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Research on the Impact of COVID-19 on Import and Export Strategies

Wenguang Tang[1], Jian Hu[1], Geovanny Genaro Reivan Ortiz[2], Fatma Mabrouk[3] and Jinghuan Li[1]*

[1]College of Science, Tianjin University of Commerce, Tianjin, China, [2]Laboratory of Basic Psychology, Behavioral Analysis and Programmatic Development PAD-LAB, Catholic University of Cuenca, Cuenca, Ecuador, [3]Department of Economics, College of Business Administration, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia

Due to the spread of COVID-19, the public health crisis is bound to have a huge impact on the world economy and international trade. How to study the import and export strategies under the coronavirus pandemic has become a major issue that many scholars need to solve urgently. Therefore, a two-stage game model is constructed, and the reverse solution method is used to obtain the optimal output of enterprises in importing countries and exporting countries before and after the outbreak of pandemic, as well as the optimal subsidies for enterprises from exporting countries and the optimal import quarantine rate for importing countries. Based on the game between the two countries without the pandemic outbreak, the impact of the pandemic on the output, profits, and social welfare of enterprises in the two countries was compared. Enterprises in exporting countries face double threats from the pandemic and import quarantine fees. The increase in import quarantine fees reduces the social welfare of exporting countries. In order to effectively control the spread of the pandemic, subsidies are an effective means to restore exports to normal. Reasonable collection of import quarantine fees by importing countries can promote bilateral trade, but an excessive collection will be counterproductive. The governments of exporting countries should establish emergency mechanisms and relevant subsidy policies, and enterprises should continuously improve their competitiveness. At the same time, countries should abandon the concept of trade protection and negotiate and cooperate to jointly deal with the pandemic.

Keywords: COVID-19, stackelberg game, import and export, import quarantine fee, strategies

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****Correspondence:***
Wenguang Tang
lxytwg@tjcu.edu.cn

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INTRODUCTION

With the ongoing global pandemic of COVID-19, the unprecedented public health crisis is bound to have a huge negative impact on the world economy, environment and international economic and trade cooperation (Razzaq et al., 2020; Khan et al., 2021; Yu et al., 2021; Irfan et al., 2022). The forecast report released by the World Trade Organization in 2020 pointed out that the pandemic will significantly shrink global trade. After the pandemic outbreak, the scale of global import and export trade showed a sharp decline amid fluctuations. In the first half of 2020, the year-on-year decline in global import and export trade scale reached 11.98% and 13.48%, respectively. The above-mentioned restrictive measures will lead to an obvious trade-inhibitory effect, the direct consequence of which is to weaken the degree of trade liberalization between countries, leading to high market access barriers, sharp rise in trade costs, and may even induce trade protectionism (Shahzad et al., 2021). Therefore, under the impact of the Coronavirus pandemic, how to alleviate the adverse impact of the pandemic

to promote international trade to enter the fast lane of recovery has become a major issue that the international community urgently needs to deal with.

Due to the rapid spread of COVID-19 worldwide, countries worldwide have to take trade protection measures (Xuefeng et al., 2021), the international free trade system is increasingly fragile, and new trade barriers are gradually formed. Taking China as an example, in foreign trade, statistics from the General Administration of Customs show that most enterprises with actual import and export results in 2019 are private enterprises, with the number reaching 406,000. In addition, among the export-oriented enterprises in China, small, medium and micro enterprises contribute about 60% of the total national import and export (Zhang, 2020). The addition of such an entry quarantine fee by foreign governments is a severe blow to many export-oriented enterprises facing difficulties in China at the moment. Therefore, export-oriented enterprises must not expand their production blindly because of a series of favorable policies introduced by the state. Each enterprise should reasonably adjust its output and set the optimal production decision according to the international market situation.

The COVID-19 is characterized by high risk, suddenness, and rapid spread and is a typical global public health emergency. It is well known that sudden major public health events usually affect the normal operation of political, economic, and social activities, some scholars conduct research on sudden public health events in the context of social emergency management (Sun et al., 2014; Liang et al., 2019; Xi and Zang, 2020). Numerous scholars have argued that this COVID-19 has created potential trade barriers and negatively impacted exports. (Duan et al., 2020). noted that more than 18 million SMEs in China were severely affected by the pandemic, most of which have export-led businesses. (Baldwin and Di Mauro, 2020). argued that this COVID-19 pandemic will have a more severe impact on the economy and environment than any other pandemic since World War II, with border closures and factory shutdowns, which will cause a significant drop in exports of the corresponding industries in the countries where the pandemic occurred. Meanwhile, some scholars have proposed policy recommendations for the government to respond to major public health events such as the pandemic from the perspective of maintaining foreign trade. For example Wang and Zhang (2020), point out that the pandemic may cause significant losses to export country's economies and trade, and is a major test of national governance system and governance capacity. According to (Shen, 2020), countries need to "stabilize foreign trade" and support import and employment growth by stabilizing the export market, and the government should help enterprises to resume work and production in an orderly manner and introduce policies such as tax reduction and fee reduction. However, these studies usually focus on studying the situation in a single country and fail to consider the interactions between the two countries in terms of import and export.

