



Studies on the Current Situation and Optimization Plan of the Green and Low-carbon Development of Manufacturing Product Chain in Liaoning Province

Wei Li¹, Mingxi Jiang^{2,*}

¹School of Foreign Languages, Liaoning Normal University, Dalian 116029, Liaoning, China.

²College of International Business, Liaoning Normal University, Dalian 116029, Liaoning, China.

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***Corresponding author:** Mingxi Jiang, College of International Business, Liaoning Normal University, Dalian 116029, Liaoning, China.

Abstract

As a secondary industry, manufacturing has always been a major foundation of Liaoning Province's economy and significant development momentum. Since a series of important meetings, like the Two Sessions of the National People's Congress in 2021 and the "14th Five-Year Plan", have made important arrangements for carbon peak and carbon neutrality, Liaoning Province is still promoting the manufacturing product to reach carbon peak and carbon neutrality requirements, and developing towards green and low-carbon. This article explores the current situation of manufacturing products in Liaoning Province through data analysis and identifies problems and optimizations in 3 aspects: upstream, midstream, and downstream. Through analysis and research, it is shown that the manufacturing product in Liaoning Province still faces problems such as high energy consumption from traditional energy sources, insufficient use of green energy, and shallow extent of green innovation. It is necessary for them to achieve "Carbon peak and carbon neutrality" by concentrating resources in an orderly manner, increasing investment in green transition and innovation funds, and focusing on resource recycling and utilization to solve existing problems.

Keywords

Green Development; Carbon Peak and Carbon Neutrality; Manufacturing Product Chain; Liaoning Province

1. Introduction

Liaoning Province, renowned as one of the cradles of China's manufacturing and a pivotal industrial hub within the nation, boasts a cluster of advantageous sectors including equipment manufacturing, petrochemicals, fine chemicals, and metallurgical materials. These sectors hold a substantial position within the broader manufacturing framework. Nevertheless, the manufacturing landscape in Liaoning has historically been characterized by labor-intensive processing and assembly operations, which possess a relatively low technological sophistication. Though, as a result of the industrial revolution and the realization of mass production, the level of human society's productivity increased dramatically with the help of its manufacturing. However, this has also caused tremendous ecological and environmental cost, which was not brought by, but arose during industrialization. In light of this, the present study endeavors

to inspect the current status of the manufacturing product chain development in Liaoning Province through the lens of green and low-carbon practices. This article analyzes the current situation of the development of Liaoning Province's manufacturing product chain from the perspective of green and low-carbon development. By introducing the concepts of green and low-carbon development and product chain optimization theory, it enriches the research framework for the green and low-carbon development of the manufacturing, accurately locates the key links restricting development, and constructs an optimization plan to accelerate the green transition of the mode of Liaoning Province's manufacturing from the perspective of the product chain. Additionally, it provides certain reference and experience for other regions, especially traditional industrial areas, to explore the path of green transition with hope of promoting the transition and upgrading both the manufacturing and the popularization of the green development model across the country.

2. Literature Review

The product chain, which encompasses the integrated linkages of various products, forms the fundamental framework and the essence of the circular economy industrial chain. This chain is established through the meticulous processing, intensive deep-processing, and sophisticated fine-processing of primary raw materials. Such a product chain does not merely enhance the intrinsic value of commodities, but also plays a pivotal role in significantly reducing logistics expenditure and production costs. Recently, most oversea studies on product chain are focused on product chain optimization or macro-industrial economics at the enterprise level (Including Philip Kotler, 2002; Michael E. McGrath, 2012; Kilsun Kim & Dilip Chhajer, 2000; M. Stuit & G. Meyer, 2008), while studies of systematically analyzing impact of product chain on the green and low-carbon transition of manufacturing at the regional level is insufficient. In China, the research on green transition of manufacturing is mainly divided into 3 parts, including digital perspective (Qiansheng Gong, 2023; Yuanying Chi, 2023; Ming Chen, 2023; Zhang Xin, 2022; Jia Chunjie, 2023), policy perspective (Yin Xu, 2023; Li Xiaoyi, 2022; Chen Huipeng, 2021; Zhou Guirong, 2014) and area selection perspective (Sun Hongzhe, 2022; Zhang Jinhua, 2021; Li Yuhua, 2021; Zhang Feng, 2019; Chen Yan, 2023; Xiao Jing, 2023; Xie Xuemei, 2022).

