**Seafood Supply and Demand Disruptions: The Covid-19 Pandemic and Shrimp**

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## Abstract

We develop a theoretical trade model based on classical welfare economics and apply it empirically to both importers and exporters of shrimp, the most traded seafood, to determine the effects of the Covid-19 pandemic on the excess supply and excess demand of shrimp industry. We consider two time periods and compare these to the base period before the pandemic. Period 1 (March–June 2020): there is a net economic loss globally of $194 million due to lockdowns. Period 2 (July 2020–June 2021): there is a net welfare gain globally of $885 million due to increased shrimp demand. Overall, the global net economic gain was $692 million. For the United States alone, shrimp consumers gained $470 million while shrimp producers gained $24 million, which is relatively consistent with the net quasi-consumer gain of $475 million due to the Covid-19 pandemic.



**Keywords:** Covid-19, excess demand, excess supply, price, welfare effects

**JEL Classifications:** F10, Q22, Q27

## Introduction

The debates about the disruptions caused by the Covid-19 pandemic to food supply chains, demand, and trade are evolving due to its different effects on production, consumption, and trade. During the Covid-19 pandemic, global imports are down 8%, whereas the imports of agriculture have increased by 3.5% (Arita et al., 2021). Although the closures of restaurants and food services have experienced a large decrease in gross domestic product (GDP), agricultural production and trade markets have been very resilient during the pandemic (Beckman & Countryman, 2021). Moreover, some food supply chains, market segments, companies, small-scale actors, and society have shown signs of greater resilience compared to others (Love et al., 2021a).

Seafood is not only a primary source of protein, it is also among the most traded of all food commodities (Asche et al., 2015). Therefore, any shocks in the supply and demand sides of seafood would have a direct impact on human food security, welfare, and trade flows among countries. In the United States (U.S.), although Covid-19 has created many challenges to food supply and demand, its long-term effects are uncertain (Walters et al., 2020). The most recent report by the National Oceanic and Atmospheric Administration (NOAA, 2021) indicates that the losses of the U.S. fishing and seafood sector due to Covid-19 vary by sector, region, and industry. Lebel et al. (2021) indicate that the effects of the responses to Covid-19 on aquaculture producers in five countries in the Mekong region of Asia are not homogenous because they depend on farm size, production goals, cultured species, and levels of intensification.

Shrimp is a major traded seafood commodity and it is the most consumed seafood in the United States (Love et al., 2021b). In 2019, 95% of the shrimp consumed in the United States was imported (Figure 1). Therefore, factors affecting imported shrimp supply sources have a direct influence on U.S. domestic consumption, food security, and welfare. The Covid-19 pandemic has greatly impacted the shrimp supply chain in the United States, accounting for 22% of the global poundage of shrimp exports in 2019 (Comtrade, 2021). Moreover, because the shrimp market in the United States is part of the integrated world shrimp market, any domestic demand shocks (positive or negative) influence the global shrimp sector and vice versa (Asche et al., 2012).

In response to Covid-19, the U.S. government has imposed various policies to deal with the spread of the coronavirus, which have generated significant economic costs to foodservice venues, such as restaurants (Fajgelbaum et al., 2020; Love et al., 2020). The temporary closure of U.S. foodservice venues has significantly reduced seafood consumption away from home (AFH) seafood consumption, while increasing consumption at home (AH) of frozen and fresh seafood sold in grocery stores  (Halzack, 2021). Specifically, seafood sold in U.S. grocery stores has had the highest growth rate at 28.4%, followed by meat (18.7%), produce (11.3%), and deli items (0.9%) (Browne, 2021). Switching from shrimp consumption AFH to shrimp consumption AH could explain the 9% increase in shrimp imports in 2020 compared to 2019 in the United States (NOAA, 2021). The global market has also experienced a significant increase in retail sales of shrimp due to the lockdowns and other measures to combat the Covid-19 pandemic (FAO, 2020).

Covid-19 has negatively impacted shrimp producers worldwide due to production input shortages, higher input costs, and logistics challenges (Lebel et al., 2021). This is especially true for some of the major shrimp suppliers in Asia. For example, Kumaran et al. estimate that Covid-19 has caused shrimp production and exports in India to decrease by 40% (Kumaran et al., 2021), and 103 seafood factories in Vietnam temporarily closed (Dao, 2021).

This paper adds to the above discussion on the impacts of Covid-19 on the shrimp sector in the global and U.S. markets. We determine the effects of the Covid-19 pandemic on export supply, import demand, market prices, and the welfare impact on shrimp net exporters and net importers within a classical welfare economic framework. Under different supply and demand conditions, we estimate the net economic impacts of Covid-19 on global producers and consumers of shrimp. We also provide a detailed assessment of the effects of Covid-19 on U.S. shrimp producers and consumers.

## Effects of Covid-19 on the Global Shrimp Sector: Theoretical Framework

The analysis of the effects of Covid-19 on the global and U.S. shrimp markets is based on classical welfare economics within an international trade framework (Just et al., 2004; Schmitz et al., 2010, 2020). In addition, the partial Equilibrium Displacement model is applied to analyze the shifts in domestic demand and supply and market prices due to the coronavirus under the excess supply and demand perspectives. The model is calibrated and simulated to determine the welfare effects in both the global and U.S. shrimp markets.

The effects of the Covid-19 pandemic are demonstrated in Figure 2 (Panels A & B), where we divide the global shrimp market into two regions: net importers and net exporters. Our model is simplified in the global shrimp market where there is only one net importer (i.e., the United States) and six net exporters (i.e., India, Indonesia, Ecuador, Thailand, Vietnam, and the rest of world [ROW]). Because the U.S. shrimp market is a large consumer in the global market, any shocks in U.S. demand cause changes in the excess demand, excess supply, and price of shrimp. This assumption is consistent with Houck (1992), indicating that a nation is large if potential changes in either its exports or imports are sizable enough to cause relevant changes in world price. Before the Covid-19 pandemic, the global excess demand is $ED_0$ and the excess export supply is $ES_0$. The global shrimp equilibrium price is $PE_0$ and the amount traded is $QE_0$.

The excess supply and demand curves are derived from foreign supply and domestic demand curves. For exporters, the domestic demand is $D_x$ and domestic production is $S_x$. At the global market price $PE_0$, $X_0$ is the imports from the net exporters. For net importers, the U.S., domestic demand is $D_{m0}$ and domestic supply is $X_m$. $M_0$ is the import volume.

The effects of the Covid-19 virus are analyzed in two time periods based on the statistical data of the U.S. shrimp imports and market trends. Period 1 represents the impacts of the Covid-19 pandemic on the global shrimp market during from March 2020 to June 2020. In this period, the U.S. demand for shrimp decreases due to lockdown requirements and restaurant closures. The supply side remains unchanged over this short period. Figure 1, Panel A, presents the changes in the excess demand and excess supply curves during period 1. In the United States, domestic demand decreases, causing the U.S. domestic demand curve to shift inward from $D_{m0}$ to $D_{m1}$. The corresponding shift in domestic demand for shrimp causes the excess demand curve to shift in the same direction from $ED_0$ to $ED_1$. As a result, the equilibrium price and quantity of shrimp in the global market decrease from $PE_0$ and $QE_0$ to $PE_1$ and $QE_1$, respectively. This demand shift creates negative effects on both net importers and net exporters. The import volume from the net importer decreased from M0 to M1 and the export volume decreased from $X_0$ to $X_1$. Specifically, the lower price confers a welfare loss to global net producers equal to the shaded area ($PE_0abPE_1$) and a welfare loss to global net consumer equal to area ($PE_1bdPE_2$). Overall, in period 1, the Covid-19 pandemic causes negative effects on both producers and consumers, with the gross welfare loss equal to area ($PE_0abdPE_2$).