The related research on the analysis of oligopoly competition strategy is one of the commonly used methods to construct an application scenario model based on game theory, analyze the influence of different strategic behaviors and the changing trend of important variables by means of numerical simulation. Based on the US Rice Export Program to Japan and South Korea (Lee and Kennedy, 2006), attempted to analyze both import markets incorporating econometric estimates and public choice theory in a game-theoretic framework. Du and Wang (2018) proposed a multi-level threshold public goods game model to research how income redistribution affects the evolution of global cooperation. The effect of different thresholds on the strategy was investigated by numerical simulation. Andoni et al. (2021) modeled the problem of deducing how much capacity each player should build as a non-cooperative Stackelberg-Cournot game. Using data-driven analysis to analyze investor decision-making. Based on the game theory (Yang et al., 2021), analyzed the behavior of countries when carrying out regional cooperation to govern the epidemic and put forward specific cooperative income distribution schemes according to the different attributes of the countries. Using numerical simulations, they analyze the effect of the variation of different parameters on the utility of the two countries in different cooperation situations.

Scholars have also conducted many studies on the use of game theory to study bilateral trade. Ferreira and Ferreira (2009) considered an international trade under the Bertrand model with differentiated products and unknown production costs. The impact of tariff changes on corporate profits is analyzed. Yang and Wei (2013) constructed a three-stage game model for the continuation of the United States carbon tariff policy based on a two-stage game model in which the United States implemented a carbon tax policy only on its domestic enterprises and introduced a carbon tariff on imports from China. The impact of carbon tariffs on trade between China and the United States is analyzed. Xie et al. (2016) construct a theoretical game model in which a domestic firm exports to a third country through an intermediary in the third country and competes with a firm located in another country that exports directly to the third country. It is analyzed whether the bargaining power affects the choice of a country's strategic trade policy when a country firm chooses a third-country intermediary to export its products. Xie et al. (2018) constructed a model of duopoly international market competition in which producers compete on price against the background of product quality differences and with the actual situation of Chinese exporters. And on this basis, using game theory, a country's optimal strategic trade policy is explored in terms of trade benefits and social welfare. Mizuno and Takauchi (2020) considered a third-market model with a vertical trading structure. The change in optimal export policy as product-substitutability increases is examined, along with a discussion of welfare comparisons between the downstream Gounod and Bertrand cases.

In order to study the impact of the pandemic on import and export strategies and the changes in the profits and social welfare of companies in various countries under the pandemic, we used game theory to model the import and export strategies under the impact of the pandemic. Compared with the existing literature, the contributions of this paper are mainly reflected in the following aspects: under the pandemic, we examined the impact of the collection of import quarantine fees on the

TABLE 1 | Model notations and variables.

Variables	Descriptions
Q_E	The output of enterprises in the exporting E country (decision variable)
Q_I	The output of enterprises in the importing I country (decision variable)
s	Subsidy given by exporting country per unit of product (decision variable)
a	Potential price of the product
b	The sensitivity of price to output
c_E	The marginal cost of production for the exporting country
c_I	The marginal cost of production for the importing country ($c_I > c_E > 0$)
τ	Import quarantine fee per unit of product
s	Export enterprises relevant subsidy

production strategies of importing and exporting countries; under the pandemic, we have given the optimal subsidy strategy of exporting countries based on their own social welfare; under the pandemic, we compared the changes in the enterprises' profits and social welfare of the respective governments after the game between importing and exporting countries, and analyzed the measures that importers and exporters should take to deal with the impact of the pandemic jointly.

THEORETICAL MODEL

Problem Description and Assumptions

Consider two countries: an exporter (E country) and an importer (I country). Similar to the setting in Xie et al. (2018), Tang et al. (2020), Mizuno and Takauchi (2020), Tang et al. (2020), we assume that each of them has only one enterprise (enterprise E and enterprise I, respectively) that produces a homogeneous product. The products produced by the exporting enterprise E are all exported to the importing I country, and the products of the importing enterprise I can only be sold in its own market, i.e., the importing country is the only consumer of the product. There are two sources of supply in the production market: in addition to the domestic enterprises, they can also import from the exporting E country. We further make the following assumptions. The marginal cost of production, transportation, and tariffs for the exporting country is c_E, and the marginal cost of production for the importing country is c_I. Since enterprises in the exporting country have relatively low costs, this paper assumes that $0 < c_E < c_I$. Since consumers in the importing I country consume only one homogeneous product, the demand function for the product is:

$$P = a - b(Q_E + Q_I),$$

where $a > 0$ is the potential price of the product, $b > 0$ is the sensitivity of price to output, Q_E and Q_I represent the output of enterprises in the exporting E country and importing I country, respectively.

