and secondary industry growth, and finally the number of patents.

The high population density of Japan and South Korea has led to the greatest impact of urbanization in the three East Asian countries, and the lowest impact of patents on the low-carbon economy. Patents in the three countries are all positively correlated, indicating that invention is a positive internal driving force in the three countries.

Due to the impact of aging in Japan, only urbanization has a negative correlation, and the rest are all positive correlations. This shows that Japan invests mostly in environmental protection.

South Korea's urbanization rate has remained stable at 91 %, partly due to the concentration of capital in the hands of consortiums[12].

As a developing country, China's economy needs to continue to develop, which leads to a negative correlation between its urbanization rate, capitalization rate and secondary industry[13].

A table of coefficients 1 is produced using the most recent data from China, South Korea, and Japan from 2011 to 2020. The World Bank provided all of the statistics for this article, while World Intellectual Property Organization WIPO provided the data on patents.

Policy recommendations and evaluation: Based on the research findings, researchers can

[12] World Bank Open Data. URL: https://data.worldbank.org.

[13] WIPO IP Statistics Data Center // World Intellectual Property Organization (WIPO). URL: www3.wipo.int/ipstats/ips-search/patent.

Table 1

**Regression Analysis of Relevant Factors Affecting Low-Carbon Economy in PRC, Japan, and the ROK**

| Country | x1 | x2 | x3 | x4 | e |
|---|---|---|---|---|---|
| Japan | 3,7640 | 11,9153 | 6,9866 | –152,9298 | 582,7164 |
| South Korea | 1,9963 | –4,2550 | 3,1936 | 143,1362 | –648,9738 |
| China | 0,0487 | –0,4374 | –0,0209 | –2,7696 | –2,9554 |

Source: compiled by the authors.

provide policy recommendations that are appropriate for their own nations by looking at the pertinent policies and initiatives of the low-carbon economy in China, Japan, and South Korea. These suggestions could include adjustments to government regulations, financial incentives for companies to adopt low-carbon procedures, or education campaigns to encourage sustainable behaviour.

Researchers must simultaneously evaluate the efficacy of policy recommendations. This could entail tracking changes in energy use or greenhouse gas emissions over time, or evaluating how policy changes would affect the economy as a whole [12]. The evaluation's goals are to determine whether the policy succeeds in its stated objectives and to point out areas that could be improved.

## Results & Discussion

According to Japanese data, there is a negative correlation between urbanization and patents, but a positive correlation between capital formation, secondary industries, and the low-carbon economy. In South Korea, there are both positive and negative correlations between urbanization and capital formation. The rate of urbanization in Japan has reached a saturation point, therefore speeding it up won't benefit the low-carbon economy. The relative patent situations of the two countries can show that the relevance of the patents increases with the strength of the relationship between them. Both capital gains and secondary industries have important functions. The positive correlation between patents and China's low-carbon economy and the inverse correlation between secondary industries, capital gains, and urbanization suggest that Chinese patents are more advantageous than those from other nations. Table 2 below gives a summary of the policies and programs implemented by China, Japan, and South Korea in connection to reducing the intensity of carbon emissions, increasing the number of related patents, increasing capital investment, and altering energy structures:

Table 2

**Policies and measures of PRC, Japan, and the ROK in promoting low-carbon economic development**

| Indicator | China | Japan | South Korea |
|---|---|---|---|
| Advantages of natural resources | Coal resources; rare earth resources and hydropower resources | Forestry resources; Aquatic product resources; Mineral resources | Aquatic product resources; mineral resources; agricultural product resources |
| Low Carbon Policy Goals | Be Carbon Neutral by 2060 | Be Carbon Neutral by 2050 | Be Carbon Neutral by 2050 |
| Reduce carbon intensity | Improve energy efficiency; promote clean energy; strengthen carbon emission regulation; encourage low-carbon transformation of enterprises | Promote renewable energy; strengthen energy transformation; encourage energy conservation and emission reduction; promote carbon emission trading | Promote renewable energy; strengthen energy transformation; encourage energy conservation and emission reduction; promote carbon emission trading |
| Increase the number of related patents | Promote intellectual property strategy; encourage enterprise innovation; build an innovative country | Strengthen intellectual property protection; support enterprise innovation; strengthen research and development cooperation | Promote intellectual property strategy; encourage enterprises to invest in research and development; build an innovative country |
| Increase capital investment | Formulate green financial policies, establish green funds, and support new energy companies | Promote green finance, establish green investment funds, and support green enterprises | Promote green finance, establish green investment funds, and support green enterprises |
| Energy structure change | Implement the revolutionary strategy of energy production and consumption; promote the development of new energy; strengthen energy and environmental protection and other measures | Promote the development of renewable energy; promote the resolution of nuclear energy issues; promote energy-saving technologies | Promote the development of renewable energy; strengthen nuclear energy safety management; promote energy-saving technologies |

Source: compiled by the authors.

China established its carbon neutrality date later than the other two countries [13; 14]. China, a sizable industrialized nation, possesses a plenty of primary resources for growth. The industrial processes use a lot of energy, and the largest industries in South Korea and Japan need a lot of electricity despite their tiny size. The model's results of positive association are compatible with the three nations' respective patent ambitions. Of the three, Japan and South Korea have the most energy-structured policies that prioritize nuclear energy safety and disaster avoidance [7; 14].

Japan and South Korea are small nations that have grown more cautious about using nuclear energy since the Fukushima nuclear accident in 2011. China, a nation with high energy consumption, has to increase the use of renewable energy, gradually phase out the production of coal power, and move to the comparatively clean source of natural gas for generating power. The same rationales underpin the decrease of carbon emissions.

## Conclusions

China, Japan, and South Korea all have different advantages in terms of natural resources. China has a lot of water, rare earth, and coal; Japan has a lot of forestry, aquatic products, and rare and special metals; and South Korea has a lot of iron ore, aquatic products, and agricultural products. The benefits of these natural resources are essential for the economic development and energy security of these nations. Because China, Japan, and South Korea have many diverse forms and fields of cooperation that encompass energy, environmental protection, urban development, the carbon market, and other areas, they will assist the growth of the low-carbon economy. The following list summarizes development-related policies and actions:

Japan and South Korea have enhanced energy transformation by promoting efficient energy utilization technologies and the development of new energy vehicles like electric vehicles and hydrogen energy in order to reduce the intensity of carbon emissions. Furthermore, policies in Japan and South Korea are now more supportive of energy-saving practices in buildings, industries, and transportation. In order to promote carbon emission trading and encourage enterprises to reduce carbon emissions, Japan and South Korea accepted the system, formed the carbon emission trading system, and used the carbon emission right trading mechanism.

China and South Korea support intellectual property strategies by creating and implementing intellectual property plans, improving intellectual property management and protection, and raising the standard of patent applications and authorizations in order to increase the number of related patents. In addition, China and South Korea implement laws like tax cuts and funds for technological innovation that drive companies to expand spending on technological R&D.

While South Korea and Japan actively promote green finance by pushing banks, securities, insurance, and other financial institutions to offer green financial products like green bonds, China largely develops green financial aid in order to stimulate capital investment [15–17]. In addition, China, South Korea, and Japan have created green investment funds to finance sectors including environmental protection and clean technology.

China, South Korea, and Japan have all boosted their support for novel energy sources like wind, solar, and biomass energy as part of the restructuring of the global energy structure. Nuclear energy safety management has been upgraded in South Korea and Japan. Japan is also taking steps to support the resolution of nuclear energy challenges, such as disposing of nuclear waste. To increase the safety of nuclear energy, South Korea is encouraging nuclear waste disposal as well as other measures.

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