Period 2 covers July 2020 to June 2021, in which the consumption of shrimp in the United States recovered and the net exporters had enough time to adjust their export volume following the changes in global shrimp supply and demand. In period 2,  shrimp demand increased in the United States(Goldschmidt, 2020), while global shrimp supply decreased, causing the global excess demand and the excess supply curves to shift simultaneously.

The effects of the Covid-19 pandemic on excess supply and excess demand in period 2 are presented in Figure 2, Panel B — the excess demand curve shifts outward, corresponding to the increase in shrimp consumption in the United States, and the excess supply curve shifts inward, simultaneously. Similar to the above framework, increased shrimp demand by the United States causes the global excess demand to shift upward from $ED_0$ to $ED_1$. The new equilibrium price and quantity are $PE_1$ and $QE_1$. However, during period 2, higher transportation costs, shipping container shortages, labor hiring difficulties, and higher input prices for net suppliers cause a decrease in shrimp supply for the net exporters. As a result, the global excess supply curve shifts inward from $ES_0$ to $ES_1$. The new equilibrium price $PE_2$ is above the equilibrium price $PE_1$ and the corresponding quantity is $QE_2$ located between $QE_0$ and $QE_1$. Because the new equilibrium price and quantity are higher than those at the initial equilibrium market, the shifts in demand and supply curves create a welfare gain to both producers and consumers. The gains in excess producer welfare and excess consumer welfare are ($PE_2cdI_0$) and ($I_1ecPE_2$), respectively. Therefore, the net welfare effect from Covid-19 in period 2 is equal to area ($I_1ecdI_0$). While the Covid-19 pandemic causes a negative effect on both shrimp producers and consumers in the first period, the recovery in the shrimp sector in the second period generates benefits for consumers and producers. These aggregate effects are quantified using EDM models and its results are presented in the next section.

## Excess Demand and Supply Models

### *The Disruption of the Covid-19 Pandemic on Excess Demand of Shrimp*

We develop a comparative statistic result by specifying an Equilibrium Displacement Model (EDM)[1] of the world shrimp market. This model is similar to the model built by Kinnucan and Myrland (2005) for the world salmon market. The United States is the largest net importer of shrimp. U.S. domestic demand and supply are expressed as follows:

| | | |
|---|---|---|
| (1a) | Domestic demand curve | D = D(Pus, $CD_{US}$) |
| (2a) | Domestic supply curve | S = S(Pus) |
| (3a) | Import supply curve | M = M(P) |
| (4a) | Domestic price | Pd = P + C |
| (5a) | Market equilibrium | D = S + M |

where $P_{us}$ is the U.S. domestic shrimp price, P is the world shrimp price, C is the per-unit cost associated with shipping the product from the exporting countries to U.S. consumers, and $CD_{US}$ is the disruption parameter representing the effects of Covid-19 on domestic demand in the United States (net importer). The key interest in this model is the effects of the Covid-19 shock in domestic demand and the increase in shipping costs on import demand[2] and prices. To address this interest, we first write the model in equilibrium-displacement form as follow:

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[1] EDM is one of the prominent models applied in economic analysis providing a set of comparative statistic results presented in elasticity form (Wohlgenant, 2011) that was first expressed in quantitative terms by Allen (1938) and Hicks (1957) related to the industry-derived demand for a factor. This model was popularized in partial equilibrium and general settings by Muth (1964) and Jones (1965), respectively. Muth (1964) describes the shifts in demand and supply in responding to two exogenous factors. Piggott (1992) discusses strengths and weaknesses of applying the EDM for policy analysis. Davis and Espinoza (1998) discuss the essential of sensitivity analysis in the EDM. Hertel (1997) discusses applications of the EDM to global trade analysis. For a more comprehensive history of EDM, see Chapter 11, written by Wohlgenant, in the book *The Oxford Handbook of the Economics of Food Consumption and Policy* edited by Lusk et al. (2011).

[2] Import demand is the excess demand. It is the amount that a country imports when the market price is below the equilibrium price for the closed model of domestic supply and demand.

(1b) $D^* = \eta_{us} P_{us}^* + cd_{us}$

(2b) $S^* = \varepsilon_{us} P_{us}^*$

(3b) $M^* = \varepsilon_{mus} P^*$

(4b) $P_{us}^* = (1-\tau)P^* + \tau C^*$

(5b) $D^* = \kappa_{us} S^* + \kappa_m M^*$

where the asterisked variables indicate relative changes (X* = dX/X), $\eta_{us}$ $(< 0)$ is the values of the U.S. demand elasticity, $\varepsilon_{us}$ $(\geq 0)$ is the U.S. supply elasticity, $\varepsilon_{mus}$ $(\geq 0)$ is the U.S. import demand elasticity, $\kappa_{us} = S/D$ is the share of domestic consumption from domestic production, $\kappa_m = M/D$ is the share of domestic consumption from imports, $cd_{us}$ is the parameter causing a horizontal shift in the domestic demand curve due to the Covid-19 pandemic (the shift in the quantity direction with price held constant), and $\tau = \frac{C}{P_{us}}$ is the proportional transportation cost. The excess demand curve is obtained by deleting equations (3b) and (4b) and solving the remaining equations simultaneously:

$$M^* = -\left(\frac{-\eta_{us} + \kappa_{us}\varepsilon_{us}}{\kappa_m}\right) P_{us}^* - \frac{cd_{us}}{\kappa_m}$$

(6) or $M^* = -\eta' P_{us}^* - cd'_{us}$

where $\eta' = \frac{-\eta_{us} + \kappa_{us}\varepsilon_{us}}{\kappa_m}$ is the price elasticity of import demand and $cd'_{us} = \frac{cd_{us}}{\kappa_m}$ is the parameter representing the effects of the Covid-19 pandemic on excess demand of shrimp in the global market. If the share of domestic consumption from imports increases, the effects of the Covid-19 pandemic on the import demand will be decreased.

***The Disruption of the Covid-19 Pandemic on Excess Supply of Shrimp***

We derive individual global shrimp net exporters *i*[3] along with their export supply[4] functions below:

(7a) Domestic demand curve $D_i$ = D($P_i$)

(8a) Export demand curve $X_i$ = X($P_i$)

(9a) Domestic supply $S_i$ = S($X_i$, $CS_i$)

(10a) Market equilibrium $S_i$= $D_i$ + $X_i$

where *i* denotes the net shrimp exporter *I*; $P_i$ is the market price in which the domestic price is assumed to be equal to the world price (the domestic market is integrated with the world market using the Law of One Price [LOP]); and CV is the shift variable indicating the effects of Covid-19 on the shrimp supply in the net exporting countries. Covid-19 shifts the supply curve to the left ($\partial S_i/CV_i < 0$). The key interest is the effects of Covid-19 on excess supply from a net export country $i$. Similar to the above excess demand model, we first write the model in equilibrium-displacement form as follow:

(7b) $D_i^* = \eta_i P_i^*$

(8b) $X_i^* = \eta_{ei} P_i^*$

(9b) $S_i^* = \varepsilon_i P_i^* - cs_i$

(10b) $S_i^* = l_d D_i^* + l_e X_i^*$

where the asterisked variables indicate relative changes, $\eta_i$ $(< 0)$ is the values of the domestic demand elasticity by country $i$, $\eta_{ei}(< 0)$ is the export demand elasticity, $\varepsilon_i$ $(\geq 0)$ is the domestic supply elasticity, $l_d = D_i/S_i$ is the share of domestic consumption from the domestic

