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# Subsidies Increase or Tariffs Reduction? A Study on the Economic and Welfare Effects of China's Policies to Stabilize the "Pig Cycle"

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**Abstract:** ***To stabilize the "pig cycle" and ensure the supply and consumption of pork, the China has implemented a series of policy measures in recent years. However, whether these policies have effectively mitigated the "pig cycle" and how to accurately measure their economic and welfare impacts remain underexplored in systematic research. This paper uses a computable partial equilibrium model of monopolistic competition (GSIM model) and draws on global data on pork production, trade, and consumption in 2019 to empirically examine the economic, welfare, and environmental impacts of China's pork production subsidy policy and frozen pork import tariff policy from a global perspective and industry level. The simulation results show the following: First, there are significant differences in output and price effects between subsidy and tariff policies. A 1% production subsidy for live pigs will increase China's annual pork output by 0.22%, raise producer prices by 0.67%, lower consumer prices by 0.3%, and boost domestic sales by 0.22%. In contrast, a 1% reduction in frozen pork import tariffs will reduce China's annual pork output by 0.38%, lower both producer and consumer prices by 0.11%, and decrease domestic sales by 0.05%. Second, subsidies generate higher economic welfare than tariffs. Specifically, the live pig production subsidy policy will increase China's annual producer surplus by $6.85 billion, consumer surplus by $3.14 billion, and net social welfare by $9.93 billion. Meanwhile, a reduction in frozen pork import tariffs will reduce China's annual producer surplus by $460 million but increase consumer surplus by $600 million, resulting in a total annual increase in social welfare of $40 million. Third, subsidies lead to more greenhouse gas emissions than tariffs. Simulation results indicate that production subsidies will increase China's annual greenhouse gas emissions by 69.87 $CO_2$ equivalents, while a reduction in import tariffs will reduce annual greenhouse gas emissions by 4.73 $CO_2$ equivalents. Therefore, for the purposes of mitigating the pig cycle and protecting the atmospheric environment, tariff policies are superior to subsidy policies. Based on these findings, this paper proposes recommendations for the cautious use of production subsidies. The research not only provides a theoretical basis for China's policy orientation in stabilizing the pig cycle but also offers analytical ideas and tools for experts and scholars to evaluate the welfare effects of economic policies.***

**Keywords:** China's pork prices; Production subsidy policy; Tariff reduction; GSIM model; Welfare effects.

## 1. INTRODUCTION

China has become the world's largest producer and consumer of pork, accounting for 50% of global pork production and consumption. Pork is the primary meat consumer product for Chinese residents, and fluctuations in pork prices exert a pivotal impact on China's Consumer Price Index (CPI). Since 2019, the combined effects of African swine fever and the "pig cycle" have led to a period of rapid increase in China's pork prices, followed by a decline in 2021 as national hog production recovered. However, recent frequent fluctuations in pork prices have once again brought the pig farming industry into the spotlight. The 14th Five-Year Plan for Promoting Agricultural and Rural Modernization, issued by the State Council on November 12, 2021, states: "It is necessary to ensure the effective supply of grain and other important agricultural products, and consolidate and enhance hog production capacity. Develop modern animal husbandry, improve the long-term mechanism for the stable and orderly development of the hog industry, promote standardized large-scale breeding, and stabilize pork production capacity at around 55 million tons to prevent drastic fluctuations in production." This highlights the urgency and necessity of stabilizing pork output and keeping prices within a reasonable range.

Historically, hog production is highly sensitive to fluctuations in pork prices due to factors such as the stock of breeding sows, newborn piglets, and fattening hogs. Thus, relying solely on the "invisible hand" of the market to regulate hog production is insufficient. To address the phenomenon of "high prices hurting consumers and low prices hurting farmers" caused by the "pig cycle," it is essential to leverage the role of the government's "visible hand." Production subsidies for the pig farming industry have long been a policy tool for the government to regulate pork production and prices. The Opinions on Promoting High-Quality Development of Animal Husbandry, issued by the General Office of the State Council on September 28, 2020, notes: "Animal husbandry is an important industry related to national economy and people's livelihood. The development goals include steadily improving

the overall competitiveness of animal husbandry and significantly enhancing the security capacity of livestock product supply, with the aim of maintaining a pork self-sufficiency rate of around 95%." The Opinions further propose: "Implement subsidies for improved hog breeds to accelerate the promotion and application of high-quality breeds; continue the reward policy for major hog-exporting counties; strengthen guidance and support for small and medium-sized farmers; develop large-scale breeding in accordance with local conditions; guide farms (households) to upgrade infrastructure, expand breeding scale, and improve standardized breeding levels." Mitigating the negative impacts of "pig cycle" fluctuations is an urgent priority. As Liu Tong argues, "Two hands are better than one"—such measures aim to "level peaks and fill valleys," preventing drastic fluctuations in pork prices and providing strong guarantees for the healthy, stable, and balanced development of the breeding industry. Therefore, research on the role of pork subsidy policies has become an extremely important issue.

The economic and welfare effects of government hog subsidies have emerged as a hot research topic. As the world's largest pork producer and consumer, how China's various pork subsidy policies and tariff reduction policies affect pork production, prices, trade, and consumption in China and globally has attracted widespread attention from pork producers and consumers worldwide. However, existing studies mostly focus on closed domestic market conditions, macro-level empirical analyses, or micro-level elaborations based on farmer surveys. There is a lack of in-depth theoretical and empirical analysis at the industry level within the context of an open international economy characterized by "domestic circulation as the mainstay, with domestic and international circulations reinforcing each other." Additionally, research on whether hog industry subsidy policies impact environmental protection and carbon emissions remains limited.

Building on the literature by Francois and Hall (2003, 2007), this paper constructs a partial equilibrium model. First, it theoretically analyzes the economic and welfare impacts of subsidy policies at the industry level. Then, by operationalizing and programming the partial equilibrium model, it uses global data on pork trade, production, and consumption in 2019 to simulate the impacts of government hog production subsidy policies and frozen pork import tariff reduction policies on pork production, prices, trade, producer and consumer welfare, carbon emissions, and environmental protection in major countries (regions).

The main contributions of this paper are as follows: First, it modifies the computable partial equilibrium Global Simulation Model (GSIM) developed by Francois and Hall (2003, 2007) by introducing policy subsidy and tariff variables, simulating the economic, welfare, and environmental effects of government production subsidy policies for the hog industry and frozen pork import tariff reduction policies, thereby expanding the evaluation and analysis framework for economic policy effects. Second, it assesses the effectiveness of subsidy and tariff policies in stabilizing the "pig cycle." Finally, based on the research results, it proposes recommendations highly aligned with practical policy implementation, providing a robust theoretical basis for the government to select and implement "pig cycle" stabilization policies under the principle of green development.

## 2. LITERATURE REVIEW

### 2.1 Research on the Necessity and Efficiency of Pig Subsidy Policies

Research on the Necessity of Pig Subsidy Policies: Xin et al. (2011) proposed that China should support the pig industry through pig subsidy policies by summarizing the successful experiences of agricultural subsidy policies in developed countries, especially by providing income subsidies to pig farmers to stimulate their enthusiasm for breeding. Tan (2012) pointed out that a country's subsidy for the livestock industry would have a significant positive effect on the production and trade of livestock products under the WTO subsidy principles. China's pig subsidy policies still have a lot of room for development. It should increase financial investment in the pig industry, reasonably implement a combined and coordinated "yellow box" and "green box" subsidy policy, provide appropriate feed subsidies, and strive to form a long-term mechanism for pig industry subsidies. Liu et al. (2014) pointed out that timely and appropriate pig subsidy policies have a positive significance in stabilizing pig supply and reducing market price fluctuations. Zhang et al. (2019) pointed out that the government should provide support and subsidies for agricultural insurance when studying the role of insurance and cooperatives in China's pig industry to ensure the smooth operation of agricultural insurance. Teng (2020) believed that the increase in pork prices in 2019 was a long-term result caused by the accidental African swine fever and the inevitable downward trend of the market pig cycle and the implementation of environmental protection policies. The government should provide comprehensive subsidies for the pork supply chain and key subsidies for environmentally friendly pig farming projects.

Research on the Efficiency of Pig Subsidy Policies: Yu (2013) found that pig subsidy policies play a positive role in stabilizing pig supply and promoting large-scale pig farming through the study of the effects of pig subsidy policies. Zhou (2014) used the grey correlation degree analysis method and based on the data of the pig industry in Guangdong Province, concluded that pig subsidy policies would have a positive impact on pig supply. He then proposed suggestions for optimizing subsidy policies to improve subsidy efficiency and promote the development of the pig industry. Zhao et al. (2016) used an unbalanced panel model to study the efficiency of pig farming support policies. The empirical results showed that the expansion of the pig farming scale in the current year was indeed due to the implementation of support policies. Chang (2019) analyzed the impact of pig subsidy policies on the behavior of pig farmers in Jilin Province and found that pig subsidy policies played a significant positive role in increasing farmers' confidence and income, stabilizing pig production, and ensuring the effective supply of pigs. Li (2021) used the DID model and difference-in-differences method to analyze whether pig subsidy policies would affect the production efficiency of the pig industry. The empirical results showed that pig subsidy policies would have a positive effect on improving the technical efficiency of the pig industry and expanding the scale of production. Ma et al. (2021) believed that pig subsidy policies would have a positive effect on stabilizing pork prices in the long term, but the current government subsidy policies for the pig industry could not suppress prices in the short term. Shifting part of the subsidies to the alternative industries of pork would be an effective measure to suppress prices in the short term. Liu (2021) used a game theory framework to analyze the optimal subsidy plan for government pig subsidies. By comparing the different efficiencies brought by subsidies to different subjects such as pig farmers and consumers, it provided relevant suggestions for the formulation of subsidy policies. Ding et al. (2022) based on the analysis of the livestock subsidy situation in Tumushuke City, the Third Division of Xinjiang Production and Construction Corps, pointed out that local pig farmers' willingness to breed and their ability to resist risks were generally enhanced under the incentive of subsidy policies. Subsidy policies are of great significance for ensuring the stability of meat product supply, increasing farmers' income, and promoting rural revitalization.

### 2.2 Disputes and Evolution in the Formulation of Agricultural Subsidy Policies

In the late 1950s, with the introduction of the Common Agricultural Policy (CAP) originating from the Treaty of Rome, government subsidies for the agricultural production sector became a reality. The development of agricultural subsidy practices has driven theoretical research, and many achievements have emerged since then. For instance, in their agricultural economics theory, Yuzo Nishimizu and Yoshihisa Nakamura revealed that the implementation of agricultural subsidy policies would have an impact on the production, domestic sales, and foreign trade of agricultural products. Although it has become a consensus that agricultural subsidy policies affect the production and sales of agricultural products and social welfare, whether the impact is more beneficial or detrimental has become a controversial issue in the theoretical circle. Therefore, whether the government should provide subsidies to agriculture has become the focus of both theory and practice.

Cai (1993) and Lin (2003) et al. believe that agricultural subsidy policies have a high degree of price distortion. Subsidy policies not only increase the fiscal burden but also pass this burden on to taxpayers and consumers, and they also have a certain hindrance to the improvement of agricultural efficiency. Therefore, the government should not make such a wrong policy choice. On the contrary, some hold the view that agricultural subsidy policies have positive significance for the development of agriculture and rural areas, and thus support increasing the intensity of agricultural subsidies. Specifically, experts and scholars who support the implementation of agricultural subsidy policies include Ke (2001), He et al. (2003), Zhang (2005) and Cheng (2011).

### 2.3 Economic Effect of Agricultural Subsidy Policy

Agricultural subsidy policy will affect agricultural production activities from beginning to end, and then affect the overall development of a country's economy. The economic effects of agricultural subsidy policy will be elaborated from the micro and macro perspectives respectively.