When a pandemic occurs in the exporting country, the government of the importing country, to protect its national health and the share of its own enterprises in the market, will enhance the exporting country enterprises to impose a unit of production import quarantine fee $\tau > 0$. At this point, the government of the exporting country, in order to maintain the normal operation of export enterprises, will choose to encourage exports in the short term by giving export enterprises relevant subsidy $s > 0$. These assumptions are mostly common practices, thus can be made without the loss of generality of this study. The notations and variables used in our analysis are shown in **Table 1**.

Game Model of Two Enterprises in the Absence of a Pandemic

When there is no pandemic, the enterprises of the two countries compete in Cournot game in the consuming country I (importing country). Enterprises' profits $\pi_E(Q_E, Q_I)$ and $\pi_I(Q_E, Q_I)$ are given by (see Fernanda A.)

$$\begin{cases} \pi_E(Q_E, Q_I) = (P - c_E)Q_E \\ \pi_I(Q_E, Q_I) = (P - c_I)Q_I \end{cases}.$$

The enterprises of each country determine the optimal output by maximizing their profits, and the maximization problem can be expressed as:

$$\begin{cases} \max_{Q_E,Q_I} \pi_E(Q_E, Q_I) = (P - c_E)Q_E \\ \max_{Q_E,Q_I} \pi_I(Q_E, Q_I) = (P - c_I)Q_I \end{cases} \quad (1)$$
$$s.t. \begin{cases} Q_E \geq 0 \\ Q_I \geq 0 \end{cases}$$

From the first-order condition of the optimization problem (**Eq. 1**) equation, we know that when $a > 2c_I - c_E$, the optimal output of the enterprises in the two countries are:

$$Q_E^* = \frac{a - 2c_E + c_I}{3b}, \; Q_I^* = \frac{a + 2c_E - 2c_I}{3b},$$

This leads to the optimal price of the product and the optimal profit of the two enterprises, respectively:

$$\begin{cases} P^* = \dfrac{a + c_E + c_I}{3} \\ \pi_E^* = \dfrac{(a - 2c_E + c_I)^2}{9b} \\ \pi_I^* = \dfrac{(a + c_E - 2c_I)^2}{9b} \end{cases}$$

Property 1. In the absence of a pandemic, the enterprise's optimal output is a decreasing function of the marginal cost of products from domestic enterprise, is an increasing function of the marginal cost of products of the enterprise from other country; the product price is an increasing function of the marginal cost of the product of the enterprise from both countries.

Since $Q_E^* - Q_I^* = \frac{c_I - c_E}{b}$ and $\pi_E^* - \pi_I^* = \frac{(2a - c_E - c_I)(c_I - c_E)}{9b}$, and since $c_I > c_E$ and $a > 2c_I - c_E$, we obtain the following property.

Property 2. Enterprises in exporting country have higher output and profit than enterprises in importing countries due to their lower marginal costs, i.e.,

$$Q_E^* > Q_I^*, \ \ \pi_E^* > \pi_I^*.$$

Game Model of Two Countries When a Pandemic Occurs in the Exporting Country

When a pandemic occurs in the exporting country, on the one hand, the importing country will impose an additional import quarantine fee τ, and the exporting country will give enterprises subsidy s, the profit structure of exporting enterprises changes. On the other hand, the price of raw materials rises and additional protective equipment lead to an increase in the marginal cost of exporting enterprises, which is recorded as c_E^m, and $c_E^m > c_E$. At this point, the game process between the two governments and enterprises is divided into two stages: in the first stage, due to the pandemic in the exporting country, the exporting government determines the optimal subsidy s^* to the exporting enterprise based on maximizing its social welfare after learning that the importing country imposes import quarantine fees τ on the exporting enterprise; in the second stage, after the enterprises observe the optimal subsidies given to the enterprises of the exporting country, the enterprises of the two countries conduct the Cournot game to determine their respective optimal output. For this two-stage Stackelberg game, we use the inverse solution method to find the optimal solutions of each stage with reference to Tang et al. (2020), Tang et al. (2021), and the superscript denotes the game with pandemic.