In summary, scholars have achieved rich theoretical and practical results in the fields of product chains and the green and low-carbon transition of the manufacturing. However, as is mentioned above, studies at the regional level are still insufficient, especially systematic analysis of the coordinated development of upstream and downstream product chains and the improvement of resource utilization efficiency. Research on the green transition of the manufacturing mainly focuses on the impact of digital technology empowerment and policy incentives, but the specific mechanism of the coordinated role of the two in promoting the green and low-carbon transition of product chains has not been deeply explored. In addition, existing research at the regional level mostly focuses on macro-issues such as industrial structure optimization, carbon emission assessment, and the improvement of total factor productivity, while insufficiently exploring the unique paths and models of the green and low-carbon development of the manufacturing product chains in specific regions (including Liaoning Province). Therefore, this article takes manufacturing in Liaoning Province as the research object, cuts in from the perspective of the product chain, and systematically explores the path selection of upstream-downstream coordinated development, and provides a new perspective for relevant research fields. It can not only fill the gaps in existing research but also provide important theoretical support and practical guidance for the sustainable development of regional economies.

3. Definition of Relevant Concepts

3.1 Manufacturing

According to the latest "National Economic Industry Classification" (GB/T 4754-2017) issued by the National Bureau of Statistics, the manufacturing can be subdivided into 29 categories, including agricultural, sideline products processing industry, food manufacturing, textile industry and so on. The development of the manufacturing can not only provide intermediate products for further production, high-quality and inexpensive consumer goods for consumers, but also effectively promote local economic development and create a large number of employment opportunities. The strength of the manufacturing directly reflects the economic competitiveness and sustainable development ability of a region and is an important pillar of regional economic development.

3.2 Product chain

The construction of the product chain should be based on the composition structure of raw materials. It's necessary to analyze the available components, select the leading products, and extend both the product chain and by-product chain. Through economic, technical, and environmental feasibility analysis, a product chain structure that conforms to regional economic development should be reasonably designed. The product chain includes both the existing product chain structure and the structure with development potential. For the existing product chain, the focus should be on analyzing the rationality of the product structure and industrial structure, and further extending and strengthening the mainstream. For potential product chains, priority should be given to the parts that are relatively easy to achieve in the short term, while considering the potential for coordinated development with other industries in the region. During the construction of the product chain, attention should be paid to the form of resource utilization at each node, optimizing the resource utilization rate to form a stable and efficient product chain. In addition, the construction should not blindly pursue the integrity of the chain or the formation of the final product but should select the most favorable industrial development model according to regional characteristics to achieve an organic combination of economic benefits, technical feasibility, and environmental protection..

3.3 Green and low-carbon development

Low-carbon development is a sustainable development model with the core characteristics of low energy consumption, low pollution, and low emissions, which is of great significance for the sustainable development of the economy and society. It is an organic combination of "low-carbon" and "development", emphasizing not only the reduction of carbon dioxide emissions but also the coordinated development of the economy and society. Low-carbon development does not simply pursue the reduction of carbon dioxide emissions but promotes the all-round progress of the economic society by innovating the economic development model, improving efficiency and competitiveness while reducing emissions. Promoting low-carbon development has a significant effect on optimizing the energy structure, protecting the environment, promoting the transition and upgrading of the industrial structure, and cultivating long-term sustainable competitiveness.

4. Current Situation of the Green and Low-carbon Development of Liaoning Province's Manufacturing

In 2021, various development plans such as the outline of the "14th Five-Year Development Plan" of Liaoning Province will take "carbon peak" and "carbon neutrality" as key development goals. In recent years, the manufacturing in this region has achieved considerable results in the low-carbon transition, but there are still some problems.