From the micro point of view, the direct impact of agricultural subsidy policy is on agricultural producers. The production decision and behavior, income level and welfare level of agricultural producers will be affected by the subsidy policy Impact of agricultural subsidy policy on farmers' production decisions and behaviors: Liu (2010), Wu et al. (2010) and Bopp et al. (2020) pointed out that agricultural subsidy has a positive impact on farmers' choice of agricultural product planting area. Zang et al. (2013), Li, Chen (2018), Guo et al. (2021), Zou et al. (2020) and Çullu et al. (2022) believe that agricultural subsidies will significantly change farmers' crop selection, variety selection and technology selection decisions. Hoffmann and Jones (2021) points out that price incentives and

technology subsidies can encourage farmers to increase the use of food safety measures in food production. Vissers et al. (2022) believes that subsidies to broiler farmers can encourage farmers to invest in PM10 emission reduction in the process of raising chickens. However, the Nasrin et al. (2019) concluded that fertilizer subsidies in Bangladesh had no significant effect on the amount of fertilizer used by farmers during production. Impact of agricultural subsidy policy on farmers' income and welfare: Gu Zheng (2014), Tian et al. (2018), Alizamir (2019), Bai et al. (2022), Bopp et al. (2020), Zhang et al. (2019). The empirical results of the Bojnec and Latruffe (2013) show that the agricultural subsidy policy plays an important role in improving the income level of farmers. Luo et al. (2017) and Guo et al. (2018) used econometric models to conclude that there is a significant positive correlation between the level of agricultural subsidies and the level of farmers' welfare, and pointed out that different ways of subsidies have different degrees of improvement on farmers' welfare.

From a macro point of view, the government's agricultural subsidy policy is of great significance to national food security, regional economic development and common prosperity. Impact of Agricultural Subsidy Policy on Grain Production: Gao et al. (2017), Deng et al. (2020), Khonje et al.(2022), Tsiboe et al. (2021) and S. Zeng et al. (2022) hold that subsidy policy can improve agricultural production efficiency and regional agricultural development level, and promote national food security and agricultural economic development. In contrast, the analysis of Xu et al. (2022) shows that farm output is insensitive to all subsidies, while FrFrýd and Sokol (2021) argues that agricultural subsidies have a negative impact on agricultural development. The impact of agricultural subsidy policy on common prosperity: Lin (2005), Qin et al. (2011), Chen et al. (2018), Zhang et al (2020).

### 2.4 Computable Partial Equilibrium Models and Their Applications

Scholars typically use CGE (Computable General Equilibrium) models when studying the economic and welfare impacts of subsidy or tax policies. However, the theoretical foundation of CGE models is not sufficiently rigorous, and they require a large number of equations and data for calculation, making their operation relatively difficult. To minimize simulation errors caused by the shortcomings of CGE models, Francois and Hall (1997) proposed the "Commercial Policy Analysis System" (COMPAS model) based on traditional price theory and the Armington (1969) model. The bilateral COMPAS model, which belongs to the category of computable partial equilibrium models, can simulate and analyze the economic and welfare impacts of specific trade policy changes on industry-level outcomes in particular countries. Francois and Hall (2003; 2007) further expanded the COMPAS model to develop the Global Simulation Model (GSIM model).

Compared with computable general equilibrium models, computable partial equilibrium models have three main advantages: (1) Since they only consider the equilibrium of a single market, computable partial equilibrium models require far fewer equations to solve than computable general equilibrium models, improving the model's flexibility and operability; (2) By only needing to collect industry-level data, they can effectively avoid "aggregation errors" in data simulation and enhance the accuracy of simulation results; (3) Computable partial equilibrium models can use limited industry-level data to conduct in-depth analysis of the economic and welfare impacts of specific economic policies on the target industry.

In recent years, some domestic scholars have used computable partial equilibrium models to analyze the welfare effects of China's participation in international trade across different industries. Hong and Huang (2014) applied the COMPAS partial equilibrium model to study the impact of U.S. anti-dumping and countervailing measures on China's photovoltaic industry on producers, consumers, and overall economic interests in both countries. Chen (2018) used an innovative COMPAS model to examine the impact of the signing of the Cross-Strait Economic Cooperation Framework Agreement on textile production and trade between mainland China and Taiwan. Xiang et al. (2019) used a computable partial equilibrium model and global data on wine production and consumption in 2016 to study changes in welfare effects brought about by reforms in wine tax policies. Kuang et al. (2021) applied the computable partial equilibrium GSIM model to simulate changes in economic welfare effects in China, the U.S., and even globally after the U.S. imposed tariffs on Chinese masks. Chen and Xiang (2022) used a computable partial equilibrium model to empirically study the impact of the signing of the Regional Comprehensive Economic Partnership (RCEP) on global agricultural production and trade.

## 3. ANALYSIS OF CURRENT SITUATION

### 3.1 Current Status of Global Pork Production and Trade

According to statistics from the United States Department of Agriculture, the global live pig production in 2019

was 101.03 million tons, a decrease of 9.73% compared with 2018. Figure 1 shows the top 10 countries in global live pig production in 2019. China, the European Union, and the United States remain the traditional major live pig-producing countries. Among them, China ranked first with a production volume of 42.55 million tons, followed by the European Union and the United States in second and third places respectively, while Brazil and Russia ranked fourth and fifth. In addition, Vietnam, Canada, the Philippines, Mexico, and South Korea are also important live pig-producing countries. In 2019, the total live pig production of these 10 countries reached 94.175 million tons, accounting for nearly 93.2% of the global production. This indicates that the global live pig production has a high degree of concentration.

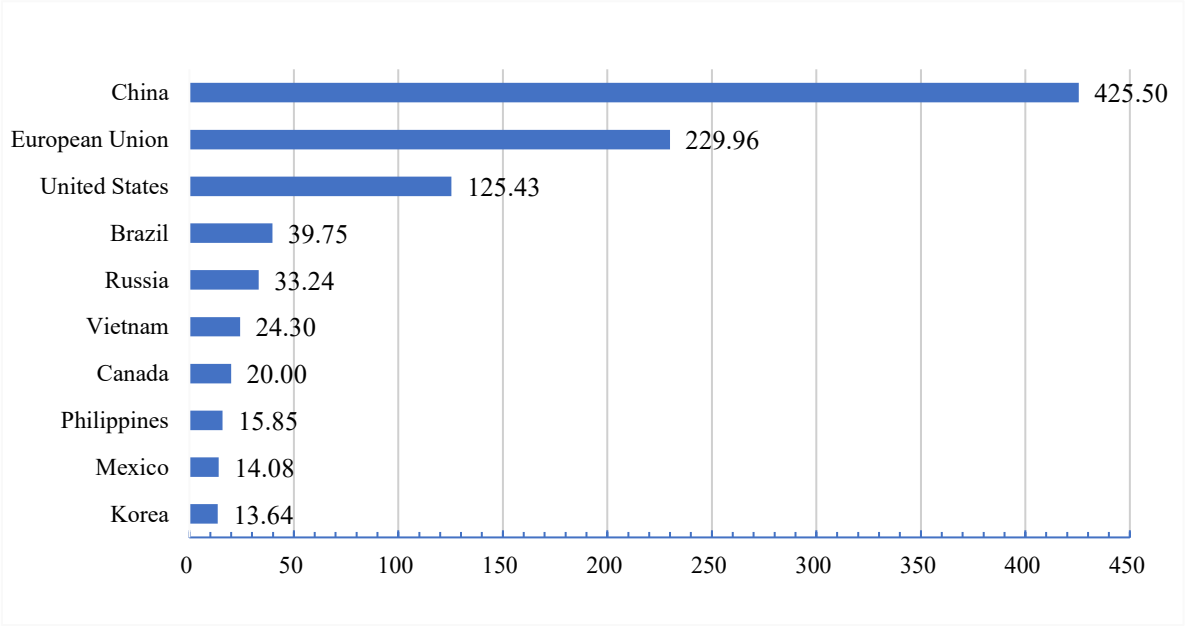


**Figure 1:** top 10 countries in global pig production in 2019 and their production (MT)

Major live pig-producing countries are often also the primary consumers of live pigs. Statistics from the United States Department of Agriculture show that global live pig consumption in 2019 reached 99.827 million tons, a decrease compared to the 2018 consumption volume of 111.036 million tons. China has maintained its position as the world's largest live pig consumer; in 2019, its live pig consumption was 44.866 million tons, a 18.9% decrease from the 2018 consumption of 55.295 million tons. The European Union and the United States ranked second and third respectively, with live pig consumption of 18.894 million tons and 10.066 million tons. The countries ranking fourth to tenth were Russia, Brazil, Japan, Vietnam, Mexico, South Korea, and the Philippines. In 2019, the total live pig consumption of these 10 countries amounted to 91.488 million tons, accounting for approximately 91.6% of the global total live pig consumption that year.

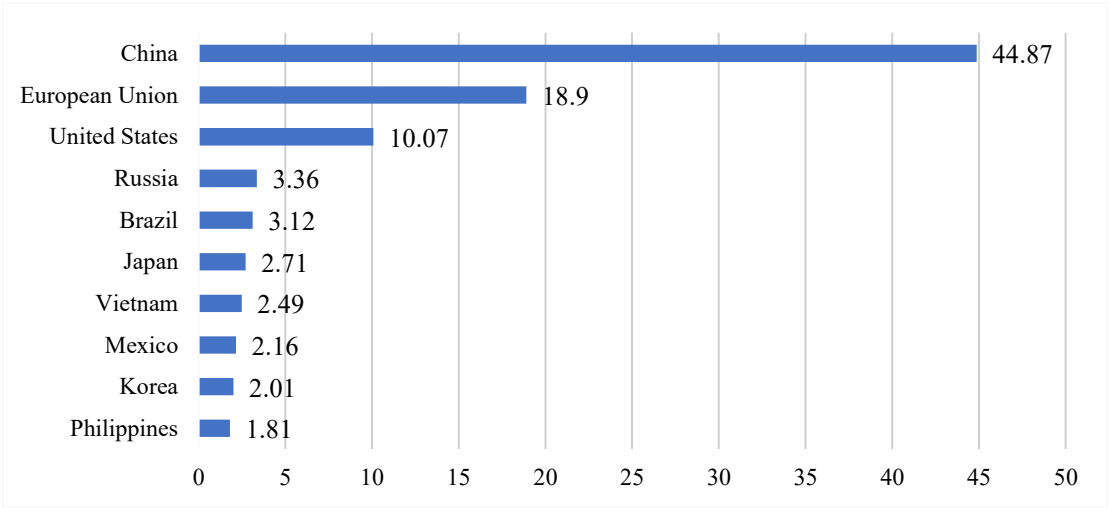


**Figure 2:** top 10 hog consumption countries in 2019 and their consumption (MT)

In general, pig-raising costs mainly consist of feed costs, piglet costs, labor expenses, medical and epidemic prevention costs, machinery and workshop expenses, water and electricity costs, etc. In addition, there are also some administrative expenses, sales expenses, and financial expenses. Whether in the free-range breeding mode or large-scale breeding mode, feed costs account for the largest proportion, reaching about 50%. Internationally, countries such as the United States and Brazil have high yields of grains like corn and soybeans, so their feed costs are relatively lower than those of other countries. There is little difference in piglet costs and medical and epidemic prevention costs among countries around the world. In terms of labor expenses, developed countries in Europe and America have higher technical levels and much higher large-scale breeding levels than China, thus enjoying lower labor expenses. Regarding machinery and workshop expenses, although European and American countries have a high level of mechanization, with the continuous improvement of large-scale breeding, the unit cost allocated to each pig remains low, resulting in the total machinery and workshop costs being only slightly higher than those in China. In the future, as China's pig-raising mechanization gradually replaces manual labor, this cost will also rise gradually. Figure 3 shows the pig-raising production costs in major countries in 2020. It can be seen from the figure that China's pig-raising production cost is nearly three times that of the United States, Brazil, and Canada, and nearly twice that of European Union countries.