Consider the game process of the second stage. The enterprise's profit is given by

$$\pi_E^m\left(Q_E^m, Q_I^m, \middle| s\right) = \left(P^m - c_E^m + s - \tau\right)Q_E^m,$$

at this time, the profit per unit product of the exporting country's enterprise has changed. The enterprises in both countries maximize the profits to determine their optimal output Q_E^{m*}, Q_I^{m*}, the game model is:

$$\begin{cases} \max_{Q_E,Q_I} \pi_E^m\left(Q_E^m, Q_I^m, \middle| s\right) = \left(P^m - c_E^m + s - \tau\right)Q_E^m \\ \max_{Q_E,Q_I} \pi_I^m\left(Q_E^m, Q_I^m, \middle| s\right) = \left(P^m - c_I\right)Q_I^m \end{cases} \tag{2}$$

$$s.t. \begin{cases} Q_E^m(s) \geq 0 \\ Q_I^m(s) \geq 0 \end{cases}$$

where the demand function for the product is $P^m = a - b(Q_E^m + Q_I^m)$; τ is a constant, which indicates the import quarantine fees levied by the government of the importing country for enterprises in the exporting country.

From the first-order conditions of the optimization problem (2), the optimal price of the product and the optimal output of the two enterprises are obtained as:

$$\begin{cases} P^{m*}(s) = \dfrac{a + c_E^m + c_I - s + \tau}{3} \\ Q_E^{m*}(s) = \dfrac{a - 2c_E^m + c_I + 2s - 2\tau}{3b} \\ Q_I^{m*}(s) = \dfrac{a + c_E^m - 2c_I - s + \tau}{3b} \end{cases} \tag{3}$$

Property 3. When a pandemic occurs in the exporting country, the exporting country's subsidies for its own enterprises will increase the export volume of its own enterprises, reduce the output of the importing enterprises, and lower the price of the product; the import quarantine fees imposed by the importing country on the exporting country will reduce the export of the exporting country, increase the output of its own enterprises, and increase the price of the product.

Since $Q_E^{m*}(s) - Q_E^{m*}(s) = \frac{-c_E^m + c_I + s - \tau}{b}$, the following property can be obtained.

Property 4. When a pandemic occurs in the exporting country

(1) If $s < c_E^m - c_I + \tau$, the output of enterprises in the exporting country is less than the output of enterprises in the importing country.
(2) If $s > c_E^m - c_I + \tau$, the output of the enterprises in the exporting country is greater than the output of the enterprises in the importing country.

Consider the game process of the first stage. The exporting country government maximizes its social welfare to determine the optimal subsidy to enterprises, and the social welfare function is:

$$\omega_E^m(s) = \pi_E^{m*}(s) - sQ_E^{m*}(s) \tag{4}$$

It consists of the profits of enterprises minus subsidy expenses.

Substituting the conclusion from **Eq. 3** into **Eq. 4** yields:

$$\omega_E^m(s) = \frac{-2s^2 + s\left(a - 2c_E^m + c_I - 2\tau\right) + \left(a - 2c_E^m + c_I - 2\tau\right)^2}{9b}$$

the optimal subsidy from the government of the exporting country to the enterprises should satisfy

$$\frac{\mathrm{d}\omega_E^m(s)}{ds} = 0$$

From the fact that the second order derivative is less than 0, there exists an unique optimal solution when $a > 2c_E^m - c_I + 2\tau$:

$$s^* = \frac{a - 2c_E^m + c_I - 2\tau}{4}$$

Due to the uncertainty of the pandemic, subsidy policy should be adjusted depending on the situation of the pandemic. Reasonable subsidies will also avoid trade protection by importing countries and promote healthy trade relations between the two countries. However, suppose high export subsidies are given to enterprises across the board for a long period of time. In that case, it will not only harm the interests of enterprises in the importing countries and cause unfair trade

competition, but also inhibit technological innovation and weaken the intrinsic motivation of enterprises.

Property 5. When a pandemic occurs in the exporting country, the optimal subsidy from the government of the exporting country to the enterprises is a decreasing function of the import quarantine fees in the importing country, a decreasing function of the marginal cost of the product of the enterprises in the exporting country, and an increasing function of the marginal production cost of the enterprises in the importing country.