[3] Country *i* in this research represents India, Indonesia, Ecuador, Thailand, Vietnam, and the Rest of the World ($ROW$). The details of these countries will be presented in the next section describing the global shrimp model.
[4] The export supply is the excess supply that a country could supply to another country if the market price is above the equilibrium price of the domestic supply and demand.

supply of a country $i$, $l_e = X_i/S_i$ is the share of export in domestic supply of a country $i$, and $cs_i$(>0) is the parameter that represents a proportional horizontal shift in the supply curve of the net exporter $i$ due to Covid-19 (the shift in the quantity direction with price held constant). The excess supply curve is obtained by deleting equation (8b) and solving the remaining equations simultaneously:

$$X_i^* = \left(\frac{\varepsilon_i - l_d \eta_i}{l_e}\right) P_i^* - \frac{cs_i}{l_e}$$

or

(11) $X_i^* = \varepsilon_i' P_i^* - cs_i'$

where $\varepsilon' = \frac{\varepsilon_i - l_d \eta_i}{l_e}$ is the price elasticity of export supply and $cs_i' = \frac{cs_i}{l_e}$ is the parameter that shifts the excess export supply curve in specific country $i$ inward due to the Covid-19 pandemic that caused shrimp export supply to decrease.

***The Disruption of the Covid-19 Pandemic on the Global Shrimp Sector***

In this model, we assume that the excess demand ($M^*$) for shrimp by the United States is satisfied by the excess supply from six identified net exporters: India (*IND*), Indonesia ($INO$), Ecuador ($ECD$), Thailand ($TLD$), Vietnam ($VNM$), and Rest of the World ($ROW$). We also assume the domestic and imported shrimp are perfect substitutes, and the domestic market is integrated with the world market such that the LOP holds. Therefore, the world shrimp model in equilibrium displacement form is as follows:

U.S. excess demand:

(12) $M^* = -\eta' P_{us}^* - cd_{us}'$

World excess supply:

(13) $X_i^* = \varepsilon_i' P^* - cs_i'$ ($i$ = *IND, INO, ECD, TLD, VNM, ROW*)

Price link:

(14) $P_{us}^{*} = (1-\tau)P^{*} + \tau C^{*}$

Market equilibrium:

(15) $M^{*} = \sum_{i=1}^{6} kx_i \, X_i^{*}$

where $Q^{*} = dQ/Q$ is the proportional change in variable Q, $\eta'$(>0) is the price elasticity of excess demand, and $\varepsilon_i'$ (>0) are source-specific supply elasticities for the U.S. shrimp consumption. The model contains nine endogenous variables: one to represent changes in excess demand ($M^{*}$), six to represent changes in excess supply ($X_{IND}^{*}$, $X_{INO}^{*}$, $X_{ECD}^{*}$, $X_{TLD}^{*}$, $X_{VNM}^{*}$, and $X_{ROW}^{*}$), and two to represent changes in prices that the net exporters received ($P^{*}$) and net importer, the U.S., paid ($P_{us}^{*}$). The equilibrium model is displaced by eight exogenous factors causing the changes in excess demand ($cd_{us}'$), excess supply from a country ($cs_i'$) [i.e, six variables representing for six exporters], and transportation cost ($C^{*}$). Other exogenous variables that affect supply and demand are suppressed.

## Empirical Simulations of the Effects of Covid-19 on the Global Shrimp Market

Similar to the above model, we define the net importer as the United States, and the net exporters as India, Indonesia, Ecuador, Thailand, Vietnam, and ROW. The numerical values for the EDM model's structural elasticities $\eta'$, $\varepsilon_i'$, $cd_{us}'$, and $cv'$ are derived from the following formulas:

(16a) $\eta' = \frac{-\eta_{US} + \kappa_{us}\varepsilon_{us}}{\kappa_m}$

(16b) $cd_{us}' = \frac{cd_{us}}{\kappa_m}$

(16c) $\varepsilon' = \frac{\varepsilon_i - l_d \eta_i}{l_e}$

(16d) $cs_i' = \frac{cs_i}{l_e}$

where $\kappa_{us}$ is the share of U.S. domestic consumption from U.S. domestic production, $\kappa_m$ is the share of U.S. domestic consumption from imports, $l_d$ is the share of domestic consumption from domestic supply in a net exporting country, and $l_e$ is the share of exports in the domestic supply in a net exporting country. Equation 16a is the import demand elasticities derived as equation 6, and equation 16c is the export supply elasticities derived as equation 11.

The values of $\kappa_{us}$, $\kappa_m$, $l_d$, $l_e$ are presented in Table 1. Between 2010 and 2020, U.S. imports accounted for 93% of the total domestic shrimp consumption (Figure 3). Therefore, $\kappa_m$ is equal to 0.93, so $\kappa_{us} = 0.07$. U.S. shrimp demand elasticity is based on the estimation by Zhou (2015) in which the value is 1.041. The supply elasticity of U.S. shrimp is assumed to be 0.70, an average of 0.89 based on the estimation by Salim and Biradar (2009) and 0.5 based on Baughman (2004). The effects of the Covid-19 pandemic on U.S. shrimp demand are assumed to be equal to the changes in U.S. imports. This is reasonable because shrimp imports account for 93% of domestic consumption in the United States. According to the data provided by NOAA (2021), from March 2020 to June 2020, shrimp imports to the United States decreased by 15% compared to the same time in 2019 (March 2019 – June 2019). However, the shrimp imports from August 2020 to June 2021 increased by 20% compared to the same times in 2018 and 2019. Therefore, we set the value of $v$ as a shift in the domestic demand curve in which $cd_{us}^1 = -0.15$ in Period 1 and $cd_{us}^2 = 0.20$ in Period 2.

The demand and supply elasticities of shrimp for the net exporters are taken from the work by Dey et al. (2008) to estimate fish demand at an aggregate level in these countries. Specifically, the own-price demand elasticities of shrimp in India, Indonesia, Thailand, and Vietnam are equal to -1.0, -1.02, -0.74, and -3.06, respectively. For Ecuador and ROW, the demand elasticity based on the fish demand elasticity by Gallet (2009) is -0.79. We assume the supply elasticity of shrimp for the net exporters is similar at 1.2 (Kinnucan & Myrland, 2007; Nguyen & Kinnucan, 2018). The shares of the net exporters' production exported are also presented in Table 1. Based on these parameters, the excess demand and excess supply elasticities in the global market are computed and presented in Table 2. In addition, the export shares of India, Indonesia, Ecuador, Thailand, Vietnam, and ROW are also presented in Table 2 which is given in more detail in Figure 4, and is separated for before and since the Covid-19 pandemic began in Appendix 1. Specifically, the volume share of shrimp from India, Indonesia, Ecuador, Thailand, Vietnam, and ROW in 2019 was approximately 43%, 19%, 12%, 6%, 6%, and 14%, respectively (Appendix 1). These proportion shares have changed relatively since the Covid-19 pandemic began in which the import share from Ecuador increased from 12% in to 22% in the first six months of 2021 and the import share from India and Thailand decreased relatively.

## Results

### ***The Effects of Covid-19 on the Shrimp Excess Supply, Excess Demand, and Prices***

In the period from 2015 to 2019, U.S. imports of shrimp are approximately 650 thousand metric tons (MT) per year, equivalent to a value of $6 billion. In comparison, domestic shrimp landing accounts for only 7% of the total domestic consumption at 57 thousand MT per year, or a value of $672 million. Because the U.S. shrimp sector depends significantly on imports and a major market of foreign suppliers, any changes in the domestic supply and demand are expected to influence the global shrimp export market. The impact of Covid-19 on shrimp is the aggregated impact of Period 1 (March 2020 to June 2020) and Period 2 (July 2020 to June 2021).