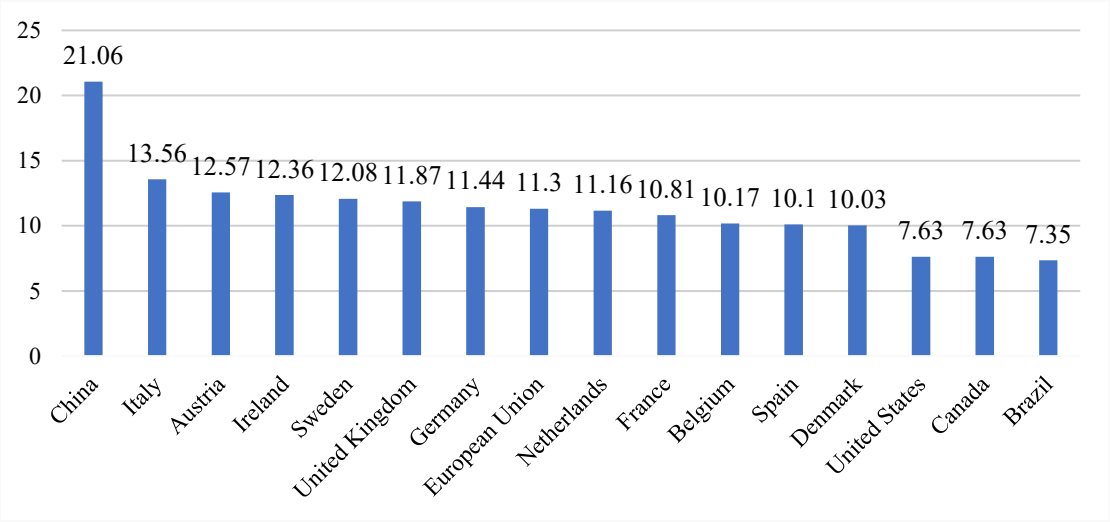


**Figure 3:** cost of pig breeding in main countries in 2020(in Yuan)
Data source: Compiled by the author based on data from the Ministry of Agriculture and Rural Affairs of the People's Republic of China, China's 2020 Rural Statistical Yearbook, the United States Department of Agriculture, and the Agriculture and Horticulture Development Board of the United Kingdom. Prices are converted into RMB based on the euro exchange rate at the end of June 2022.

According to statistics from the United Nations Commodity Trade Statistics Database (UN Comtrade), the global total import value of live pigs in 2019 was approximately 31.907 billion US dollars. Table 1 shows the top 10 countries in terms of global live pig import value in 2019. Among them, Japan was the world's largest importer of live pigs, with an import value of 4.634 billion US dollars. China followed closely in second place with a live pig import value of 4.509 billion US dollars. The combined live pig import value of Japan and China in 2019 accounted for nearly 30% of the global live pig import value. Italy ranked third with an import value of 2.339 billion US dollars, accounting for 7.3% of the global total. Germany ranked fourth, with an import value of 1.868 billion US dollars. The live pig import values of Poland, South Korea, and Mexico in 2019 were relatively similar, ranking fifth, sixth, and seventh with global shares of 5.2%, 5.0%, and 4.8% respectively. The United Kingdom, the United States, and France are also important importers of live pigs. The total live pig import value of these 10 countries in 2019 was approximately 21.39 billion US dollars, accounting for 67.04% of the global total live pig import value that year, indicating a high concentration of live pig imports.

**Table 1:** Top 10 Countries with the Largest Import Values of Live Pigs in 2019 (Unit: $100 million)

| COUNTRY | JP | CN | IT | DE | PL | KR | MEX | UK | USA | FR |
|---|---|---|---|---|---|---|---|---|---|---|
| RANK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| IMPORTS | 46.34 | 45.09 | 23.39 | 18.68 | 16.43 | 16.00 | 15.46 | 12.15 | 11.00 | 8.56 |
| PERCENTAGE | 14.5% | 14.1% | 7.3% | 5.8% | 5.2% | 5.0% | 4.8% | 3.80% | 3.4% | 2.7% |

Data source: Compiled by the author based on data from UN Comtrade.

In 2019, the global total export value of live pigs reached 32.846 billion US dollars, and the top 10 countries by export value are shown in Table 2. As can be seen from Table 2, the United States was the country with the largest live pig export value in the world, with its export value reaching 5.218 billion US dollars in 2019, accounting for 15.9% of the global live pig export value. Spain and Germany, ranking second and third, followed closely in terms of live pig export value, accounting for 15.6% and 15.4% of the global live pig export value respectively, which are not much different from the proportion of the United States. Denmark, the Netherlands, and Canada are also three important live pig exporting countries. In 2019, their live pig export values were 2.77 billion US dollars, 2.715 billion US dollars, and 2.596 billion US dollars respectively, accounting for 8.4%, 8.3%, and 7.9% of the global total live pig export value, ranking fourth, fifth, and sixth. Major live pig exporting countries also include Brazil, Belgium, France, and Poland, among others. The total live pig export value of these 10 countries reached 28.483 billion US dollars, accounting for 86.72% of the total live pig export value that year. It is evident that global live pig export trade is highly concentrated.

**Table 2:** Top 10 Countries with the Largest Export Values of Live Pigs Globally in 2019 (Unit: $100 million)

| COUNTRY | USA | ES | DE | DK | NL | CA | BR | BE | FR | PL |
|---|---|---|---|---|---|---|---|---|---|---|
| RANK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| IMPORTS | 52.18 | 51.30 | 50.51 | 27.70 | 27.15 | 25.96 | 14.88 | 14.33 | 11.28 | 9.55 |
| PERCENTAGE | 15.9% | 15.6% | 15.4% | 8.4% | 8.3% | 7.9% | 4.5% | 4.4% | 3.4% | 2.9% |

Data source: Compiled by the author based on data from UN Comtrade.

Since China's accession to the World Trade Organization, its live pig imports have generally grown at a relatively rapid pace. According to data from UN Comtrade, China's live pig import value was $520 million in 2008, and by 2019, the import value soared to $4.51 billion, an increase of nearly 9 times in just a decade. Figure 4 shows the top 10 source countries of China's live pig imports in 2019. It can be seen that Spain is currently the largest source country of China's live pig imports. In 2019, China's live pig import value from Spain reached $908 million, accounting for 21% of the total import value. Germany, Brazil, and the United States are the second, third, and fourth largest source countries of China's live pig imports, with import values of $669 million, $607 million, and $507 million respectively in 2019. The combined share of these three countries in the total import value is nearly 40%. The Netherlands and Canada rank sixth and seventh in turn, with China's live pig import values from them in 2019 being $363 million and $318 million respectively. France, Chile, and the United Kingdom are also important sources of China's live pig imports. In 2019, China imported nearly $4.31 billion worth of live pigs from the 10 countries listed in Figure 4, accounting for 95.57% of China's total live pig import value that year.

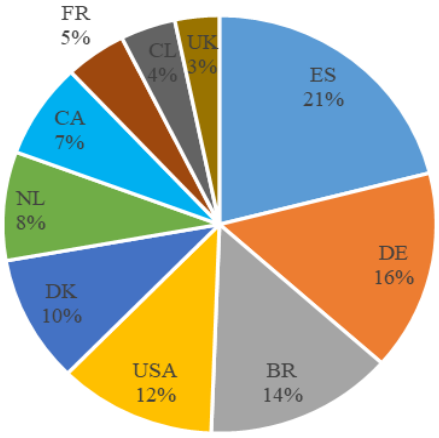


**Figure 4:** Top 10 source countries of China's pork imports in 2019 and their proportions
Data source: Compiled by the author based on data from UN Comtrade.

### 3.2 Review of China's "Pig Cycle", Subsidy Policies, and Import Tariff Policies

3.2.1 A Review of China's four "pig cycles" since 2006

The "pig cycle" refers to the phenomenon of price fluctuations in the process of live pig production and pork sales. Specifically, when pork prices rise, farmers will expand production, increase the number of breeding sows, drive up the stock of live pigs, and as pigs mature and are sent to market, the supply of pork increases, leading to a drop in prices. When farmers observe the decline in pork prices, they will reduce production, cull breeding sows, resulting in a decrease in the stock and slaughter of live pigs, a reduction in pork supply, and a subsequent rebound

in pork prices. This recurring pattern is known as the “pig cycle.”

The production cycle of pigs determines that a complete pig cycle lasts 3–4 years, and within a single year, it also exhibits small periodic fluctuations affected by holidays and climate. The essence of the pig cycle lies in the relationship between supply and demand: the demand side remains generally stable, while the key lies in the supply side. Fluctuations on the supply side are mainly due to the periodic nature of pig breeding. In addition, factors such as policy interventions (environmental protection measures, fiscal subsidies, and reserve purchase and release systems), natural disasters, and epidemics can amplify supply volatility. China’s pig breeding industry is dominated by small-scale household farming, with a high degree of homogeneity among producers, low industry concentration, and weak influence of individual producers on market prices. Producers are more likely to “chase rising prices and sell at falling prices.” Moreover, insufficient epidemic prevention technology and capital make the industry more prone to drastic fluctuations, causing pork prices to show obvious characteristics of a cobweb cycle.

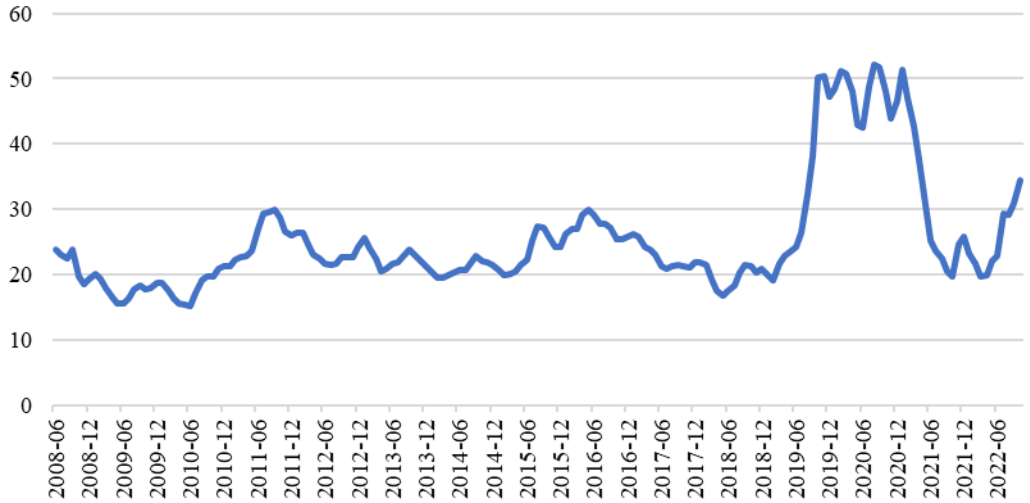


**Figure 5:** Average pork prices in 22 provinces and cities in China from June 2008 to October 2022 (Unit: yuan/kg)

Since 2006, China has roughly experienced four “pig cycles”. The first “pig cycle” was from mid-2006 to May 2010, lasting for four years, including two years of upward cycle and two years of downward cycle. The outbreak of highly pathogenic porcine reproductive and respiratory syndrome (PRR) across the country in 2006, the outbreak of Influenza A (H1N1) in 2009, and the occurrence of food safety incidents such as clenbuterol and water-injected pork in 2010 all played a contributing role during this period. The second “pig cycle” was from June 2010 to April 2014, lasting about four years. Among them, the upward cycle lasted for 15 months and the downward cycle lasted for 32 months. This cycle is a relatively classic pig cycle. The price is mainly driven by the internal driving force of the pig cycle, with fewer external interfering factors. The third cycle was from May 2014 to May 2018, lasting for four years, with the upward cycle lasting for two years and the downward cycle lasting for two years. Since 2014, China has begun to implement strict environmental regulations

The regulations on the ban on breeding and the outbreak of swine erysipelas in the first half of 2015 have had a certain impact on the cycle. The fourth cycle was from mid-2018 to 2022, lasting nearly four years. This round of pork prices has been influenced by multiple factors such as African swine fever, environmental protection production restrictions, the internal upward momentum of the pig cycle, and large-scale breeding. It has shown characteristics of large and rapid increases, with the price increase being the largest in all previous pig cycles, and can be called a “super pig cycle”. According to the official monitoring data on October 11th, in the 39th week of 2022 (September 26th to September 30th), the weekly average of the total index of lean white pork ex-factory prices in 16 provinces (municipalities directly under the Central Government) was 31.44 yuan per kilogram, up 107.2% year-on-year. For the recently continuously rising and high-level pig prices, studying the policy effects to stabilize the pig cycle is of great significance for stabilizing market expectations and maintaining the stable operation of the food market.

3.2.2 Subsidy policies for pig production in China

Pig production subsidies refer to the financial support provided by the government's financial department to pig farmers during the pig breeding process to subsidize their production activities. The subsidy policy for pig production is a policy implemented by the government to regulate the supply and demand relationship in the pig market, stabilize the output and price of pigs, and provide financial support to pig farmers. The subsidy funds are jointly borne by the central and local financial departments. China's subsidy policy for pig production was implemented relatively late. In 2006, the outbreak of highly pathogenic porcine reproductive and respiratory syndrome (PRRS) across the country led to a sharp reduction in the supply of pigs in China and a significant increase in pork prices. The contradiction between supply and demand in the market urgently needed to be alleviated. In order to regulate the pig industry and ensure the basic living needs of residents, the central government issued the "Opinions on Promoting the Development of Pig Production and Stabilizing Market Supply" in 2007. The opinion proposed to increase financial support to regulate the production and supply of live pigs. Under the guidance of this opinion, governments at all levels began to formulate a series of subsidy policies one after another. This was the starting point of China's live pig subsidy policy.