Substituting s^* into **Eq. 3** yields the optimal output of the two enterprises in the case of a pandemic in the exporting country when $\frac{-a+3c_I}{2} - c_E^m < \tau < \frac{a+c_I}{2} - c_E^m$, respectively:

$$\begin{cases} Q_E^{m*} = \dfrac{a - 2c_E^m + c_I - 2\tau}{2b} \\ Q_I^{m*} = \dfrac{a + 2c_E^m - 3c_I + 2\tau}{4b} \end{cases}$$

Since the social welfare function of the importing country is:

$$\omega_I^m(s) = \pi_I^{m*}(s) + CS(Q^{m*}) + \tau Q_E^{m*}(s) \tag{5}$$

it consists of the profit of domestic enterprises, consumer surplus and import inspection and quarantine fee income, where $CS(Q^{m*})$ indicates consumer surplus

$$CS(Q^{m*}) = \int_0^{Q_E^{m*}+Q_I^{m*}} (P^m - P^{m*})\mathrm{d}Q = \frac{b}{2}\left(Q_E^{m*}(s) + Q_I^{m*}(s)\right)^2$$

The optimal price of the product, the profit of the two firms and the social welfare of the two countries can be obtained as:

$$\begin{cases} P^{m*} = \dfrac{a + 2c_E^m + c_I + 2\tau}{4} \\ \pi_E^{m*} = \dfrac{4\tau^2 - 4\tau\left(a - 2c_E^m + c_I\right) + \left(a - 2c_E^m + c_I\right)^2}{4b} \\ \pi_I^{m*} = \dfrac{4\tau^2 + 4\tau\left(a + 2c_E^m - 3c_I\right) + \left(a + 2c_E^m - 3c_I\right)^2}{16b} \\ \omega_E^{m*} = \dfrac{4\tau^2 - 4\tau\left(a - 2c_E^m + c_I\right) + \left(a - 2c_E^m + c_I\right)^2}{8b} \\ \omega_I^{m*} = \dfrac{-20\tau^2 + 4\tau\left(3a - 2c_E^m - c_I\right) + 2\left(a + 2c_E^m - 3c_I\right)^2 + \left(3a - 2c_E^m - c_I\right)^2}{32b} \end{cases}$$

Property 6. When a pandemic occurs in the exporting country, the optimal output of enterprises in the exporting country, the profits of enterprises and the social welfare of the exporting country are all decreasing functions of import quarantine fees; the optimal output of enterprises in the importing country, the profits of enterprises and the prices of products are all increasing functions of import quarantine fees; when $\tau < \frac{3a-2c_E^m-c_I}{10}$, the social welfare of the importing country is an increasing function of import quarantine fees, and when $\tau > \frac{3a-2c_E^m-c_I}{10}$, the social welfare of the importing country is a decreasing function of import quarantine fees.

COMPARISON OF EFFECTS IN EXPORTING COUNTRIES WITHOUT AND WITH PANDEMIC

Using the absence of a pandemic as a benchmark, we compare the impact on product prices, production and profits of enterprises in both countries, and social welfare in both countries under the scenario of a pandemic in the exporting country.

Impact on Production, Product Prices and Corporate Profits of Enterprises in Both Countries

The optimal output of enterprises in both countries, the optimal price of the product and the social welfare of the governments in both countries are compared for the two scenarios, and the results are as follows:

$$Q_E^{m*} - Q_E^* = \frac{a - 6\left(c_E^m + \tau\right) + 4c_E + c_I}{6b}$$

$$Q_I^{m*} - Q_I^* = \frac{-a + 6\left(c_E^m + \tau\right) - 4c_E - c_I}{12b}$$

$$P^{m*} - P^m = \frac{-a + 6\left(c_E^m + \tau\right) - 4c_E - c_I}{12}$$

$$\pi_E^{m*} - \pi_E^* = \frac{\left[5a - 6\left(c_E^m + \tau\right) - 4c_E^m + 5c_I\right]\left[a - 6\left(c_E^m + \tau\right) + 4c_E^m + c_I\right]}{36b}$$

$$\pi_I^{m*} - \pi_I^* = \frac{\left[7a + 6\left(c_E^m + \tau\right) + 4c_E^m - 17c_I\right]\left[-a + 6\left(c_E^m + \tau\right) - 4c_E^m - c_I\right]}{144b}$$

Property 7.

(1) If $c_E^m + \tau < \frac{a+4c_E^m+c_I}{6}$, the impact of the pandemic on exporters is small, and timely and effective subsidies from the exporting country's government lead to an increase in production and profits for the exporting country's enterprises, a decrease in optimal production and profits for the importing country's enterprises, and a decrease in product prices.

(2) If $\frac{a+c_I}{2} > c_E^m + \tau > \frac{a+4c_E^m+c_I}{6}$, the impact of the pandemic on exporters is greater at this time. The occurrence of the pandemic in the exporting country will lead to a reduction in production and profits of enterprises in the exporting country, an increase in production and profits of enterprises in the importing country, and a rise in product prices.