4.1 Current situation of energy consumption

In the process of economic and social development of Liaoning Province, the manufacturing occupies the core position, its scale is huge, but corresponding to this is the significant energy consumption and carbon emissions in the production and transportation links. The province is characterized by heavy industry, and the manufacturing is highly dependent on energy. The main types of energy consumption in Liaoning Province include coal, petroleum, natural gas, electricity, hydropower, nuclear power and other forms of power generation, and the specific proportion of various types of energy consumption is shown in Figure 1.

According to the latest statistics in Figure 1, in the energy consumption structure of Liaoning Province in 2022, coal, as the main component of total energy consumption, accounts for 50.77%, ranking first in the energy consumption source of Liaoning Province. Petroleum, with a share of 29.07%, ranked second and became the second largest source of energy consumption in Liaoning Province. The combined consumption of these two types of resources accounted for nearly 80% of the total energy consumption in Liaoning Province. The consumption of natural gas and electricity accounted for 4.33% and 15.84% of the total energy consumption respectively. In terms of the evolution trend of energy consumption structure, in the decade from 2012 to 2022, the proportion of coal in total energy consumption decreased by 10.57%, the proportion of petroleum decreased by 2.57%, while the proportion of natural gas and electricity increased by 0.53% and 12.64%, respectively.

The comprehensive analysis shows that although the proportion of electricity consumption in the energy

consumption structure of Liaoning Province is low, its growth rate is the fastest. Natural gas has changed relatively little over the decade, but it has also shown an increasing trend. Therefore, we can draw a conclusion: In general, the energy consumption structure of Liaoning Province is still dominated by traditional fossil energy. However, the growth rate of main fossil energy consumption is lower than that of electricity consumption, which reflects that the energy consumption structure of Liaoning Province is undergoing a continuous optimization process.

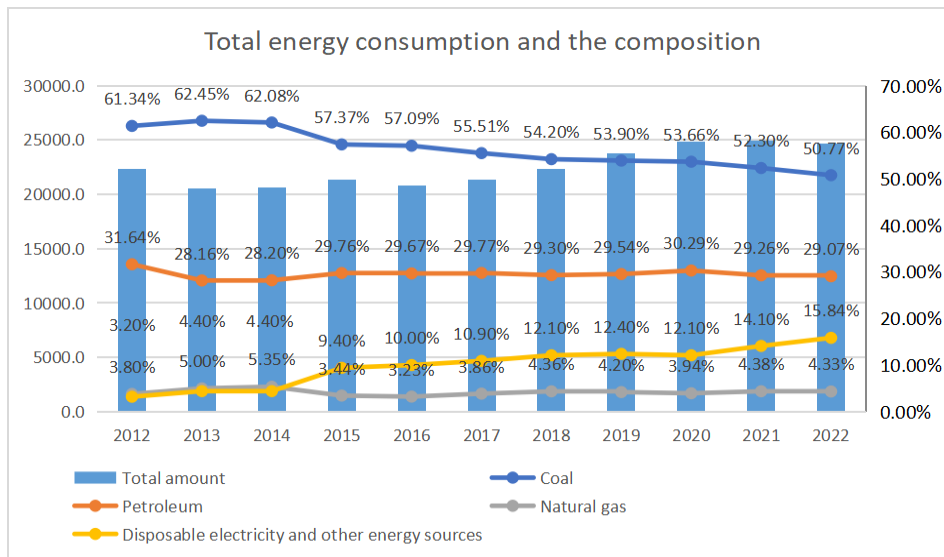


Figure 1. Total energy consumption and composition table.

4.2 Current situation of carbon emissions

At present, carbon emissions are difficult to detect directly, and the common practice is to calculate carbon emissions using the Intergovernmental Panel on Climate Change 2006 (IPCC). This article also uses this method to measure the carbon emissions in Liaoning Province. The calculation formula is as follows:

$$C = \sum_{i=1}^n q_i E_i F_i$$

In the formula, C represents carbon emissions, q_i stands for the consumption of energy i, E_i is the conversion coefficient of standard coal of energy i, F_i represents the carbon emission coefficient of energy i, and n represents the type of energy.