In Period 1, we assume the inward parallel shift of shrimp consumption in the United States equals 15% and the transportation cost equals 5%. Based on equation 16b, the shift in excess demand curve equals 16%. The effects of the excess demand shift and transportation cost on excess supply, excess demand, and prices in this period are simulated and presented in Table

3. The result shows that in Period 1, the Covid-19 pandemic has caused the total excess demand of shrimp to decrease by 15%, in which the decrease in domestic demand causes the excess demand to decrease by 16% and the transportation cost reduces the excess demand by 4%. The effects of the Covid-19 pandemic on excess supply vary by country. Specifically, Indonesia and Thailand are the most influential (excess supplies decrease by 26% and 11%, respectively), and India and Ecuador are the least influential, approximately 5% in each country). The Covid-19 pandemic causes the excess supply from Vietnam to decrease by 7%.

In period 2, shrimp consumption in the United States recovers, increasing by 20% compared to U.S. consumption in the pre-Covid-19 period June 2018 to June 2019 (NOAA, 2021). An increase of 20% in U.S. domestic demand causes excess demand to shift outward by 22%. Conversely, because the effect of the Covid-19 pandemic on the global shrimp supply has not been reported yet, we initially assumed that the Covid-19 pandemic would cause the global shrimp supply to decrease by 15%. Based on equation 16d, the decreases in excess supply from India, Indonesia, Ecuador, Thailand, Vietnam, and ROW are equal to 15%, 47%, 15%, 25%, 16%, and 25%, respectively. The effects of the Covid-19 pandemic on excess demand, excess supply, and prices in Period 2 are simulated and presented in Table 4.

In particular, the increase of 20% in shrimp import demand in the United States increases the excess demand by 15%. At the same time, the decrease in excess supply from the net exporters ranges from 7% (India) to 36% (Indonesia). Overall, the Covid-19 pandemic in period 2 causes total excess demand to increase, total export supply to decrease, and market prices to increase. Specifically, the excess demand increases by 2%. The excess supply from Indonesia, India, Ecuador, Thailand, Vietnam, and ROW decreases by 7%, 27%, 8%, 8%, 13%, and 10%, respectively. Moreover, the price paid by net shrimp importers increases by 11% and the price received by net exporters increases by 13%.

***The Effects of Covid-19 on the Global Shrimp Market***

The Covid-19 pandemic has impacted shrimp excess suppliers and excess consumers differently depending on the flexibility of this sector in each country and the adaptation to changes from the consumers. To determine the total effects, we calculate the effects on shrimp excess suppliers and excess consumers from periods 1 and 2.

Period 1 shows that the demand decrease due to the lockdowns shifts the excess demand curve inward. The formulas by Alston et al. (2005) are used to measure both the consumer and producer welfare effects in this period:

(17) The change in excess supplier surplus: $\Delta \mathrm{PS} = \mathrm{P}^0\mathrm{Q}^0 P^*\left(1+\frac{1}{2}Q^*\right) < 0$

(18) The change in excess consumer surplus: $\Delta \mathrm{CS} = \mathrm{P}^0\mathrm{Q}^0 (V_D - P^*)\left(1+\frac{1}{2}Q^*\right) < 0$

(19) Total change in economics welfare: $\mathrm{TS} = \Delta \mathrm{PS} + \Delta \mathrm{CS} < 0$

where $\mathrm{P}^0$ and $\mathrm{Q}^0$ are the shrimp equilibrium price and quantity in the global market before the Covid-19 pandemic during the same time as period 1, $P^*$ and $Q^*$ are the changes of the equilibrium price and quantity due to Covid-19 as presented in Table 3; $V_D < 0$ is the decrease in market price when quantity is held constant, and $(V_D - P^*) < 0$. A decrease in demand always decreases consumer and producer welfare.

The welfare effect in period 2 is an aggregate of an outward shift in excess demand and an upward shift in excess supply. The surplus changes due to the excess demand shifting outward and excess supply shifting inward simultaneously can be calculated using the following equations:

(20) The change in excess supply surplus: $\Delta \mathrm{PS} = \mathrm{P}^0\mathrm{Q}^0 (P^* - V_{ES})\left(1+\frac{1}{2}Q^*\right) > 0$

(21) The change in excess demand surplus: $\Delta\mathrm{CS} = \mathrm{P}^0\mathrm{Q}^0(V_{ED} - P^*)\left(1 + \frac{1}{2}Q^*\right) > 0$

(22) Total change in economics welfare: TS= ΔPS + ΔCS > 0

where $\mathrm{P}^0$ and $\mathrm{Q}^0$ are the shrimp equilibrium price and quantity in the global market before the pandemic; $V_{ES}$ is the increase in market price when excess supply quantity is held constant $(P^* - V_{ES}) > 0$. The excess supplier welfare increases when the excess supply decreases and excess demand increases simultaneously. $V_{ED}$ is the increase in market price when excess demand quantity is held constant. Because $(V_{ED} - P^*) > 0$, an increase in demand and a decrease in supply in this case increase consumer welfare. Overall, in period 2, the total welfare from excess demand and excess supply is positive. In this case, the total economic welfare increases.

The welfare changes due to the demand increase only can be calculated using the following equations:

(23) The change in supplier surplus: $\Delta\mathrm{PS} = \mathrm{P}^0\mathrm{Q}^0 P^*\left(1 + \frac{1}{2}Q^*\right) > 0$

(24) The change in consumer surplus: $\Delta\mathrm{CS} = \mathrm{P}^0\mathrm{Q}^0(V_D - P^*)\left(1 + \frac{1}{2}Q^*\right) > 0$

(25) Total change in economics welfare: TS= ΔPS + ΔCS > 0

where $V_D$ is the increase in market price when quantity is held constant. Because $(V_D - P^*) > 0$, an increase in demand always increases consumer welfare. In other words, demand growth increases the price, consumer surplus and producer surplus are positive, and total economic welfare increases.

For the simulation in period 1, we set $Q_0$ and $P_0$ as the shrimp quantity and average price for U.S. imports from the world during the same time as period 1 (March to June) in 2019. Specifically, $Q_0$ is equal to 204,060 MT and $P_0$ = $7,467/MT (equals the U.S. import price

[$8,298/MT – 10% of the transportation cost]). The estimated parameters in Table 2 show that import demand decreases by an amount of $Q^* = 15\%$ and price ($P^*$) decreases by 4%. The price changes can be derived from equation (12) as $P^*_{us} = -\frac{1}{\eta'} M^* - \frac{cd'_{us}}{\eta'}$ where $\frac{cd'_{us}}{\eta'}$ is the percent change in price when the import demand quantity does not change due to the Covid-19 pandemic ($M^* = 0$). Based on the parameters in Table 1, $V_D = -14\%$ when the import demand quantity does not change. These parameters are replaced in equations 17-19 to estimate the changes in the welfare of excess suppliers and excess consumers in Period 1.