Impact on Social Welfare

To further analyze the impact of the COVID-19 on social welfare in both countries, numerical simulation is presented. Simulation explored the effect of import quarantine rates and the marginal cost of exporting enterprises on social welfare. For this quantitative demonstration, we assigned values to each parameter based on the assumptions described in the previous sections and the practical implications. The parameters $a = 10$, $b = 3$, $c_E = 1$, $c_I = 3.5$ were used as the benchmark case when there is no pandemic. By calculating the optimal social welfare (ω_E^{m*}) of exporting countries with

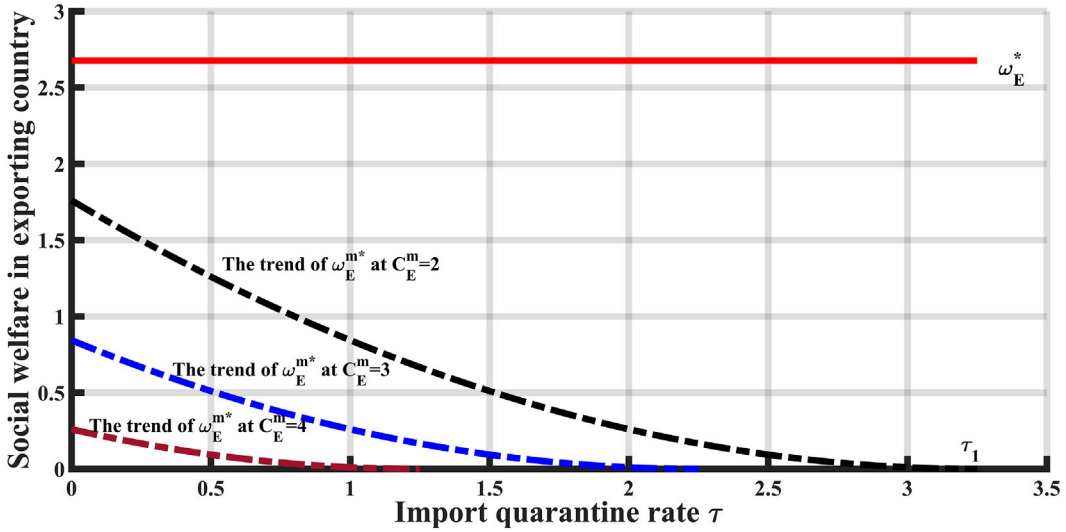

FIGURE 1 | Trend of social welfare changes in exporting country. (Source: Simulation data for numerical calculations).

different c_E^m and τ, we draw **Figure 1** as follows, which describes the trend of social welfare of exporting countries with the import quarantine fee and different production cost.

The upper horizontal line in **Figure 1** is the social welfare of the exporting country in the absence of the pandemic, which is independent of τ and c_E^m. The lower three curves show the decreasing trend of social welfare in the exporting country for $c_E^m = 2, 3, 4$, respectively. In addition, the increase of import quarantine fees brings a double blow to exporters; social welfare will be further reduced and decreases as τ increases. With $c_E^m = 2$, for example, the social welfare of exporting countries decreases with the increase of import quarantine rate, and the levy of quarantine fees has a great impact on exporting countries. It is clear from the figure that when the quarantine rate is low, i.e., $\tau < \tau_1$, exporters will still export, but when the quarantine rate exceeds τ_1, exporters will not be able to afford the excessive tax and stop exporting, and trade is terminated.

In the face of the impact of the pandemic and the import quarantine fees imposed by importing countries, the government should strive to improve the competitiveness of its enterprises. Exporters should accelerate the pace of transformation and upgrading, reduce the marginal cost of production, continuously improve logistics efficiency, review the situation to improve their own management capacity and risk resistance and enhance the position of their products in the industrial chain and the competitiveness of the international market.

The trends of social welfare (ω_E^{m*}) in importing countries with τ and c_E^m are shown in **Figure 2**.

The horizontal line in **Figure 2** is the social welfare of the importing country in the absence of the pandemic, which is independent of τ and c_E^m. The three curves show the change of social welfare of importing countries with τ when $c_E^m = 2, 3, 4$, respectively, and the curves show an increasing and then decreasing trend. Taking $c_E^m = 3$ as an example, it can be clearly seen that: 1) When $\tau < \tau_2$ The social welfare of the importing country is an increasing function of the import quarantine fee, and increasing the import quarantine fee will increase the social welfare. When $\tau_2 < \tau < \tau_4$, the social welfare of the importing country is a decreasing function of the import quarantine fee, and increasing the import quarantine fee at this time will make the social welfare decrease, indicating that the high quarantine fee does not improve the social welfare of the importing country; 2) And when $\tau < \tau_1$ or $\tau_3 < \tau < \tau_4$, the social welfare is lower than that of in the absence of pandemic, indicating that when the quarantine fee is too low or too high, the social welfare of the importing country due to the pandemic will lower; and when $\tau_1 < \tau < \tau_3$, the social welfare of the importing country is higher than before the pandemic, indicating that an appropriate import quarantine fee will increase the social welfare of the importing country; 3) When $\tau > \tau_4$, the exporting country will not export the product due to the high import quarantine fee and the trade between the importing and exporting countries will stop.