The conversion coefficients of various energy sources into standard coal were obtained from "China Energy Statistical Yearbook 2020" and "National Greenhouse Gas Emission Inventory Guide" respectively, as shown in Table 1.

Table 1. Table of conversion coefficient and carbon emission coefficient of standard coal after various energy sources

Energy type	Conversion coefficient of standard coal (kilogram standard coal /kg)	Carbon emission coefficient (ton carbon /t)
Raw coal (tons)	0.7143	0.7559
Coke (10,000 tons)	0.9714	0.855
Crude oil (tons)	1.4286	0.5857
Gasoline (10,000 tons)	1.4714	0.5538
Kerosene (10,000 tons)	1.4714	0.5714
Diesel (10,000 tons)	1.4571	0.5921
Fuel oil (tons)	1.4286	0.6185
Natural gas (billion cubic meters)	1.3330	0.4483

The calculated total carbon emission of Liaoning Province from 2012 to 2022 is shown in Figure 2 (Unit: ton carbon/t).

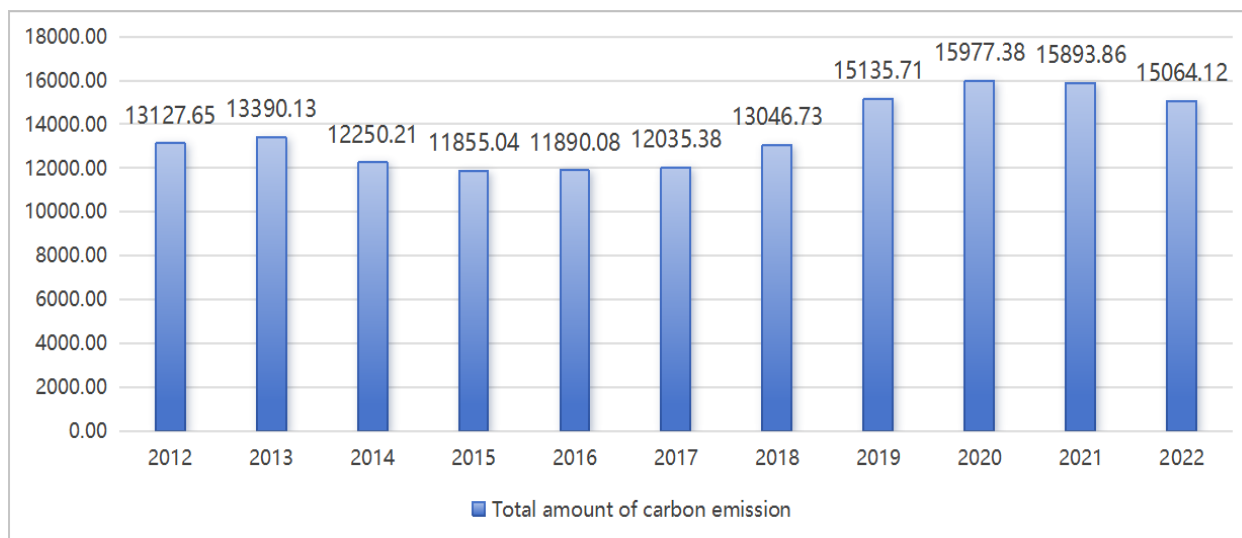


Figure 2. Total carbon emission of manufacturing in Liaoning Province.

As can be seen from Figure 2, the total carbon emissions in 2020 and 2021 are at the highest value, especially the total carbon emissions in 2020 reaching the highest historical value in ten years. The total carbon emission in Liaoning Province showed a downward trend from 2012 to 2016. From 2017 to 2022, the total carbon emission in Liaoning Province gradually increased and maintained a high level. It can be seen from the chart that although the total carbon emissions in Liaoning Province have fluctuated over the past ten years, they have generally been on the rise. Liaoning still has a long way to go before achieving its "carbon peak".