In period 2, the values of $Q_0$ and $P_0$ are equal to U.S. import volume and price during the July 2018 to June 2019 cycle before Covid-19 occurred. In 2019, $Q_0$ = 588,779 MT and $P_0$ = $7,765/MT. The increase in the excess demand shifts the excess demand curve outward. Specifically, the import demand increases by 9% ($Q^* = 0.09$) and the market price increases by 5% ($P^* = 0.05$). Similarly, the percent change in price when the excess demand quantity does not change due to the Covid-19 pandemic ($M^* = 0$), $V_{ED} = 19\%$. The percent change in price when the excess supply does not change ($\sum_{i=1}^{6} X_i^* = 0$), $V_{ES} = 12\%$). These parameters are placed into equations 23-25 to compute the changes in the welfare of excess suppliers and excess consumers.

At the same time, the supply curve shifts inward due to the input shortage in the net exporters. On average, the shifts in supply curves from India, Indonesia, Ecuador, Thailand, Vietnam, and ROW cause the excess supply to decrease vertically by 12% ($Q^* = -0.12$) and the export price to increase by 8% ($P^* = 0.08$). In equations 12-17, $P_i^* = \frac{1}{\varepsilon_i'} X_i^* - \frac{cs_i'}{\varepsilon_i'}$ where $V_s = \frac{cs_i'}{\varepsilon_i'}$ is a percent increase in market price when export supply is held constant ($X_i^* = 0$). In other words, the value of $V_S$ is equal to 12%. These parameters are used in equations 20-22 to calculate the welfare effects of a shift in excess supply curve on excess consumers and excess suppliers.

The changes in the welfare of the net exporters and consumers are calculated and presented in Table 5. A reduction in demand in period 1 decreases the welfare of excess consumers and excess suppliers by approximately $133 million and $61 million, respectively. Overall, the total economic surplus loss is $194 million, which accounts for approximately 13% of the total trade value.

Period 2 includes two changes in excess supply and excess demand. The total effects of period 2 are a sum of the total surplus due to a simultaneous outward shift of the import demand and an inward shift of export supply. First, shrimp demand is recovered because consumers gradually adapted to changes caused by the Covid-19 impact by increasing shrimp consumption AH. As a result, total import demand increases. The higher import demand causes the excess demand to shift outward, generating higher shrimp demand and market price increases. Both producers and consumers gain from this new price and quantity. Specifically, the domestic shrimp consumers and producers gain $608 million and $278 million, respectively. At the same time, however, net exporters reduce their exports due to the shortage in inputs (e.g., fishmeal and broodstock). Therefore, the export supply curve shifts inward. Consequently, the total economic surplus decreases significantly. However, the total effects in Period 2 benefit both excess demand and excess supply. Specifically, the total impact of the Covid-19 pandemic on excess consumers is equal to $205 million, and excess producers gain an amount of $0.8 million. In aggregate, the total economic surplus benefit due to the shifts of excess demand and excess supply curves is $206 million. This value is equal to approximately 5% of the shrimp trade values before the Covid-19 pandemic in 2019.

***The Effects of Covid-19 on the U.S. Shrimp Producers and Consumers***

Because the United States is the only net importer of shrimp in this model, the effects of the pandemic on the U.S. supply and demand curves are similar to the net importer model. The consumer and producer welfare effects are estimated using equations 17-19 for Period 1 and 23-25 for period 2. The total impact of Covid-19 on U.S. producers and consumers is expected to be similar to the effect on net quasi-consumers in the global shrimp market. We assume that there is no shift in the supply curve in the U.S. shrimp market. In other words, the effect of Covid-19 on excess demand is allocated between U.S. domestic shrimp consumers and producers. Since 93% of the shrimp consumed in the United States is imported, the majority of this effect will be levied by U.S. shrimp consumers. This section shows the effective allocation of the Covid-19 pandemic between consumers and producers of shrimp in the United States in Periods 1 and 2.

In period 1, a reduction in shrimp consumption causes the domestic demand curve to shift inward. Therefore, the U.S. shrimp producer welfare decreases by an amount equal to area (PSus) = $P^0Q^0P^*\left(1+\frac{1}{2}Q^*\right) < 0$. According to the above simulation results, the domestic price decreases by 4%. Equation 2b shows the domestic supply $S^* = \varepsilon_{us}P^*_{us}$. With a price decrease equal to 2% and U.S. domestic supply elasticity $\varepsilon_{US}$ assumed to be 0.70, the change in domestic supply is $S^* = -3.5\%$. Based on data from NOAA, U.S. total shrimp landing in 2019 was 124,914 MT. We assume the landing is monthly flat linear at an average of 10,410 MT/month. The welfare effects on the U.S. shrimp producers and consumers are presented in Table 6. Period 1 includes four months with the amount of landing at approximately 41,638 MT and the price of landing shrimp at $3,906/MT. Therefore, the values of $P^0$ and $Q^0$ are assigned to be $3,906 and 41,638 MT, respectively. As a result, the U.S. producer surplus decreases by an amount of $6.6

million. In addition, the U.S. consumer surplus decreases by $151 million. Overall, the U.S. economic welfare loss is approximately $158 million due to the decrease in shrimp consumption.

In period 2, domestic demand recovery increases producer surplus as follows:

$$\Delta \mathrm{PS}_{US} = \mathrm{P}^0 \mathrm{Q}^0 P^* \left(1 + \frac{1}{2} Q^*\right) > 0$$

Similar to period 1, the domestic supply of 12 months in Period 2 is assumed to be flat linear in the year before the Covid-19 pandemic occurred, so $\mathrm{Q}^0 = 113{,}794$ MT and $\mathrm{P}^0 = \$3{,}906$. During this period, the shrimp price increased by 13%. Accordingly, the domestic shrimp supply increases by 17%. Similar to the excess trading market, U.S. consumers in period 2 gain $621 million. Consequently, the total economic benefit in period 2 is $652 million and the producer surplus increases by $30 million. Overall, the total producer surplus is positive as an aggregate of periods 1 and 2, totaling $24 million.

In aggregate, the total effect of Covid-19 on shrimp producers and consumers in the United States in periods 1 and 2 is positive, totaling $494 million. This value is relatively consistent with the net quasi-consumer welfare gain due to the shifts in the excess demand curve of $475 million. Overall, the recovery of the shrimp market in the United States benefits both domestic producers and consumers. Domestic producers and consumers gain due to the higher demand recovery in Period 2 and the increase in market price. As a result, the U.S. economy gains because the gains by domestic producers and consumers account for approximately 5% of the total values of the shrimp sector in the same period.

The above influential simulations are sensitive to the choice of price elasticities of shrimp supply and demand in the net export and net import countries. These elasticities are varied by country, data, and estimation approach. For instance, U.S. demand for seafood products is more sensitive to price compared to other countries (Gallet, 2009). Therefore, we perform a stochastic simulation of the varied shifts in the domestic demand curve and foreign supply curve. Accordingly, the stochastic simulation provides higher moments of the variable distribution. In this model, $cd_{us}$, $cs_i$, and $C^*$ are treated as random parameters that follow a triangular distribution to address parameter uncertainty. A triangular distribution requires the specification of maximum, most-likely, and minimum values. The baseline values are used as "most-likely" and its minimum and maximum values are set to 0.75 and 1.25 times the baseline values, respectively. With these distributional assumptions, the welfare impacts are simulated 10,000 times to form a sample from which to compute a mean and 95% confidence interval. The stochastic simulation results are shown in Tables 5 and 6. Overall, although the excess suppliers lose due to Covid-19, excess consumers gain almost fourfold. In aggregate, economic welfare gains due to the benefits from excess consumers is much higher than the loss by excess producers. In contrast, although both U.S. shrimp producers and consumers lose in period 1 due to demand reduction, the recovery in shrimp consumption in period 2 makes the welfare of producers and consumers positive. Overall, the U.S. producers and consumers benefit from Covid-19.