The main subsidy policies for pig production in China include: subsidies for breeding sows, insurance for breeding sows, subsidies for high-quality pig breeds, subsidies for the construction of standardized large-scale pig farms, rewards for major pig-exporting counties, subsidies for harmless treatment of diseased and dead pigs in pig farms, subsidies for pig disease prevention and control, and subsidies for the purchase of agricultural machinery and equipment for pig production, etc.

**Table 3:** Major pig subsidy policies in China

| Major subsidy policies | Subsidy target | Subsidy standards |
|---|---|---|
| | Breeding sows | 50 yuan per head |
| | Breeding sows | 48 yuan per head |
| | Breeding sows | 40 yuan per head |
| | Large-scale livestock farms | For breeding scales of 3,000 or more: 800,000<br>Farming scale of 2000 to 2999 heads: 600,000<br>Farming scale of 1000 to 1999 heads: 400,000<br>Farming scale of 500 to 999 heads: 200,000 |
| | Top 500 counties with the largest number of live pigs transferred out | No less than 1 million yuan |
| | Slaughtered pigs with diseases | 800 yuan per head |
| | Pigs died of diseases in the breeding process | 80 yuan per head |

Data source: The author compiled the data based on the data provided by the Ministry of Agriculture and Rural Affairs of the People's Republic of China.

Pig production subsidies refer to the financial support provided by the government's financial department to pig farmers during the pig breeding process to subsidize their production activities. The subsidy policy for pig production is a policy implemented by the government to regulate the supply and demand relationship in the pig market, stabilize the output and price of pigs, and provide financial support to pig farmers. The subsidy funds are jointly borne by the central and local financial departments. China's subsidy policy for pig production was implemented relatively late. In 2006, the outbreak of highly pathogenic porcine reproductive and respiratory syndrome (PRRS) across the country led to a sharp reduction in the supply of pigs in China and a significant increase in pork prices. The contradiction between supply and demand in the market urgently needed to be alleviated. In order to regulate the pig industry and ensure the basic living needs of residents, the central government issued the "Opinions on Promoting the Development of Pig Production and Stabilizing Market Supply" in 2007. The opinion proposed to increase financial support to regulate the production and supply of live pigs. Under the guidance of this opinion, governments at all levels began to formulate a series of subsidy policies one after another. This was the starting point of China's live pig subsidy policy.

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The subsidy standard is 50 yuan per head, with the central and local finances sharing 60% and 40% respectively.

Insurance subsidy policy for breeding sows. In order to motivate farmers to raise breeding sows, the state, on the basis of direct subsidies for breeding sows, also allocates funds to organize relevant agricultural insurance operating institutions to provide a certain proportion of insurance coverage for the breeding sows raised by farmers. The insurance coverage for each breeding sow is 1,000 yuan, and the related insurance premium is 60 yuan. Among this, the central government covers 30 yuan, local governments cover 18 yuan, and the farmers themselves only need to bear 12 yuan. The implementation of the insurance subsidy policy for breeding sows has significantly enhanced the production enthusiasm of farmers and consolidated the production capacity of breeding sows.

Subsidies for high-quality pig breeds. To improve pig breeds, enhance the survival rate of pig farming and the quality of pig food safety, the government provides subsidies to producers among pig farmers who carry out artificial insemination of high-quality pig breeds. The subsidy funds for high-quality breeds are mainly indirectly distributed to farmers through the supply units of high-quality semen. The subsidy amount is distributed according to the standard that each breeding sow uses 4 samples of semen per year, with a subsidy of 10 yuan for each sample of semen.

Subsidies for the construction of standardized large-scale breeding farms. In September 2019, in order to boost the enthusiasm of pig farmers for raising pigs and curb the rise in pig prices, the state issued a series of subsidy policies, including subsidies for new pig houses, subsidies for large-scale pig farming and subsidies for standardized pig farming projects. One-time subsidies were provided for the construction and expansion of new and renovated pig breeding farms and large-scale pig farms (households) before the end of 2020, as well as the relocation and reconstruction of large-scale pig farms (households) within the prohibited pig farming areas. Among them, a subsidy of 40 yuan per square meter will be provided for newly built pens, and 150 yuan per cubic meter for biogas digesters. The specific subsidy standards for large-scale pig farming are shown in Table 3. In terms of subsidies for standardized breeding projects, the main focus is on the major pig-producing areas. A “reward instead of subsidy” approach is adopted to support moderate-scale pig farms in carrying out standardized expansion and renovation, including the transformation of water-saving facilities, feed-saving equipment, manure removal facilities, slatted floors, etc., and the implementation of automated environmental control, etc. Farmers can apply for subsidies when expanding.

Rewards for major counties that export live pigs. In 2017, the Ministry of Agriculture issued a notice on the release of the “National Pig Production Development Plan (2016-2020)”, which pointed out that in accordance with the principle of “guiding production, more dispatch and more rewards, equal responsibility and authority, and emphasizing performance”, the central government’s finance will provide rewards to major pig export counties whose pig export volume and inventory and export volume meet the prescribed standards. The reward funds for major pig-exporting counties are allocated to the counties based on the factor method. The allocation factors include the average annual pig export volume, slaughter volume and inventory volume over the past three years, with factor weights of 50%, 25% and 25% respectively. The reward funds will support the top 500 major pig-exporting counties. Each major county that exports live pigs will receive a reward of no less than 1 million yuan, which will be allocated by the county-level people’s government to support the production, circulation and industrial development of live pigs in the county. The scope of support includes: Expenditures on the renovation of pig pens, the introduction of high-quality breeds, the treatment of manure and sewage, disease prevention, insurance, the construction of cattle and sheep feed bases in the pig production process, as well as cold chain logistics, warehousing, and processing facilities and equipment in the circulation and processing process.

Subsidies for pig disease prevention and control and harmless treatment of dead pigs. The prevention and control of pig diseases not only concerns the supply of pork in the market, but also the food safety of residents. To counter the impact of diseases on the pig industry, the state has gradually established a relatively comprehensive pig epidemic prevention system, such as providing free vaccines for diseases with high fatality rates and subsidizing the harmless treatment of dead pigs in the breeding and slaughtering processes. In 2011, the Ministry of Finance issued a notice on adjusting the subsidy standards for the harmless treatment of diseased pigs in the pig slaughtering process. The notice pointed out that in order to support the construction of the public epidemic prevention system for pigs and promote the sustained and healthy development of pig production, the fiscal subsidy standards for the losses of diseased pigs in the slaughtering process would be increased. The adjusted subsidy standard is 800 yuan per pig. For the harmless treatment of diseased and dead pigs in the breeding process, the subsidy standard is 80 yuan per pig. Both parts of the subsidy amounts are jointly borne by the central and local finances.

Subsidies for the purchase of agricultural machinery and equipment for pig production. In September 2019, the General Office of the Ministry of Agriculture and Rural Affairs issued the "Notice on Increasing Subsidies for Agricultural Machinery Purchases to Support the Development of Pig Production". To stabilize pig production and ensure pork supply, the notice clearly requires the optimization of the range of agricultural machinery types eligible for purchase subsidies, and supports pig farms (households) in purchasing agricultural machinery such as automatic feeding, environmental control, disease prevention and control, and waste treatment equipment. It is proposed that all the machinery items applicable to pig production within the scope of national agricultural machinery purchase subsidies be included in the subsidy scope of this province in principle. All necessary agricultural machinery equipment such as automatic feeding, environmental control, disease prevention and control, and waste treatment for pig farms (households) should be supplemented as much as possible. Priority should be given to processing subsidies for pig farms (households), optimizing services and enhancing efficiency. Where conditions permit, door-to-door services should be organized. We should intensify policy promotion and technical training, guide agricultural machinery enterprises to actively participate in policy implementation, and support and promote the purchase and use of machinery by a large number of breeding farms (households). At the same time, focusing on major pig breeding counties, a special investigation into the demand for subsidies for the purchase of agricultural machinery and equipment for pig production will be carried out to comprehensively improve the level of agricultural machinery and equipment for pig production.

3.2.3 China's pork import tariff policy

Import tariffs are policies that can directly reflect the degree of market access in trade among countries and regions around the world. The changes and adjustments of China's pork import tariffs over the years directly reflect the changes in China's pork trade policies. In China, the import tariff on pork is calculated based on the price of imported pork, which is known as AD valorem taxation. According to the data from the World Trade Organization's Tariff Analysis Online, China's pork import tariffs have gradually decreased with its accession to the WTO and the improvement of its level of opening up to the outside world. Before China's accession to the WTO, the overall import tariffs on pork were relatively high. In 1996, except for the 12% import tariff on live pigs, the import tariffs on fresh or chilled pork, frozen pork, pork offal, other pork offal, smoked pork and pork products were all as high as 45%. From 2001 to 2003, during the early stage of China's accession to the World Trade Organization, in order to align with international tariff standards, it frequently adjusted the import tariffs on pork, significantly reducing the import tariffs compared with before. From 2004 to 2019, the import tariffs on frozen pork remained at 10% for live pigs, 20% for fresh or chilled pork, 12% for frozen pork, 20% for pork offal, 12% for other pork offal, 25% for smoked pork, and 15% for pork products, without any significant adjustments. Only after the outbreak of blue ear disease in China in 2008 did the state temporarily adjust the import tariff on frozen pork by 6% in order to address the sharp increase in pork prices caused by insufficient domestic pork supply. After the outbreak of African swine fever in 2019, in the face of similar market conditions, the state adjusted the import tariff on frozen pork from 12% to 8% in order to adjust the supply situation of the domestic pork market. This new pork import tariff policy was officially implemented on January 1, 2020.

## 4. RESEARCH DESIGN AND DATA COLLECTION

### 4.1 Research Design

The basic ideas and main steps of the GSIM simulation analysis proposed by Francois and Hall (2003) reflect the distinct characteristics of comparative static analysis: First, select an investigation base period, collect and calculate data such as the output, import and export trade volume, and market share of a certain product in relevant countries or regions within the base period; Second, assuming that all conditions except for a certain trade policy remain unchanged, use the model to simulate the output, price, import and export trade and other indicator values of this product in various countries or regions when the market clears again. Thirdly, the economic and welfare impacts of trade policy changes at the industry level are calculated through the differences between the simulated values and the base period values. Although the GSIM model is a local equilibrium model, it belongs to multilateral analysis and the number of countries can be flexibly selected according to research needs. This article weighs the global production, trade and consumption of pork and adopts a 12-country model. Specifically, there are China, the United States, the European Union, Canada, Russia, Australia, the United Kingdom, Brazil, Mexico, Japan, and South Korea, and then the rest of the countries are regarded as a whole.

### 4.2 Data Collection

The data required by the GSIM model mainly include the following three categories: (1) The trade volume of pork imports and exports between the selected countries (regions) in 2019; (2) Parameters such as the demand elasticity, supply elasticity and substitution elasticity of pork in the selected country (region); (3) Changes in the subsidy rate and tariff rate of the Chinese government's subsidy policies for the pig industry around 2019.

4.2.1 The trade volume of pork between the selected countries (regions)

The author has collated the trade volume of pork imports and exports between the selected countries (regions) in 2019 based on the United Nations Commodity Trade Database, the United States Department of Agriculture and other databases (Table 1). The bolded values in the table represent the domestic sales volume of agricultural products in the corresponding countries (regions), which is obtained by subtracting the export volume from the total output value of agricultural products in that country (region).