The reason for the high energy consumption and carbon emission is that the energy structure of Liaoning Province has not been completely transformed. In the "14th Five-Year Plan" period, the overall economic development of Liaoning Province is in a good long-term direction, and the total energy consumption still maintains a certain degree of growth until now. However, due to resource constraints, the economic exploitable amount of hydropower resources in the province has exceeded 95%, and the development space is limited. The installed capacity of wind power and photovoltaic power generation will be greatly increased, but its intermittent and random characteristics make it more difficult to increase the proportion of electricity generation. As the main power source of our province, coal power is difficult to reduce the installed scale and the overall coal consumption in order to play the role of supporting the bottom and ensuring the supply and meet the regulation needs of the regional power, heat, and power system. Under such conditions, energy consumption is difficult to decrease, and carbon emissions maintain a steady and slow rise due to the needs of economic development.

5. Challenges Faced by the Green and Low-carbon Development of the Manufacturing Product Chain in Liaoning Province

Based on the above analysis of the green and low-carbon status quo of manufacturing in Liaoning Province, this part will be divided into 3 parts as upstream, midstream, and downstream of the manufacturing product chain in Liaoning Province to analyze the problems arising from the current green and low-carbon transition of manufacturing in this region.

5.1 Challenges faced by the upstream manufacturing product chain

In the above analysis, the calculation and comparison of the total carbon emissions of manufacturing in Liaoning Province in the past ten years show that the carbon emissions are still at a high level, and there is still a long way to go to reach the goal of "carbon peak". From the perspective of the upstream of the manufacturing, the problems can be basically divided into the following two aspects:

- (1) Problems of Energy structure and alternatives. The upstream raw material production sectors, such as steel and cement, are typically energy-intensive. The energy mix of these industries is dominated by coal, and finding suitable alternative fuels is challenging. While green fuels, such as hydrogen, green ammonia and green methanol, show potential to address carbon emissions, they currently face high costs and are therefore difficult to replace fossil fuels in the short term, making it difficult to significantly reduce carbon emissions from conventional energy sources as fuels. Liaoning Province, which belongs to the Northeast China, relied on the use of fossil fuels to promote the development of manufacturing in its early development, this fact became an obstacle for the transition and upgrading of the green and low-carbon manufacturing in Liaoning Province.
- (2) Problems of Green technology innovation and application. The cost of green and low-carbon technologies in the production of some raw materials is high, and it is difficult to achieve large-scale application in the short term. At the same time, some technologies are not mature enough to meet the needs of actual production. In addition, there are differences in the level of technology and innovation capacity of different enterprises, resulting in uneven pace and effect of transition. All of them have led to the challenge of large-scale standardized application of green technologies in Liaoning's manufacturing.

5.2 Challenges faced by the midstream manufacturing product chain

The midstream of the manufacturing product chain is mainly the production and processing of products, which belong to the process of reprocessing raw materials. This process takes upstream raw material suppliers and connects downstream retailers or customers. It is the most important link in the product chain. According to the above characteristics and the analysis of the status quo of manufacturing in Liaoning Province, we can conclude the following problems the midstream of manufacturing is facing in the process of green and low-carbon transition:

- (1) Difficulties in optimizing production processes. Midstream manufacturing enterprises in Liaoning Province generally suffer from difficulties like high energy consumption, insufficient information integration and weak comprehensive competitiveness. In addition, in order to realize the optimization of process flow and material scheduling, as well as the improvement of production equipment operation and the enhancement of interconnection, then achieve the purpose of optimized control of the production process and intelligent upgrading of the production line, enterprises in the midstream of the manufacturing need to invest huge amounts of money and carry out technological innovation, which undoubtedly brings significant pressure to enterprises.
- (2) Challenges of green product chain collaboration. According to the characteristics described above, the manufacturing product chain is the hub of upstream and downstream connection. In addition, green and low-carbon management is a systematic project that runs through the entire industrial chain. These two characteristics require that enterprises in the middle reaches of the manufacturing product chain in Liaoning Province must be familiar with the basic information of the upstream and downstream products under the background of green and low-carbon transition. However, in current low-carbon reform of the manufacturing product chain, there are still problems of link information opacity, information barriers and insufficient green and low-carbon integration, which not only affect the collaborative efficiency of the product chain, but also restrict the pace of green and low-carbon transition of enterprises in the midstream of the manufacturing product chain in the province.
- (3) Complex carbon footprint management. The transition and upgrading of manufacturing product chain in Liaoning Province is a systematic process. Therefore, companies in the midstream must actively collaborate with upstream suppliers to understand the carbon emissions of raw materials and required products, and guide emission reduction actions by developing differentiated procurement strategies, then jointly develop carbon footprint management plans and targets. However, there is still a lack of unified carbon footprint accounting standards and sound carbon footprint data sharing mechanism, which undoubtedly increases the complexity of carbon footprint management.