To avoid trade frictions between bilateral countries and to avoid the increase of product prices in the domestic market and the reduction of consumer surplus, the importing country should only reasonably levy import quarantine fees to improve the market competitiveness of domestic enterprises, thereby increasing corporate profits and social welfare. However, the import quarantine fee levied by the importing country cannot be too high, otherwise, it will not only seriously damage the social welfare of the exporting country but also reduce the social welfare of the importing country itself, which is not conducive to the upgrading and transformation of domestic enterprises and the adjustment of industrial structure.

The trend in total social welfare $(\omega_E^{m*} + \omega_I^{m*})$ for both countries with τ and c_E^m is shown in **Figure 3**.

The horizontal line in **Figure 3** is the sum of social welfare in the absence of the pandemic, which is independent of τ and c_E^m. The three curves show the change of the total of social welfare of the two countries with τ when $c_E^m = 2, 3, 4$, and the

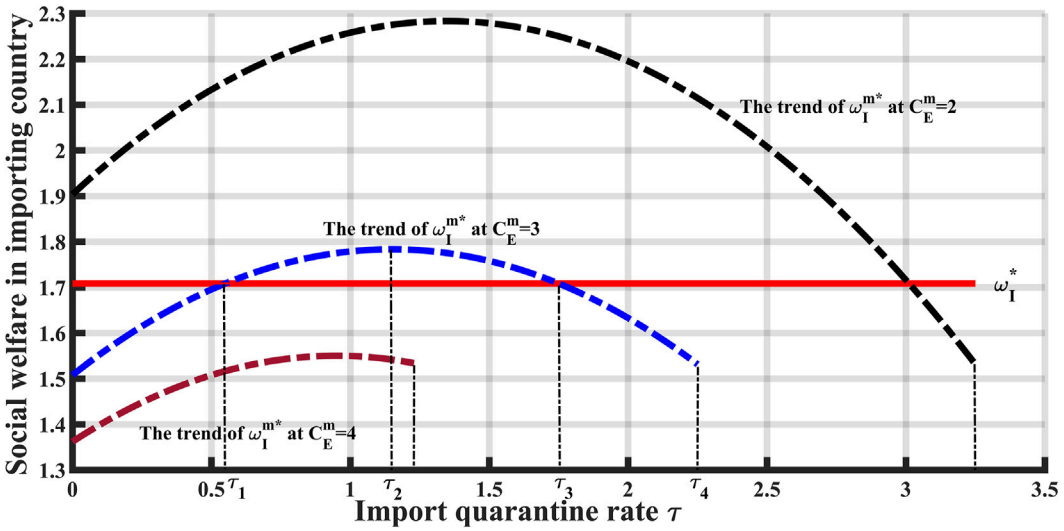

FIGURE 2 | Trends of social welfare changes in importing countries. (Source: Simulation data for numerical calculations).

curves show a decreasing trend. Affected by the pandemic, the social welfare of both countries are greatly reduced, and the greater the c_E^m, the more social welfare reduced; It can be seen from this that on the one hand, exporting countries should actively take measures to restore production capacity as soon as possible and reduce the cost of enterprises in the face of the pandemic; Social welfare has had a negative impact on the normal trade and economy of the two countries. The importing country should abandon trade protection and proceed from the overall situation of the trade between the two countries to jointly deal with the pandemic and achieve a win-win situation.

The government should be fully aware of the long-term nature and complexity of the game between the two countries and should respond to the WTO-compliant import quarantine fees imposed by the importing countries with a normal heart, and establish an early warning and response mechanism promptly, with the relevant subsidy policies for exporters. Both the governments and enterprises must actively negotiate with relevant governments and enterprises from both domestic and international perspectives and take the initiative to bear the impact of the pandemic on domestic and foreign trade.