## Concluding Remarks

In our analysis of the dynamic impact of the Covid-19 pandemic on the shrimp sector, we find a somewhat surprising result that the virus generated net welfare gains to exporters and importers in aggregate and sizable gains, especially to U.S. producers and consumers. Although both global producers and consumers experienced losses in period 1, the sharp increase in shrimp demand in the United States during period 2 was largely responsible for the net global welfare gain from the coronavirus of which the United States was the largest winner. Over time, the demand for and supply of shrimp changed dramatically. Because the U.S. shrimp market is globally integrated, the changing demand and supply shocks due to the virus directly affect the economics of the pandemic (Nguyen & Kinnucan, 2018).

There are three aspects of our results that should be kept firmly in mind. First, the selected period is critical for any analysis (Schmitz, Moss, & Schmitz, 2020). We selected two periods to measure the effects of Covid-19 on supply, demand, and market prices. When newer, more recent information comes available, it will be interesting to determine how a longer period could affect the results.

Second, there is no single explanation for the increase in shrimp consumption during the Covid-19 pandemic. Factors that impacted shrimp consumption include the reduction in household expenditures on food consumption AFH in favor of food consumption AH (Cranfield, 2020) and increased shrimp consumption due to shrimp being less expensive and easier to cook than other protein food products. Future research is needed to determine the substitutability between expenditures on food consumed AH and AFH. In addition to price, consumer preferences and income are important factors in explaining food consumption under a pandemic shock. Our research focuses mainly on the effect of market prices. Future research should include changes in consumer income and in food preferences and perceptions.

Third, in our trade model, we make a sharp distinction between the welfare effects from the virus globally and the effects only for the United States. The first part of our model and the empirical results use excess supply and demand schedules. Therefore, the net effects are not the summation of producer and consumer surpluses, but rather the effects are quasi surpluses (Just et al., 2004). However, for the United States only, the producer and consumer surplus measures apply because the results are derived from internal supply and demand schedules.

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**Table 1. Shifters, Shrimp Supply and Demand Elasticities, Trade Share Parameters Used to Compute Export Supply and Import Demand Elasticities**

| Variable | Definition | Value |
| --- | --- | --- |
| $v_1$ | An inward shift in U.S. shrimp demand (period 1)[a] | -0.15 |
| $v_2$ | An outward shift in U.S. shrimp demand (period 2)[b] | +0.20 |
| $C$ | An inward shift of supply from shrimp net exporters (period 2) | -0.20 |
| $\eta_{US}$ | U.S. shrimp demand price elasticity | -1.04 |
| $\varepsilon_{US}$ | U.S. shrimp supply price elasticity | 0.70 |
| $\eta_{IND}$ | India's shrimp demand price elasticity | -1.00 |
| $\eta_{INO}$ | Indonesia's shrimp demand price elasticity | -1.02 |
| $\eta_{ECD}$ | Ecuador's shrimp demand price elasticity | -0.79 |
| $\eta_{TLD}$ | Thailand's shrimp demand price elasticity | -0.74 |
| $\eta_{VNM}$ | Vietnam's shrimp demand price elasticity | -3.06 |
| $\eta_{ROW}$ | ROW shrimp demand price elasticity | -0.79 |
| $\varepsilon_i$ | Shrimp supply price elasticity from net exporters | 1.20 |
| $\kappa_m$ | Share of U.S. consumption imported (=$M_{US}/D_{US}$) | 0.93 |
| $l_{eIND}$ | Share of India's production exported ($= X_{IND}/S_{IND}$) | 0.99 |
| $l_{eINO}$ | Share of Indonesia's production exported ($= X_{INO}/S_{INO}$) | 0.32 |
| $l_{eECD}$ | Share of Ecuador's production exported ($= X_{EUD}/S_{EUD}$) | 0.99 |
| $l_{eTHD}$ | Share of Thailand's production exported ($= X_{TLD}/S_{TLD}$) | 0.61 |
| $l_{eVND}$ | Share of Vietnam's production exported ($= X_{VNM}/S_{VNM}$) | 0.92 |

| | | |
|---|---|---|
| $l_{eROW}$ | Share of ROW's production exported ($= X_{ROW}/S_{ROW}$) | 0.60 |

*Source*: Collected from the literature and authors' assumption

[a] In period 1, U.S. shrimp demand curve shifts inward, and domestic supply curve remains fixed[5]

[b] In period 2, U.S. shrimp demand curve shifts outward, and foreign supply curve shifts inward.

[5] In this stage, the excess supply price elasticity remains unchanged. As a result, the inward shift in the excess demand curve does not necessarily change the excess demand price elasticity.

**Table 2. The Elasticities of Import Demand, Export Supply, Export Shares, and Shifting Parameters Used for the EDM Model***

| Item | Definition | Period 1[a] $\varepsilon_i = 1.2$ & $\varepsilon_{US} = 0.7$ | Period 2[b] $\varepsilon_i = 1.2$ & $\varepsilon_{US} = 0.7$ |
|---|---|---|---|
| $\eta'$ | U.S. excess demand elasticity | -1.17 | -1.17 & -1.41 |
| $v'$ | Parameter shifts excess demand curve due to Covid-19 | -0.16 | 0.22 |
| $\varepsilon'$ | Excess supply elasticity | 2.43 | 2.43 & 2.90 |
| $\varepsilon'_{IND}$ | India's excess supply elasticity | 1.22 | 1.22 |
| $cs'_{IND}$ | Parameter shifts excess supply curve from India due to Covid-19 | 0 | -0.20 |
| $\varepsilon'_{INO}$ | Indonesia's excess supply elasticity | 5.92 | 5.92 |
| $cs'_{INO}$ | Parameter shifts excess supply curve from Indonesia due to Covid-19 | 0 | -0.63 |
| $\varepsilon'_{ECD}$ | Ecuador's excess supply elasticity | 1.22 | 1.22 |
| $cs'_{ECD}$ | Parameter shifts excess supply curve from Ecuador due to Covid-19 | 0 | -0.20 |
| $\varepsilon'_{VNM}$ | Vietnam's excess supply elasticity | 1.57 | 1.57 |
| $cs'_{VNM}$ | Parameter shifts excess supply curve from Vietnam due to Covid-19 | 0 | -0.22 |
| $\varepsilon'_{TLD}$ | Thailand's excess supply elasticity | 2.44 | 2.44 |
| $cs'_{TLD}$ | Parameter shifts excess supply curve from Thailand due to Covid-19 | 0 | -0.33 |
| $\varepsilon'_{ROW}$ | ROW excess supply elasticity | 2.53 | 2.53 |
| $cs'_{ROW}$ | Parameter shifts excess supply curve from ROW due to Covid-19 | 0 | -0.33 |
| $kx_{IND}$ | India's share of world export to U.S. market ($= X_{IND}/\sum X_i$) | 0.36 | 0.35 |
| $kx_{INO}$ | Indonesia's share of world export to U.S. market ($= X_{INO}/\sum X_i$) | 0.25 | 0.21 |
| $kx_{ECD}$ | Ecuador's share of world export to U.S. market ($= X_{ECD}/\sum X_i$) | 0.16 | 0.19 |
| $kx_{TLD}$ | Thailand's share of world export to U.S. market ($= X_{TLD}/\sum X_i$) | 0.05 | 0.05 |
| $kx_{VNM}$ | Vietnam's share of world export to U.S. market ($= X_{VNM}/\sum X_i$) | 0.07 | 0.10 |
| $kx_{ROW}$ | ROW share of world export to U.S. market ($= X_{ROW}/\sum X_i$) | 0.11 | 0.10 |

[*] *In the base case, the excess demand elasticity is -1.17 and the excess supply elasticity is 2.43. These elasticities are assumed unchanged under the parallel shifts of the excess supply curve. However, the shift of excess demand curve causes the excess demand and excess supply elasticities more elastic and it is -1.41 and 2.90, respectively.*

[a] *In period 1, excess demand curve shifts inward, and excess supply curve remains fixed.*[6]

[b] *In period 2, excess demand curve shifts outward, and excess supply curve shifts inward.*

[6] In this stage, the excess supply price elasticity remains unchanged. As a result, the inward shift in the excess demand curve does not necessary change the excess demand price elasticity.