5.3 Challenges faced by the downstream manufacturing product chain

The downstream of the manufacturing product chain is the ultimate goal of docking product production: the Consumer. Therefore, consumers' attitudes affect the development of products to a certain extent. And after the products have reached the hands of consumers and have been used by consumers, how to recycle the used waste products is all issues that need to be considered when the downstream of the manufacturing product chain in Liaoning Province carries out green and low-carbon digital transition. Therefore, according to the status quo and characteristics described above, the following questions are summarized:

- (1) Issues of market demand and product adaptation. First of all, the market demand for green and low-carbon products has not been fully stimulated, and consumers' awareness and acceptance of green products need to be improved urgently. This phenomenon leads to a low market penetration rate of green products. Given the limited demand for green products, upstream and midstream enterprises in the manufacturing lack strong motivation to promote green and low-carbon transition. At the same time, some green products have performance and quality gaps compared with traditional products, making it difficult to meet consumers' diverse needs and affecting enterprises' sales performance and profits, which becomes another factor that makes enterprises reluctant to carry out green and low-carbon transition. The manufacturing in Liaoning Province obviously faces all these similar problems. Local residents' awareness of purchasing green and low-carbon products is insufficient, which leads to challenges for the manufacturing in that region during the process of green and low-carbon transition.
- (2) Insufficient support from green finance. Transition and upgrading require huge financial support, and the green and low-carbon transition of the manufacturing in Liaoning Province is no exception. However, according to the previous analysis, although the government of Liaoning Province has stabilized its investment in the research and development of the manufacturing, both the proportion of this investment in the total fiscal expenditure and the absolute amount have decreased compared to 2012-2014. This phenomenon may lead to a shortage of funds for the manufacturing in Liaoning Province during the process of green and low-carbon transition. It is evident that the green finance system is not perfect, and it is difficult for enterprises to obtain green financial support. At the same time, financial institutions lack the ability to identify and evaluate green projects and effective risk control mechanisms, resulting in the relatively slow development and promotion of green credit, green bonds and other financial products, which makes it difficult to meet the financial needs of enterprises during the process of green transition.
- (3) Insufficient recycling of resources. China's traditional industrial waste recycling industry currently has widespread problems such as non-standard industrial management, unqualified waste resource processing equipment, and low recycling rate of waste resources, and the comprehensive utilization efficiency of industrial resources still has room to greatly improve. And the problem is also prevalent in Liaoning Province.

6. Optimization Plan for the Green and Low-carbon Development of the Manufacturing Product Chain in Liaoning Province

After the analysis of the data above and the challenges that existed in the current manufacturing of Liaoning Province, this part will propose a corresponding optimization plan for the summarized problems in the upstream, midstream, and downstream parts respectively.

6.1 Upstream optimization plan of manufacturing product chain

- (1) Optimizing the leadership of transition of manufacturing and the innovation of green-tech. The problem of technological leadership presents itself with the new technologies needed for the low-carbon energy transition. And the capability to produce and export manufactured hi-tech goods for both low-carbon energy supply and end-use is alluring from the perspective of national economic development. It promises well-paid jobs, income for communities, and spill-over effects into other industries and sectors that ensure robust growth and national prosperity, often far into the future due to path dependencies. Additionally, it provides the technological solution to the hard problem of transition.
- (2) Conduct in-depth discussions on basic research and original innovation in the application of raw materials in the upstream of the manufacturing. Currently, the upstream of the manufacturing faces numerous demands for the introduction of key technologies. However, due to the limitations of the province's own manufacturing innovation capabilities, as well as the long research and development cycles, huge investments, and numerous uncertainties in key technology research and development, it is difficult for a single enterprise to independently carry out R&D work. Therefore, Liaoning Province urgently needs to optimize and adjust its industrial structure and overcome a series of core technological problems that restrict development. At the same time, Liaoning Province should strengthen the systematic planning and layout of basic research, support universities and research institutions to enhance basic research, then improve basic research capabilities, promote the close integration of basic research bases with the province's leading industries and future industries, and strengthen the source innovation of major industrial technologies.