**Table 4:** Import and export values and domestic sales values of pork in the selected country (region) in 2019 (Unit: billions of US dollars)

| export \ import | CN | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CN | 1014.35 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.33 |
| USA | 5.07 | 227.58 | 0.06 | 3.78 | 0 | 2.70 | 0.03 | 0 | 12.78 | 12.00 | 4.95 | 7.46 |
| EU | 26.96 | 2.88 | 427.17 | 0.63 | 0 | 2.92 | 12.12 | 0 | 0.02 | 16.63 | 8.08 | 12.08 |
| CA | 3.18 | 6.65 | 0 | 21.41 | 0 | 0.26 | 0 | 0 | 2.66 | 11.18 | 1.28 | 2.56 |
| RU | 0 | 0 | 0 | 0 | 76.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0.58 |
| AU | 0.21 | 0 | 0.02 | 0 | 0 | 14.54 | 0 | 0 | 0 | 0.03 | 0.01 | 0.58 |
| UK | 1.43 | 0.48 | 0 | 0.02 | 0 | 0.05 | 33.96 | 0 | 0 | 0.04 | 0.02 | 0.32 |
| BR | 6.07 | 0.28 | 0 | 0 | 1.41 | 0 | 0 | 70.45 | 0 | 0.21 | 0.07 | 7.62 |
| MX | 0.37 | 0.64 | 0 | 0.05 | 0 | 0 | 0 | 0 | 48.81 | 4.92 | 0.42 | 0.02 |
| JP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61.36 | 0 | 0.09 |
| KR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45.47 | 0 |
| OTHER | 1.81 | 0.07 | 0.27 | 0.05 | 1.00 | 0 | 0 | 0 | 0 | 1.33 | 1.17 | 215.98 |

According to the source: The author collated it based on the United Nations Commodity Trade Database and other sources.

4.2.2 Elastic parameters

According to the estimation of Xu et al. (2016), the average price elasticity of demand for meat and poultry products among food products of Chinese residents is -0.87. He et al. (2017) estimated that the price elasticity of pork demand by Chinese residents from 2003 to 2014 was -0.5711 by using the extended linear expenditure system. Data collected by Gallet (2010) indicated that the average price elasticity of global pork demand was -0.78. Wong et al. (2015) estimated that the price elasticity of pork demand among Australian residents was -0.42 using the data from 1962 to 2011 and the whole-system modeling method. Catlett (2011) estimated that the price elasticity of demand for meat products in various countries was as follows: The United States is -0.089, Brazil -0.536, Russia -0.532, the United Kingdom -0.284, Canada -0.245, Japan -0.252, South Korea -0.387, Australia -0.257, Mexico -0.510, the average of the European Union is -0.326, the average of emerging countries is -0.6154, and the average of developed countries is -0.249. Vargas-Lopez et al. (2021) pointed out that the uncompensated self-price elasticity of Mexican residents for beef, chicken and pork was -0.081. Roosen et al. (2022) estimated that the compensatory own price elasticity of pork products for German residents was -0.791.

There are relatively few literatures estimating the substitution elasticity of pork in various countries. As the focus of this paper is on the relationship between pork imports and domestic substitution, the substitution elasticity parameter value of 4.40 for meat products of various countries in GTAP2011 is used as a substitute for the substitution elasticity of pork among countries.

There are also few literatures estimating the supply elasticity of pork in various countries. According to Wu (2011) estimation, the average supply price elasticity of pork in China from 2004 to 2009 was 0.33. However, no literature directly estimating the supply elasticity of pork in other countries was collected. Therefore, the supply elasticity of pork in other countries was replaced by the parameter values of supply elasticity of meat products in various countries in GTAP2011.

**Table 5:** Demand, supply, and substitution elasticity of pork in selected countries (regions)

| Country / Elasticity | CN | USA | BR | RU | EU | UK | CA | JP | KR | AU | MX | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| elasticity of demand | -0.57 | -0.01 | -0.54 | -0.53 | -0.33 | -0.28 | -0.25 | -0.25 | -0.39 | -0.42 | -0.51 | -0.37 |
| elasticity of supply | 0.33 | 2.14 | 1.06 | 1.06 | 1.06 | 1.06 | 1.89 | 1.22 | 1.22 | 0.80 | 1.22 | 1.19 |
| elasticity of substitution | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 |

Data source: The author collated it based on relevant research results.

4.2.3 Pork subsidy rate

In 2020, the national pig slaughter volume was 527.04 million heads, and the pork output was 41.13 million tons, with an average meat production of 78.04 kilograms per pig. According to the Ministry of Agriculture and Rural Affairs, the average selling price of live pigs per kilogram in 2020 was 33.25 yuan. Therefore, the market price of live pigs per head in China in 2020 was 2,594.83 yuan. A subsidy of 800,000 yuan will be provided for those with a breeding scale of over 3,000 heads. A subsidy of 600,000 yuan will be provided for those with a breeding scale of 2,000 to 2,999 heads. A subsidy of 400,000 yuan will be provided for breeding scales ranging from 1,000 to 1,999 heads. The subsidy standard for pig production in 2020 is 200,000 yuan for those with a breeding scale of 500 to 999 heads. After taking the median of each group and calculating based on the market price of that year, the subsidy rate for pig production in 2020 is approximately 10%.

4.2.4 China's tariff rates on imported frozen pork from selected countries in 2019

Tariffs are a policy measure that can effectively protect domestic production and increase domestic tax revenue. Therefore, countries generally set import tariffs when conducting foreign trade. The formulation of tariffs is influenced by factors such as the international trade situation and bilateral agreements. Generally, they can be classified into categories such as ordinary tariffs, most-favored-nation tariffs, free trade agreement tariffs, preferential tariffs and punitive tariffs. The tariff rate on pork imports between countries that have signed free trade agreements is zero. For countries that have not signed free trade agreements, the most-favored-nation tariff is generally applied. A few countries use punitive tariffs. For instance, the tariff rate between the United States and China has been raised to 25% due to the Sino-US trade war. Table 6 shows the import tariff rates of frozen pork from selected countries to China in 2019. Except for the 11 selected countries, the tariff rates of other countries are different. For simplicity, the import tariff rates of frozen pork from other countries are the average of the import tariff rates from the 11 selected countries.

**Table 6:** Tariff Rates of Frozen Pork Imported from Selected Countries by China in 2019

| import \ export | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CN | 25.0% | 12.0% | 12.0% | 12.0% | 0.0% | 12.0% | 12.0% | 12.0% | 12.0% | 6.0% | 10.5% |

Data source: The author collated the data based on the foreign trade practice query data of the Ministry of Commerce of the People's Republic of China and other sources.

4.2.5 Carbon emissions from pig farming in the selected country in 2020

The intensification of global air pollution and the increasing greenhouse effect have made environmental protection a consensus among all countries and regions. Animal husbandry is a significant source of greenhouse gas emissions caused by global human activities. The main carbon emissions in animal husbandry come from greenhouse gases such as methane produced during the intestinal fermentation and manure treatment of farmed animals. According to data from the Food and Agriculture Organization of the United Nations, in 2021, global greenhouse gas emissions from the livestock industry were approximately 7.1 Gt of carbon dioxide equivalent, accounting for about 15% of the total greenhouse gas emissions from human activities. Among them, emissions from pork production accounted for about 10% of the total emissions from the livestock industry. Figure 6 shows the average carbon dioxide equivalent of intestinal fermentation methane emissions per ton of pork production in the pig farming stage in the selected countries and regions in 2020. As can be seen from Figure 6, Mexico has the highest carbon dioxide equivalent emissions from intestinal fermentation per unit of pork production. China,

Russia and Brazil also have relatively high emissions, while South Korea has the lowest.

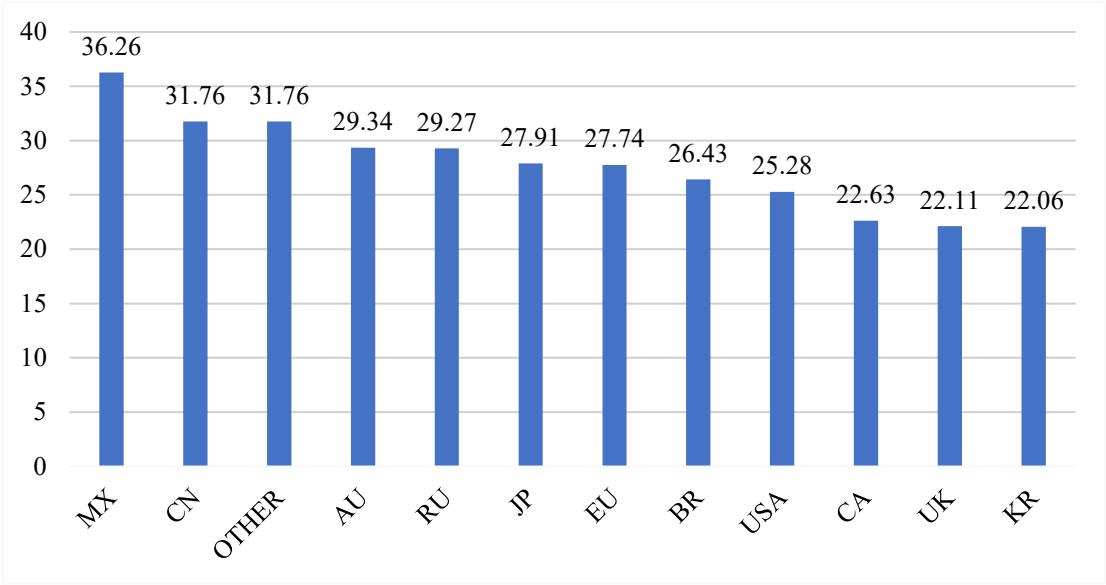


**Figure 6:** Carbon Dioxide Equivalent Emissions from Intestinal Methane Fermentation per Ton of Pork Production in the Pig Breeding Stage in Various Countries in 2020
Data source: The author collated the data from the Food and Agriculture Organization of the United Nations, the Agricultural and Horticultural Development Council of the United Kingdom, and the United States Department of Agriculture.

## 5. SIMULATION RESULTS AND INTERPRETATION

Based on the data of pork production, trade and consumption in China and globally in 2019, this paper uses the GSIM model with computable local equilibrium to simulate the economic and welfare effects of China's policies of increasing subsidies for pig production and reducing import tariffs on frozen pork on the pork industry. The simulation results of GSIM mainly include the following four aspects: (1) Changes in pork prices in various countries; (2) Changes in pork production in various countries; (3) Changes in the volume of pork trade among countries; (4) Changes in the welfare levels of pork producers, consumers, taxes and the overall social welfare in various countries. Based on the changes in pork production in various countries, the impact of increased subsidies for pig production and reduced import tariffs on frozen pork on greenhouse gas emissions was calculated according to the carbon dioxide equivalent emissions from intestinal fermentation per ton of pork production during the pig production process in each country. In terms of subsidies, according to the previous calculation, the subsidy rate for pig production provided by the Chinese government is approximately 10.02%. In terms of tariffs, the Tariff Commission of The State Council announced that as of January 1, 2020, China will temporarily reduce the import tariff on frozen pork from 12% to 8%. Under the assumption that other conditions remain unchanged, this paper uses the GSIM model to simulate the impact of subsidy and tariff policies on global pork production, prices, trade and social welfare. The model results are as follows.

### 5.1 The Price and Output Effects of the Adjustment of China's Pig Production Subsidy Policy and Frozen Pork Import Tariff Policy

According to the assumptions of the GSIM model and market theory, changes in subsidy policies and tariff policies will first affect the market price of products. As can be seen from the first column of Table 7, the implementation of China's pig production subsidy policy has led to an increase in domestic producer prices and a decrease in consumer prices. This directly reflects that the pig production subsidy policy can not only increase the profits of pig farmers or breeding enterprises, but also improve the welfare level of pork consumers. This improvement in the welfare of both parties may stem from the fact that the financial support provided by production subsidies has reduced the costs of pig farmers or breeding enterprises, improved breeding techniques and infrastructure construction of breeding farms, led to an increase in the number of live pigs sold and the supply of pork. Under the condition of relatively stable demand, the price of pork in the market has dropped, and the welfare of both producers and consumers has been improved. The increase in domestic pork supply brought about by domestic production subsidies has led to a reduction in China's pork imports. As the world's largest pork consumer, the

decrease in pork imports in China is bound to cause a decline in pork prices in the world market. This effect is consistent with the simulation results reflected in Table 7 that both producer prices and consumer prices of pork in other countries have declined under China's pig production subsidy policy. Consumer price changes

**Table 7:** Changes in national pork prices under the pig production subsidy policy (unit: %)

| COUNTRY / WELFARE | CN | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODUCER PRICE CHANGES | 6.67 | -0.43 | -0.60 | -0.53 | -0.08 | -0.38 | -0.58 | -0.60 | -0.30 | -0.38 | -0.31 | -0.35 |
| CONSUMER PRICE CHANGES | -3.04 | -0.43 | -0.60 | -0.53 | -0.08 | -0.38 | -0.58 | -0.60 | -0.30 | -0.38 | -0.31 | -0.35 |

Data source: Obtained through GSIM model simulation.