**Table 3. The Changes of Excess Demand, Excess Supply, and Prices Due to Covid-19 in Period 1* (%)**

| Variable | Excess demand shifted parameter $cd'_{us}$ =-0.16 | Shipping cost $C^{*}$=0.05 |
|---|---|---|
| | ---% | --- |
| Excess demand | | |
| $M_{US}^{*}$ | -0.11 | -0.04 |
| Excess supply | | |
| $X_{IND}^{*}$ | -0.05 | -0.02 |
| $X_{IDO}^{*}$ | -0.26 | -0.09 |
| $X_{ECD}^{*}$ | -0.05 | -0.02 |
| $X_{TLD}^{*}$ | -0.11 | -0.04 |
| $X_{VNM}^{*}$ | -0.07 | -0.02 |
| $X_{ROW}^{*}$ | -0.11 | -0.04 |
| Prices | | |
| $P_{d}^{*}$ | -0.04 | 0.04 |
| $P^{*}$ | -0.04 | -0.02 |

* In period 1, excess demand curve parallel shifts inward, and excess supply curve remains fixed[7]

[7] In this stage, the excess supply price elasticity remains unchanged. As a result, the inward shift in the excess demand curve does not necessarily change the excess demand price elasticity.

**Table 4. The Effects of Covid-19 on Excess Demand, Excess Supply, and Prices in Period 2**

| Variable | Excess demand shifted outward | Excess supply shifted inward ($cs_i' = -0.31$) | | | | | | Shipping cost |
|---|---|---|---|---|---|---|---|---|
| | $cd_{us}' = 0.22$ | $cs_{IND}'$ | $cs_{INO}'$ | $cs_{ECD}'$ | $cs_{TLD}'$ | $cs_{VNM}'$ | $cs_{ROW}'$ | $C^* = 0.05$ |
| | ---------- % ---------- | | | | | | | |
| Excess demand | | | | | | | | |
| $M_{US}^*$ | 0.15 | -0.02 | -0.04 | -0.01 | -0.01 | -0.01 | -0.01 | -0.04 |
| Excess supply | | | | | | | | |
| $X_{IND}^*$ | 0.07 | -0.18 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 | -0.02 |
| $X_{IDO}^*$ | 0.36 | 0.12 | -0.41 | 0.06 | 0.03 | 0.04 | 0.06 | -0.10 |
| $X_{ECD}^*$ | 0.07 | 0.02 | 0.05 | -0.19 | 0.01 | 0.01 | 0.01 | -0.02 |
| $X_{TLD}^*$ | 0.15 | 0.05 | 0.09 | 0.03 | -0.32 | 0.01 | 0.02 | -0.04 |
| $X_{VNM}^*$ | 0.10 | 0.03 | 0.06 | 0.02 | 0.01 | -0.21 | 0.01 | -0.03 |
| $X_{ROW}^*$ | 0.15 | 0.05 | 0.09 | 0.03 | 0.01 | 0.02 | -0.31 | -0.04 |
| Prices | | | | | | | | |
| $P_d^*$ | 0.06 | 0.02 | 0.04 | 0.01 | 0.00 | 0.01 | 0.01 | 0.03 |
| $P^*$ | 0.06 | 0.02 | 0.04 | 0.01 | 0.00 | 0.01 | 0.01 | -0.02 |

*Note:* $\varepsilon_i$ is the supply elasticity from the net exporters and it is assumed to be the same among the countries.

**Table 5. Welfare Effects of Covid-19 on Excess Supply and Excess Demand (million USD)**

| Indicator | Period 1 | | | Period 2 | | | | | | Total effects (Period 1+ Period 2) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inward shift in import demand<br>*Excess demand elasticity:* $\eta' = -1.17*$<br>*Excess supply elasticity:* $\varepsilon' = 2.43$ | | | Outward shift import demand only<br>*Excess demand elasticity:* $\eta' = -1.17*$<br>*Excess supply elasticity:* $\varepsilon' = 2.43$ | | | Shifts import demand and export supply<br>*Excess demand elasticity:* $\eta' = -1.41*$<br>*Excess supply elasticity:* $\varepsilon' = 2.90$ | | | | | |
| | (1) | | | (2) | | | (3) | | | (1) + (3) | | |
| | ........ million USD ........ | | | | | | | | | | | |
| | 5% limit | **Mean** | 95% limit | 5% limit | Mean | 95% limit | 5% limit | Mean | 95% limit | 5% limit | Mean | 95% limit |
| Net quasi-producer welfare (exporters) ΔPS | -65.0 | **-60.7** | -56.7 | 258.2 | **277.5** | 296.3 | 0.77 | **0.83** | 0.89 | -63.9 | **-59.9** | -55.7 |
| Net quasi-consumer welfare (importers) ΔCS | -142.1 | **-132.8** | -123.9 | 565.7 | **607.5** | 648.6 | 191.0 | **205.4** | 225.9 | 67.8 | **72.6** | 77.5 |
| Total net welfare ΔTS | -207.0 | **-193.5** | -182.2 | 822.0 | **885.0** | 945.9 | 192.3 | **206.2** | 219.9 | -11.8 | **12.7** | 13.6 |

Note: *: The excess demand and supply elasticities are assumed to be fixed under the shifts of excess demand in period 1 and period 2. However, the excess supply shift inward in period 2 caused the excess supply and demand elasticities more elastic and the absolute values of excess supply and demand elasticities increased from 2.43 to 2.90 and from 1.17 to 1.41, respectively.

**Table 6. The Distribution of Welfare Effects of the Covid-19 Pandemic between U.S. Shrimp Producers and Consumers (million USD)**

| Indicator | Period 1<br>An inward shift in U.S. domestic demand<br>$cd_{us1} = -15\%$<br>(1) | | | Period 2<br>An outward shift U.S. domestic demand<br>$cd_{us2} = +20\%$<br>(2) | | | Total effects<br>(Period 1+ Period 2)<br>(1) + (2) | | |
|---|---|---|---|---|---|---|---|---|---|
| | ---million USD--- | | | | | | | | |
| | 5% limit | Mean | 95% limit | 5% limit | Mean | 95% limit | 5% limit | Mean | 95% limit |
| Net producer welfare ΔPS | -6.82 | **-6.64** | -5.76 | 27.1 | **30.4** | 35.4 | 20.3 | **23.8** | 29.6 |
| Net consumer welfare ΔCS | -161.2 | **-151.0** | -140.5 | 579.5 | **621.4** | 663.9 | 418.3 | **470.4** | 523.4 |
| Total net welfare ΔTS | -167.9 | **-157.6** | -146.5 | 606.6 | **651.8** | 669.3 | 438.6 | **494.2** | 553.0 |