6.2 Midstream optimization plan of manufacturing product chain

- (1) Increase investment in diversified R&D work of key technologies and reduce the financial burden on midstream enterprises in the manufacturing product chain. Firstly, we need to increase the scale of financial investment and optimize the structure of science and technology expenditure, while strengthening support for basic research projects. Secondly, the reform of scientific research funding management should be deepened to stimulate more innovative vitality. Provincial financial departments should simplify the budget preparation process, increase the proportion of indirect expenses such as performance rewards, expand the scope of labor costs and delegate the management authority of scientific research funds to provincial universities and research institutions. Finally, through a variety of financial support to guide enterprises to increase research and development investment. Policy tools such as discount interest on loans should be used to give more effective play to the leverage and amplification effect of fiscal funds to attract more financial and social capital to jointly promote scientific and technological innovation.
- (2) Create a green and low-carbon product chain cluster area, break the information barrier, and increase the continuity of the product chain. Liaoning Province can focus on promoting the supply of raw materials for related products, going through processing, and selling cluster into regions, so as to facilitate the collection of carbon emission information and footprint of upstream and downstream enterprises in the manufacturing product chain, then facilitate the continuous and sustainable development of green and low-carbon.

6.3 Downstream optimization plan of manufacturing product chain

- (1) Make market-oriented research and development of green and low-carbon technologies. Nowadays, developing a green economy has turned into a worldwide consensus. The advancement of green economy needs the help of green innovation to ensure the organized improvement of climate and economy. This is at the same point when talking about manufacturing, as green innovation and transition can significantly ease the unnatural and mechanical shade of conventional part. But in view of consumers' lack of understanding of green and low-carbon products, the Provincial government can popularize the awareness of green and low-carbon products among the people by means of animation and advertisement, stimulate the people's demand for green and low-carbon products, and force the upstream and midstream of the manufacturing product chain to carry out market-oriented (mainly consumer-oriented), green and low-carbon innovation. Promote the green and low-carbon transition and upgrading of the whole product chain of the manufacturing.
- (2) Pay attention to the recycling and reuse of resources. The Liaoning provincial government can promulgate some laws and regulations to standardize the reuse of product resources, and draw on the experience of other provinces and cities to provide guidance to local manufacturing enterprises. Encourage manufacturing enterprises to engage in resource recycling and reuse, and play a supervisory role. For manufacturing enterprises, it is necessary to use renewable materials reasonably and reduce the use of disposable materials. While in terms of resource recycling and reuse, it is important to strengthen R&D innovation to improve the efficiency of resource utilization. When reusing resources, they have to adhere to the moral bottom line and use materials that meet the standards for reproduction. For consumers, it is necessary to establish the concept that some resources can be reused, do a good job in garbage classification, and cooperate with enterprises and the government to promote the operation of the entire manufacturing product chain's recycling and reuse, then help drive the green and low-carbon transition and upgrading of the manufacturing product chain in Liaoning Province.

7. Conclusion

By analyzing the current situation of the development of Liaoning Province's manufacturing product chain, we can deepen our theoretical understanding of the relationship between the optimization of the industrial chain and green transformation. The construction and optimization of the product chain, as an important means of industrial transformation and upgrading, are of great significance for promoting regional economic development and enhancing industrial competitiveness. Constructing an optimization plan for the green transformation of the development mode of Liaoning Province's manufacturing industry from the perspective of the product chain is conducive to accelerating and enhancing the green and low-carbon development of Liaoning Province's manufacturing product chain.

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