Under the condition of reducing the import tariff rate on frozen pork, the simulation results in Table 8 show that both domestic producer prices and consumer prices in China will slightly decrease, while producer prices abroad will slightly increase. The economic explanation for this simulation result might be that the reduction in the import tariff rate on frozen pork has led to a decrease in the price of imported frozen pork in the domestic market, giving it a price advantage over domestically produced pork. As a result, imported frozen pork has seized the domestic pork consumption market, leading to a decline in domestic pork prices. Domestic farmers have been affected to a certain extent, and consumer welfare has improved to a certain extent. In the international market, China has a huge demand for frozen pork imports. However, pig farming requires a long production cycle. Under the circumstances that the original number of pigs sent to market cannot change significantly in the short term, China's large demand will lead to an increase in the supply price of pork from foreign producers.

**Table 8:** Changes in Pork Prices in Relevant Countries Due to Reduction of Import Tariffs on Frozen Pork (Unit: %)

| COUNTRY / WELFARE | CN | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODUCER PRICE CHANGES | -0.45 | 0.20 | 0.69 | 0.50 | 0.08 | 0.25 | 0.67 | 0.69 | 0.22 | 0.34 | 0.29 | 0.28 |
| CONSUMER PRICE CHANGES | -0.45 | 0.20 | -2.91 | -3.09 | -3.50 | 0.25 | -2.93 | -2.90 | -3.36 | -3.24 | 0.29 | -2.43 |

Data source: Obtained through GSIM model simulation.

In terms of production changes, under the condition that import tariffs remain unchanged, the increase in domestic production subsidies in China has encouraged producers to invest in breeding by reducing costs and other means, leading to an increase in domestic pork production. The increase in domestic pork supply and the decline in prices will lead to a decrease in China's demand for imported pork from abroad. Moreover, as China is the world's largest consumer of pork, the shrinking of the Chinese export market will dampen the production enthusiasm of foreign productivity, thereby resulting in a reduction in foreign pork output. When the subsidy rate for pig production in China is 10% as shown in Figure 7, the simulation results of the GSIM model indicate that China's pork output will increase by 2.2%, while the pork output of other countries will all decrease.

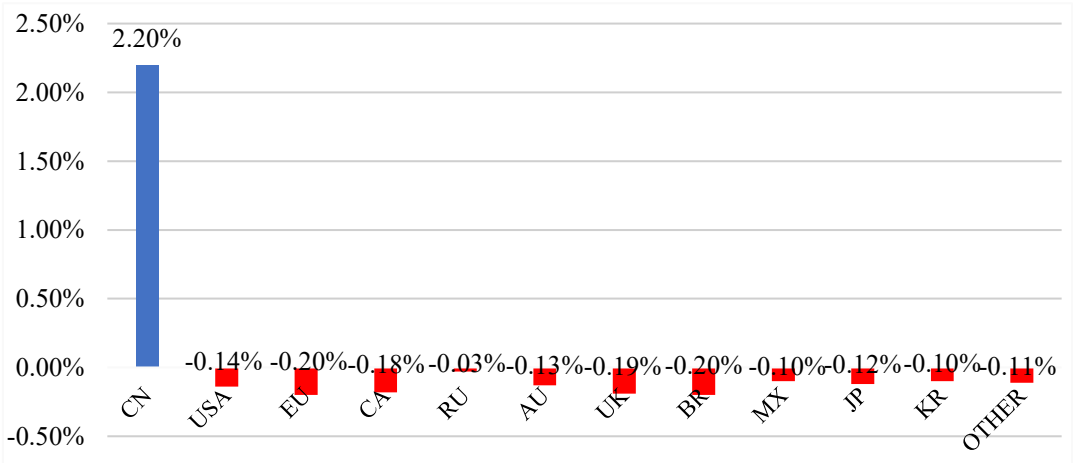


**Figure 7:** Changes in pork production in relevant countries under the increase of pig production subsidies in China

Data source: Obtained through GSIM model simulation.

In the absence of production subsidies and the unilateral reduction of the import tariff rate on frozen pork, the simulation results in Figure 8 show that domestic pork production in China will decrease by 0.15%, while pork production in other countries will all increase. This is because the reduction in the import tariff rate on frozen pork has led to an increase in imports. The domestic market has been encroached upon by imported pork. Domestic producers are mainly small-scale farmers and have relatively low levels of breeding technology. Compared with the low cost of large-scale breeding abroad, they do not have a competitive advantage. Therefore, domestic production has contracted and foreign production has increased.

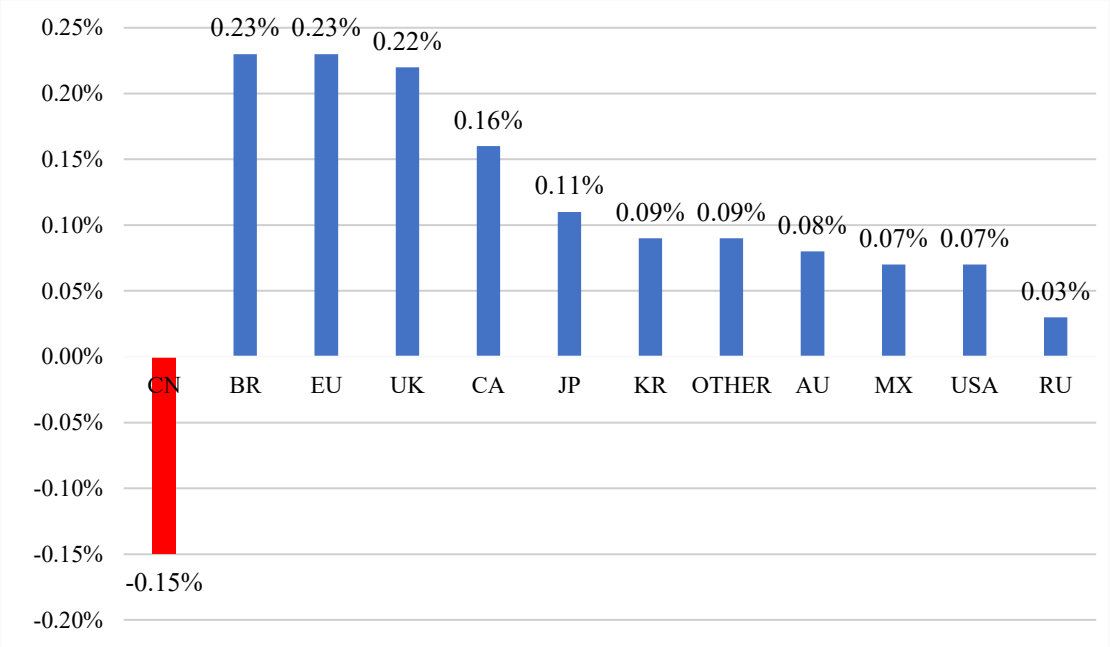


**Figure 8:** The magnitude of changes in pork production in relevant countries under the reduction of import tariffs on frozen pork from China

Data source: Obtained through GSIM model simulation.

### 5.2 The Trade Effects of China's Pig Production Subsidy Policy and the Adjustment of Import Tariffs on Frozen Pork

Changes in domestic pig production subsidy policies and import tariffs on frozen pork will have an impact on the volume of pork trade between China and other countries around the world through fluctuations in pork prices. Table 9 shows the changes in global pork import and export volumes and domestic sales in each country brought about by the above two policy changes. The following conclusions can be drawn from the GSIM simulation results:

Firstly, under the condition that the import tariff on frozen pork remains unchanged and the government provides subsidies for domestic pig production: (1) The domestic sales volume of pork in China will increase by 2.2% as shown in the first figure in Table 9. Based on the domestic sales volume in 2019, the increase in domestic sales volume brought about by production subsidies is 987.03 tons. (2) China's imports of frozen pork from most countries around the world will decrease significantly, while those from Russia, Japan and South Korea will remain unchanged, as shown in the first column of Table 9. (3) The imports of frozen pork from China by other countries such as the European Union and Japan will increase, with the increase rates being 10.9%, 11.3% and 11.8% respectively as shown in the first row of Table 9. The economic explanation for the above-mentioned changes in trade volume might be that the domestic pig production subsidy policy would reduce the production costs of domestic farmers, thereby leading to an increase in domestic pork output. When domestic consumers' demand for pork remains relatively stable, an increase in domestic pork supply can, on the one hand, fully meet domestic pork consumption demands, and on the other hand, lead to a decline in pork prices. As China is a major supplier and consumer of pork in the world, changes in the supply and demand of pork and market prices in China will affect the global pork market, leading to a reduction in China's pork imports from other countries and an increase in its exports.

**Table 9:** Changes in pork trade volume between relevant countries under the production subsidy policy (unit: %)

| export \ import | CN | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CN | 2.2 | 0.0 | 10.9 | 11.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.8 |
| USA | -9.3 | 0.0 | -0.6 | -0.3 | 0.0 | 0.2 | -0.5 | 0.0 | 0.6 | 0.1 | 0.4 | 0.3 |
| EU | -8.6 | 0.7 | 0.2 | 0.5 | 0.0 | 1.0 | 0.2 | 0.0 | 1.3 | 0.9 | 1.2 | 1.1 |
| CA | -8.9 | 0.4 | -0.1 | 0.2 | 0.0 | 0.7 | 0.0 | 0.0 | 1.0 | 0.6 | 0.9 | 0.8 |
| RU | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.2 |
| AU | -9.5 | 0.0 | -0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.2 | 0.1 |
| UK | -8.6 | 0.6 | 0.0 | 0.4 | 0.0 | 0.9 | 0.1 | 0.0 | 0.0 | 0.8 | 1.1 | 1.0 |
| BR | -8.5 | 0.7 | 0.2 | 0.0 | 2.3 | 0.0 | 0.0 | 0.3 | 0.0 | 0.9 | 1.2 | 1.1 |
| MX | -9.9 | -0.6 | -1.1 | -0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.5 | -0.1 | -0.2 |
| JP | 0.0 | 0.0 | -0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | 0.1 |
| KR | 0.0 | 0.0 | -1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 |
| OTHER | -9.7 | -0.4 | -0.9 | -0.6 | 1.2 | -0.1 | 0.0 | 0.0 | 0.0 | -0.3 | 0.1 | 0.0 |

Secondly, in the absence of domestic subsidies for pig production and with the government reducing the import tariff rate on frozen pork: (1) As shown in the first piece of data in Table 10, the domestic sales volume of pork in China will slightly decrease by 0.2%. (2) China's trade volume of frozen pork imports from the European Union, Canada, the United Kingdom, Brazil and Mexico will increase by more than 10%, but the trade volume of frozen pork imports from the United States and Australia will slightly decrease. (3) China's frozen pork exports to the United States, Russia, Australia, the United Kingdom, Brazil, Mexico, Japan and South Korea have not changed significantly, but its frozen pork exports to the European Union, Canada and other countries will increase slightly. The economic explanation for the above simulation results might be that the reduction in the tariff rate on imported frozen pork in China has led to a decrease in the selling price of imported frozen pork in the domestic market, thereby squeezing the domestic market for self-produced pork and causing a slight decrease in domestic sales volume. The low price of imported frozen pork has driven up consumer demand for it. Meanwhile, foreign frozen pork suppliers, seeing the favorable tariff conditions in China, have further increased their supply of frozen pork to the Chinese market. In 2019, due to the impact of African swine fever, domestic pork supply was hit hard and the market price of pork once soared. Under these conditions, the state announced on January 1, 2020, that it would temporarily lower the import tariff rate on frozen pork. This has largely alleviated the supply and demand contradiction in the domestic pork market and is of great significance for keeping pork prices within a stable range.