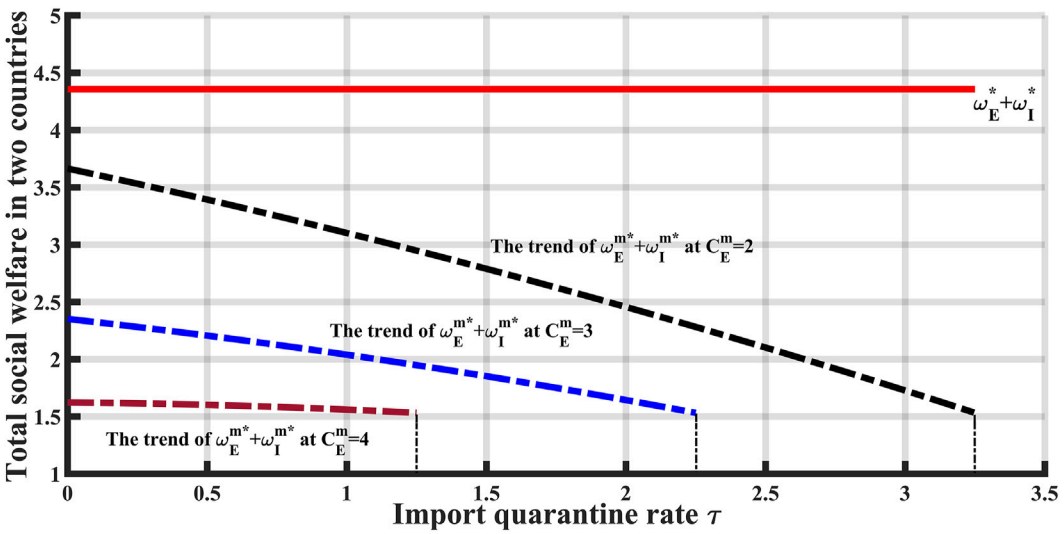

FIGURE 3 | Trend of total social welfare in two countries. (Source: Simulation data for numerical calculations).

RESULTS

In the face of the pandemic, exporting countries must first control the spread of the pandemic to reduce the costs of their enterprises. The tax exemption method or lowering export tax rate is a desirable fiscal policy to prevent enterprises from breaking their capital chains and help them smoothly overcome the hard times. Controlling the spread of the pandemic and subsidizing enterprises are effective means for exporting countries to restore the economy. However, it should not be overlooked that exporting countries make every effort to subsidize export enterprises, which will lead to unfair trade competition in the markets of importing countries, i.e., low-price competition of products, which reduces the profits of enterprises in exporting countries and reduces the profits of enterprises in importing countries, which is not conducive to the sustainable development of economy and trade.

The reasonable increase in import quarantine fees imposed by importing countries is conducive to enhancing the market competitiveness of their enterprises. However, when the importing country imposes higher import inspection and quarantine fees, not only seriously undermines the social welfare of the exporting country, bringing the possibility of trade friction between the two countries and promoting the increase in the price of products on the domestic market. Consumer surplus is reduced, which counterproductively reduces the country's social welfare and is not conducive to the upgrading and industrial restructuring of domestic enterprises themselves. Therefore, the importing country should impose lower import quarantine fees to promote their social welfare and corporate profits. Importing countries should take other positive trade measures and exporting countries should cooperate fully to achieve a win-win situation.

When the pandemic comes, all countries should abandon trade protection, eliminate trade barriers, unblock trade channels, reasonably build stable supply chains and industrial chains, and commit to developing an equal, balanced, mutually beneficial and win-win trade partnership. Both exporting and importing countries must establish subsidies and import quarantine taxes that align with their own national conditions. On the one hand, they can promote healthy competition in the consumer market, and on the other hand, they must jointly respond to the negative impact of the pandemic on the economies of both countries. The two countries should actively conduct in-depth diplomatic consultations on the impact of the pandemic, promote the signing of bilateral border health and quarantine cooperation documents, and avoid the deterioration of trade relations and escalation of trade frictions caused by the pandemic. All countries should focus on long-term trade cooperation, adhere to the deeply intertwined model of mutually beneficial cooperation, clearly express their attitude and position to work together to overcome the pandemic, and resolutely oppose unilateral trade protection.

DISCUSSION

The research further enriches bilateral trade strategies' theoretical connotation and practice under the pandemic. We only consider the situation of international duopoly competition. Still, the motive involving government intervention in the import and export of enterprises has always existed in the situation of multi-oligopoly competition. In particular, when the number of enterprises participating in international competition is more than one, the exporting country needs to consider the actual situation and negotiating power of each enterprise in formulating subsidy policies and balancing the competition effect among various enterprises. In addition, we only studied the pandemic situation in the exporting country and did not consider the pandemic situation in the importing country, nor did we consider the information asymmetry between enterprises and enterprises and between enterprises and governments. As future research, our model can be extended to multi-oligopoly competition while considering the asymmetry between firms and governments, making the model more realistic and challenging. Finally, the model is based on static decision-making, and we can also extend it to a dynamic decision-making model, that is, to study and analyze the evolution of import and export strategies over time. These deficiencies are left for future research to address.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

WT issued the idea and design for the research. JH and JL analyzed the model and drafted the manuscript. GR and FM revised the manuscript along with other authors.

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