**Table 10:** Changes in pork trade volume between relevant countries under reduced import tariffs on frozen pork (unit: %)

| export \ import | CN | USA | EU | CA | RU | AU | UK | BR | MX | JP | KR | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CN | -0.2 | 0.0 | 4.8 | 3.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 |
| USA | -3.0 | 0.1 | 1.9 | 1.0 | 0.0 | 0.4 | 1.9 | 0.0 | 0.0 | 0.7 | 0.5 | 0.3 |
| EU | 10.7 | -2.1 | -0.2 | -1.2 | 0.0 | -1.8 | -0.3 | 0.0 | -2.1 | -1.4 | -1.7 | -1.8 |
| CA | 11.5 | -1.2 | 0.6 | -0.3 | 0.0 | -0.9 | 0.0 | 0.0 | -1.3 | -0.6 | -0.8 | -0.9 |
| RU | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| AU | -3.3 | 0.0 | 1.7 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.5 | 0.2 | 0.1 |
| UK | 10.7 | -2.0 | 0.0 | -1.1 | 0.0 | -1.7 | -0.2 | 0.0 | 0.0 | -1.3 | -1.6 | -1.7 |
| BR | 10.6 | -2.1 | -0.2 | 0.0 | -2.7 | 0.0 | 0.0 | -0.4 | 0.0 | -1.4 | -1.7 | -1.8 |
| MX | 12.6 | 0.0 | 1.8 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0.6 | 0.4 | 0.3 |
| JP | 0.0 | 0.0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | -0.3 |
| KR | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| OTHER | 8.6 | -0.3 | 1.6 | 0.6 | -0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 |

Finally, the simulation results of the GSIM model show that China's pig production subsidy policy and the reduction of import tariffs on frozen pork have certain impacts on the volume of pork trade among other countries and regions in the world except China, but the overall degree of impact is relatively small. The reason might be that China is the world's largest producer and consumer of pork. Therefore, China's policy adjustments for the pork industry have a greater impact on countries that have more pork trade exchanges with China, and a smaller impact on pork trade exchanges with other countries and regions that have no pork trade exchanges with China. These minor influences generally take effect through the world market pork prices determined by China's pork

supply and demand in the world market.

### 5.3 The Welfare Effects of China's Pig Production Subsidy Policy and the Adjustment of Import Tariffs on Frozen Pork

The GSIM model can also measure the impact of industrial policy changes on producers, consumers and social welfare levels at the industry level from a global perspective. As can be seen from Table 11, there are significant differences in the impact of changes in China's pig production subsidy policy and the import tariff policy on frozen pork on welfare at the industry level between China and other countries and regions around the world.

Firstly, under the condition that the import tariffs on frozen pork remain unchanged and the government provides subsidies for domestic pig production: (1) China's producer surplus will increase significantly, while that of other countries and regions around the world will decline slightly. As can be seen from the data in the second column of Table 11, China's producer surplus will increase by approximately 6.85 billion US dollars each year, while that of other countries and regions around the world will decrease by approximately 10 million to 300 million US dollars each year. (2) China's consumer surplus will also increase significantly, but the extent of its increase will not be as large as that of producer surplus. Its added value is approximately 3.14 billion US dollars per year. As shown in the fourth column of Table 11, consumer surplus in other countries and regions around the world will also increase slightly, with the increase generally less than 100 million US dollars per year. Only the consumer surplus in the European Union will increase by approximately 260 million US dollars annually. (3) China's tax revenue will decrease by approximately 60 million US dollars each year, while the tax revenue of other countries and regions will not increase or decrease due to changes in China's industrial policies. (4) The net welfare level of Chinese society will increase significantly, with an increase of up to 9.93 billion US dollars. The changing directions of social net welfare levels in other countries and regions vary. Among them, the social net welfare in the United States, the European Union, Canada and Brazil will decrease. The net social welfare levels in countries such as the United Kingdom, Japan and South Korea will increase, but generally speaking, the increase or decrease is relatively small and the changes are not very significant. The economic explanation for the above changes might be that the subsidy for pig production in our country is a welfare policy solely aimed at domestic pig producers, so domestic producers naturally become the biggest beneficiaries of this policy. When subsidy policies act on market prices through supply, consumers can also obtain benefits from them, but the level of their benefits is far lower than that of producers. The result of production subsidies is that the government has achieved stable growth in the pig breeding industry and a significant increase in the net welfare level of society through relatively small expenditures. In addition, as production subsidy policies are more covert than export subsidy policies and tariff policies and distort prices to a lesser extent, they are less likely to be retaliated against by trading partners. Therefore, production subsidy policies are regarded as an effective policy tool.

**Table 11:** Welfare effects of China's production subsidies and import tariff reduction policies (Unit: billions of US dollars)

| Welfare | Producer surplus change (A) | | Consumer surplus change (B) | | Tax revenue change (C) | | Net welfare level change (D=A+B+C) | |
|---|---|---|---|---|---|---|---|---|
| policy | Increase subsidies | Reduce tariffs | Increase subsidies | Reduce tariffs | Increase subsidies | Reduce tariffs | Increase subsidies | Reduce tariffs |
| | 68.5 | -4.6 | 31.4 | 6.0 | -0.6 | -1.0 | 99.3 | 0.4 |
| | -1.2 | 0.6 | 1.0 | -0.5 | 0.0 | 0.0 | -0.2 | 0.1 |
| | -3.0 | 3.5 | 2.6 | -2.9 | 0.0 | 0.0 | -0.4 | 0.6 |
| | -0.3 | 0.2 | 0.1 | -0.1 | 0.0 | 0.0 | -0.2 | 0.1 |
| | -0.1 | 0.1 | 0.1 | -0.1 | 0.0 | 0.0 | 0 | 0 |
| | -0.1 | 0.0 | 0.1 | -0.1 | 0.0 | 0.0 | 0 | -0.1 |
| | -0.2 | 0.2 | 0.3 | -0.3 | 0.0 | 0.0 | 0.1 | -0.1 |
| | -0.5 | 0.6 | 0.4 | -0.5 | 0.0 | 0.0 | -0.1 | 0.1 |
| | -0.2 | 0.1 | 0.2 | -0.1 | 0.0 | 0.0 | 0 | 0 |
| | -0.2 | 0.2 | 0.5 | -0.4 | 0.0 | 0.0 | 0.3 | -0.2 |
| | -0.1 | 0.1 | 0.2 | -0.2 | 0.0 | 0.0 | 0.1 | -0.1 |
| | -0.8 | 0.6 | 1.0 | -0.8 | 0.0 | 0.0 | 0.2 | -0.2 |

Secondly, in the absence of domestic subsidies for pig production and with the government reducing the import tariff rate on frozen pork: (1) China's producer surplus will decrease, while the producer surplus in the vast majority of other countries and regions around the world will increase. As shown in the third column of Table 11, the reduction in China's producer surplus is approximately 460 million US dollars per year. Among other countries and regions, the European Union has the largest increase in producer surplus, approximately 350 million US dollars per year. (2) China's consumer surplus will increase, with an annual increase of approximately 600 million US dollars. In other countries and regions, consumer surplus will decrease, ranging from 10 million to 290 million US dollars. The European Union will also experience the largest reduction in consumer surplus. (3) China's tax revenue will decrease by approximately 100 million US dollars each year, while the tax revenue of other countries and regions will not increase or decrease due to changes in China's industrial policies. (4) China's net social welfare level will increase slightly, but its added value of 40 million US dollars is less than that of the EU's 60 million US dollars. That is to say, the adjustment of China's import tariff policy on frozen pork will bring the greatest benefit to the EU in terms of the total social welfare level, followed by China. The economic explanation for the above changes might be that the reduction of import tariffs on frozen pork in China has provided favorable conditions for foreign frozen pork to enter the Chinese market. As the largest trading region for China's frozen pork imports, the European Union will enjoy the benefit of the tariff reduction to the greatest extent, thereby leading to an increase in its own producer surplus and net welfare level. The increase in the import of frozen pork from abroad will lead to a decline in domestic self-sale volume, thereby resulting in a reduction in domestic producer surplus. Domestic consumers will benefit from the price drop brought about by the increase in pork market supply, which will increase consumer surplus to a certain extent. However, since domestic consumer surplus is higher than the sum of producer losses and tax losses, the overall social welfare level will still increase, but the increase will be very limited.

Finally, the simulation results of the GSIM model show that China's pig production subsidy policy and the reduction of import tariffs on frozen pork have certain impacts on the welfare levels among other countries and regions in the world except China and the European Union, but the overall degree of impact is relatively small. The main reasons are similar to those for the impact of industrial policies on the aforementioned trade volume and will not be elaborated here. Furthermore, the welfare impact of the import tariff policy on frozen pork on China is less than that brought by production subsidies. One possible reason for this is that the reduction in tariff rates is less than the increase in production subsidies. On the other hand, it might be that production subsidies are more targeted at domestic industries in our country, while tariffs are policies aimed at imported products from abroad.

### 5.4 Environmental Effects of China's Pig Production Subsidy Policy and the Import Tariff Policy on Frozen Pork

Pig farming generates greenhouse gas emissions, so adjustments in industrial policies will affect the atmospheric environment through changes in output. This paper first simulates and calculates the impact of China's pig production subsidy policy and frozen pork import tariff policy on China's pork output through the GSIM model, and then calculates the environmental effects of industrial policy adjustments by combining the carbon dioxide equivalent emitted from intestinal fermentation per ton of pork output during the pig breeding stage.

Firstly, under the condition that the import tariff on frozen pork remains unchanged, the environmental effects of the government's subsidies for domestic pig production are shown in Figure 9: (1) China's carbon dioxide equivalent emissions will increase significantly. As can be seen from Figure 9, a 10% production subsidy rate will increase the carbon dioxide equivalent emissions of China's pork production industry by 69.87%. (2) In other countries and regions around the world, the carbon dioxide equivalent emissions from intestinal fermentation during the pig production stage will all decrease, but the absolute amount of reduction is very limited. (3) From a global perspective, China's subsidies for pig production will lead to an increase in total greenhouse gas emissions, resulting in negative environmental effects. The economic explanation for this environmental effect is consistent with the output effect of the aforementioned industrial policy, and thus will not be elaborated here.

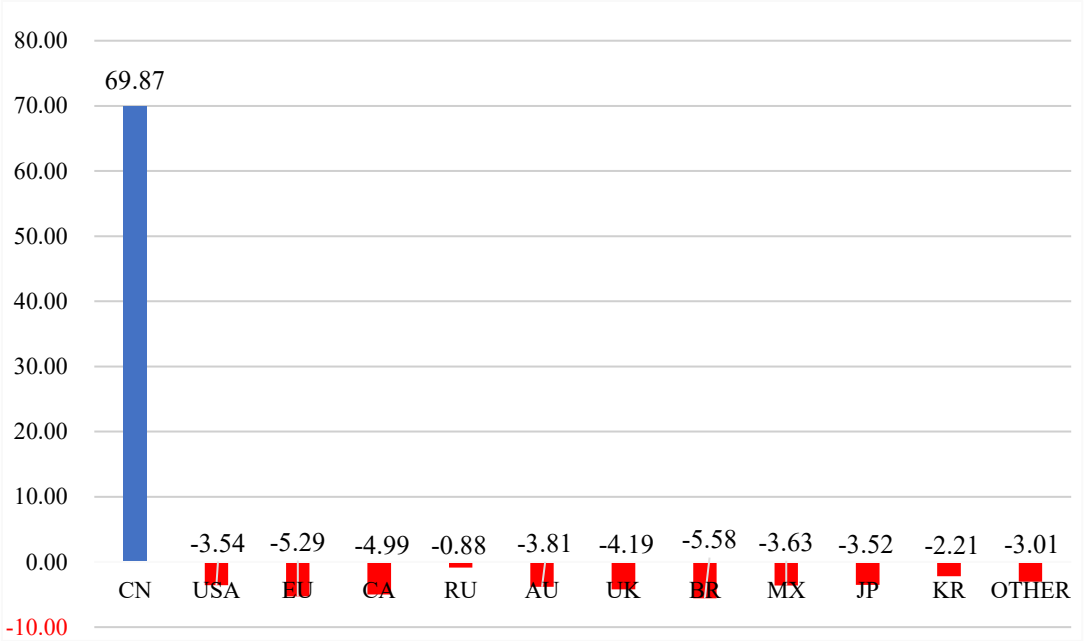


**Figure 9:** Environmental impact of China's production subsidy policy from a global perspective (unit: carbon dioxide equivalent)

Secondly, in the absence of domestic subsidies for pig production, the environmental effects of the government's reduction of the import tariff rate on frozen pork are shown in Figure 10: (1) The carbon dioxide equivalent emissions from intestinal fermentation during the pork production stage in China will decrease by 4.73. (2) The carbon dioxide equivalent emissions from intestinal fermentation during the pork production stage in other countries and regions around the world will all increase. Among them, the European Union and Brazil will have the largest increase in emissions, followed by Canada and the United Kingdom. The increase in emissions in other countries will be relatively small. (3) From a global perspective, the reduction of the import tariff rate on frozen pork in China will lead to an increase in total greenhouse gas emissions, resulting in negative environmental effects. Its economic explanation will not be elaborated here either.

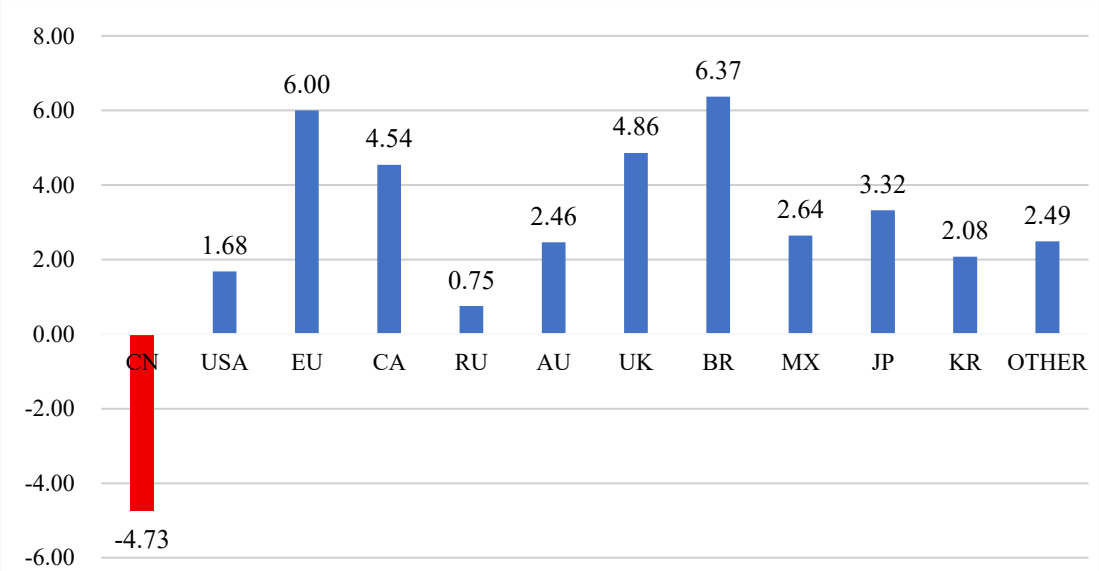


**Figure 10:** Changes in carbon dioxide equivalent emissions from intestinal fermentation during pork production stages in various countries under the reduction of China's frozen pork tariff rate

Data source: obtained through simulation using the GSIM model

Finally, a comprehensive comparison of the environmental effects of the policy of increasing subsidies for pig production and reducing the import tariff rate on frozen pork reveals that all the above industrial policies will have negative environmental effects. However, the tariff policy brings about less greenhouse gas emissions than the

subsidy policy.

## 6. CONCLUSIONS AND SUGGESTIONS

Due to the long production cycle of live pigs, the cyclical fluctuations in pig breeding have led to long-term fluctuations in the price of live pigs during the process of pork production and sales. In China, pig farming is mainly carried out by individual farmers in a scattered manner. The technology and funds that can be invested in the breeding process are limited. Compared with foreign countries, the production cost is relatively high and lacks international competitiveness. Moreover, the industry concentration is low, and the influence of individual farmers on market prices is weak, which leads to weak risk resistance of farmers. When there is an epidemic and environmental policy intervention, the price of pork will show a relatively distinct cobweb cycle pattern. Frequent fluctuations and sharp ups and downs in pork prices can bring many uncertainties to the production plan formulation of pork producers, affecting their production enthusiasm and the stable development of the industry. It will also affect the daily demands and welfare levels of pork consumers. Especially the outbreak of African swine fever in 2019 triggered the largest price fluctuation in the pig cycle since the 21st century. The price of pork once rose to over 50 yuan per kilogram, leaving the common people sighing at the meat. In view of the above reasons, in order to stabilize the supply of pork and ensure the daily consumption demands of residents, the state has adjusted the supply of the pork market from two aspects. On the one hand, continue to provide financial subsidies for pig production, hoping to enhance the production enthusiasm of farmers by reducing their production costs and stabilize the supply of the pork market. On the other hand, the import tariff rate on frozen pork is temporarily reduced, hoping to use the pork production from abroad to ease the supply and demand contradiction in the domestic pork market.

However, against the backdrop of economic globalization, the economic and welfare effects of China's pig production subsidy policy and the policy of reducing import tariffs on frozen pork are not clear. The implementation of the production subsidy policy, on the one hand, will reduce the production costs of domestic farmers, which may lead to an increase in domestic pork output and a decrease in market prices. On the other hand, the continuously increasing financial subsidies may increase the financial burden. Moreover, in a situation where small-scale farmers account for the vast majority and the production technology level is generally low, it may lead to situations where more subsidies result in more production, less subsidies result in less production, and no subsidies result in no production. This is not conducive to the long-term high-quality development of the pig breeding industry. The implementation of the policy of reducing import tariffs on frozen pork will, on the one hand, lower the tax burden of foreign frozen pork entering the Chinese market, increase its supply in the Chinese market, thereby lowering the market price of pork and alleviating the contradiction between supply and demand. On the other hand, foreign pork has an advantage in production costs over domestically produced pork. The reduction in tariff rates has led to an increase in the import of frozen pork, thereby intensifying competition in the domestic pork market and possibly dampening the production enthusiasm of domestic farmers. Therefore, this paper utilizes relatively detailed industry data based on the rapidly developing computable local equilibrium GSIM model in recent years, The aim is to explore the impact of the two major policy adjustments, namely the subsidy policy for pig production in China and the reduction of the import tariff rate on frozen pork, from the industry level on pork production, market prices, trade flows, as well as the overall welfare levels of producers, consumers and society between China and other countries and regions around the world. Based on the above simulation results and the carbon dioxide equivalent emissions during the pig production stage, the impacts of the two major policies on the global atmospheric environment were calculated. According to the research and simulation in this article:

First, subsidies for pig production will reduce the cost of pork production, leading to a significant increase in domestic pork output. Producer prices will rise compared to before the policy was implemented, while consumer prices will fall, promoting an increase in domestic pork sales. The simulation results show that the production subsidy policy will increase the annual average output of domestic pork by 2.2%, raise domestic producer prices by 6.67%, lower consumer prices by 3.04%, and increase domestic sales by 2.2%. The reduction of the import tariff rate on frozen pork has alleviated the tax burden on foreign pork entering the Chinese market, resulting in a slight decrease in domestic pork production, a slight increase in foreign pork production and a slight drop in domestic pork prices, which has led to a reduction in the domestic sales volume of domestic pork. The simulation results show that a reduction in the import tariff rate of frozen pork will lead to a 0.15% decrease in domestic pork production, a 0.45% drop in domestic pork prices, and a 0.2% decrease in domestic sales volume.

Second, subsidies for pig production will reduce the import volume of frozen pork in China. Simulation data indicates that China's imports of frozen pork from the United States, Australia and Mexico will all decrease by

more than 9%, and the imports from the European Union, Canada, the United Kingdom and Brazil will all drop by more than 8.5%. The reduction of the import tariff rate on frozen pork will increase China's imports of frozen pork. China's imports of frozen pork from the European Union, Canada, the United Kingdom, Brazil and Mexico have all grown by more than 10%.

Thirdly, in terms of welfare levels, Chinese pork producers and consumers are the biggest beneficiaries of the pig production subsidy policy, and the overall social welfare level in China will also increase due to production subsidies. In the context of the reduction in the import tariff rate on frozen pork, the consumers who benefit the most come from China, while the producers and the increase in total social welfare that benefit the most both occur in the European Union. The welfare effect of production subsidies is higher than that of reduced import tariffs.

Fourth, in terms of the level of environmental effects, both production subsidies and the reduction of import tariff rates will lead to an increase in greenhouse gas emissions, generating negative environmental effects. However, the negative impact of production subsidies on the atmospheric environment is more significant compared to the reduction of tariffs.

In conclusion, the research conclusions of this paper can lead to the following referential suggestions:

Firstly, based on the research results of this paper, subsidies for pig production will significantly increase China's pork output, lower the consumption price of pork, and promote the production and consumption of domestic pork. Reducing the import tariffs on frozen pork will decrease China's pork production and slightly lower domestic pork consumption prices. Compared with domestic pork production, foreign pork production has lower production costs due to its high level of scale and technology. Therefore, the profit margin of domestic pork production is relatively low. The profit margin gap between domestic and imported pork, the inherent pig cycle phenomenon in the pig production industry, and the strong impact of African swine fever on production have severely dampened the production enthusiasm of pig farmers, leading to a situation where the supply of domestic pork once dropped to a level that could not meet the daily pork consumption demands of residents. Therefore, the policies of subsidies for pig production and reduction of import tariffs on frozen pork are of great significance for easing the supply and demand contradiction in the domestic pork market, stabilizing pork market prices and ensuring the living standards of residents. However, when the stabilization of the pig cycle is taken into account, the use of subsidy policies needs to be carefully considered. Specifically, if the government provides subsidies to pig farmers during the period of shortage in the pork market and high market prices, it is hoped that this will stimulate the production enthusiasm of farmers and thereby expand the production scale. However, due to the particularity of the pig breeding industry, the expansion of production scale brought about by the increase in subsidies in the current period cannot promptly lead to an increase in output. Therefore, the contradiction between supply and demand in the current period cannot be effectively alleviated, and the market price of pork will still remain at a high level. The current high prices and subsidies stimulate large-scale production by farmers, which will cause a significant increase in pork supply after one production cycle, leading to an oversupply of pork and a sharp drop in prices. As a result, the pork production subsidy policy not only failed to stabilize the pig cycle but also exacerbated it on the original basis, leading to even more intense fluctuations in pork supply and prices. However, the reduction of the tariff rate on imported pork is more flexible than the adjustment of subsidy policies. When domestic pork supply is tight, tariffs are lowered to increase imports and lower market prices. When domestic pork supply recovers, the policy of reducing tariffs is cancelled to stabilize market prices. Therefore, for stabilizing the pig cycle, the effect of tariff policies is superior to that of subsidy policies. When the government is stabilizing the market price of pork and mitigating the negative impact of the pig cycle, it can be more inclined to adjust import tariffs. The use of subsidy policies should be carefully considered and appropriately adopted. In the "Notice of the Tariff Commission of The State Council on the Adjustment Plan for Provisional Tariff Rates and Others in 2020" released in December 2019, the import tariff rate for frozen pork was reduced from the previous 12% to 8%. However, when domestic pig production gradually resumed, this provisional tariff rate was restored to the legal rate. According to the Import and Export Tariff of the People's Republic of China (2023), the current import tariff rate for frozen pork has been restored to a collection level of 12%, indicating that the policy orientation of the state is highly consistent with the suggestions of this article.

Secondly, according to the simulation results of this paper, compared with the production subsidy policy, the policy of reducing import tariffs emits less greenhouse gases. Against the backdrop of increasingly severe global environmental and climate change and the successive proposal and implementation of carbon tariff policies by the European Union and other Western developed countries, in order to achieve the goal of "actively and steadily promoting carbon peaking and carbon neutrality" proposed in the report of the 20th National Congress of the

Communist Party of China, China must manage the emissions from livestock production more reasonably. Therefore, priority can be given to using tariff policies to stabilize the pig cycle. If subsidy policies are still needed after comprehensive consideration, the subsidy amount for harmless treatment of livestock manure can be increased in the production subsidy, promoting the green and high-quality development of the breeding industry through a dual approach of financial subsidies and technical subsidies. The research results of this paper will, to a certain extent, help reduce the concerns of policymakers and provide a theoretical basis for the optimization of the government's policy choices to stabilize the pig cycle.

Finally, it should be pointed out that although the computable local equilibrium GSIM model has outstanding advantages in examining the welfare impact of industrial policies at the industry level, there are also some deficiencies that need to be optimized and improved: Firstly, this model is a comparative static analysis suitable for analyzing short-term impacts. For policymakers, it seems to have greater reference value on how to measure the long-term effects of economic policies. Secondly, compared with the computable general equilibrium model, the advantage of the GSIM model lies in its greater operability. Therefore, it is inevitable that the welfare impact of economic policies on the entire industrial chain and other related competitive industries will be overlooked. Therefore, there is still room for development and improvement in this research.

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