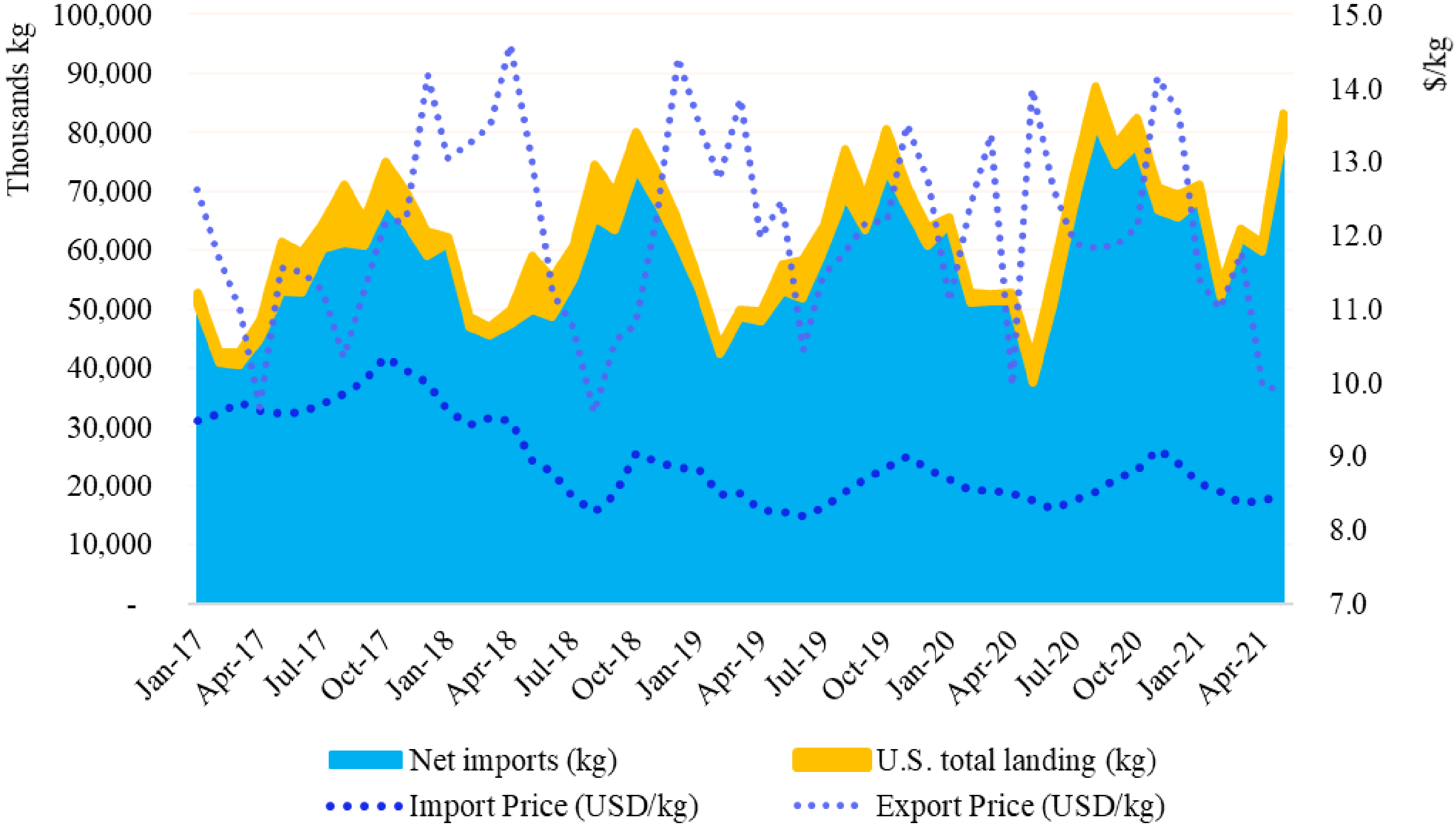
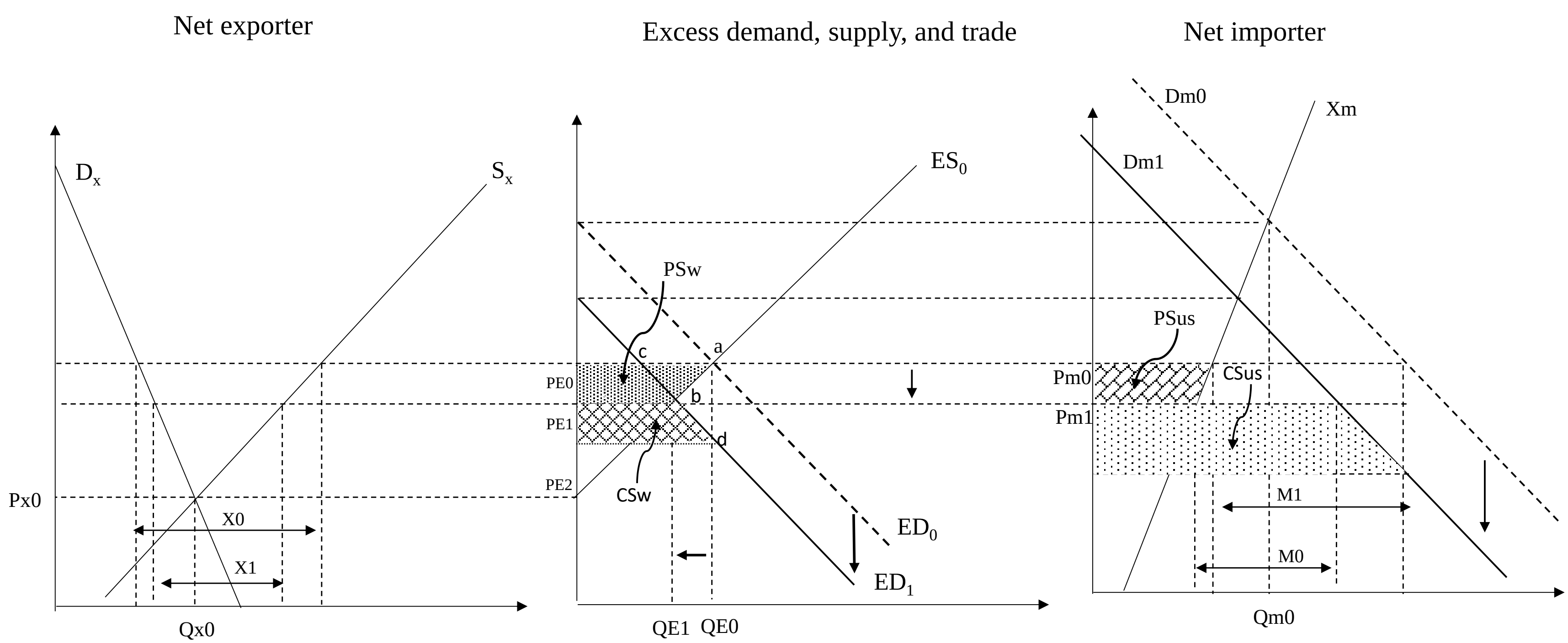



Figure 1. The Contribution of Net Imports and Domestic Landing in the U.S. Domestic Consumption and Import Price from 1/2017 to 5/2021

*Note: Domestic consumption = (Imports - Exports + Total landing) and around 75% of the shrimp harvested in the U.S. comes from the Gulf of Mexico (NOAA, 2020).*

*Source: Shrimp imports, exports, import price, and export price from NOAA (2021), and U.S. total landing from Southern Shrimp Alliance*

Panel A. The effects of Covid-19 on shrimp excess demand and excess supply when the U.S. domestic demand decreases



Panel B. The effects of Covid-19 on shrimp excess demand and excess supply when the U.S. domestic demand increases and foreign supply decreases simultaneously.

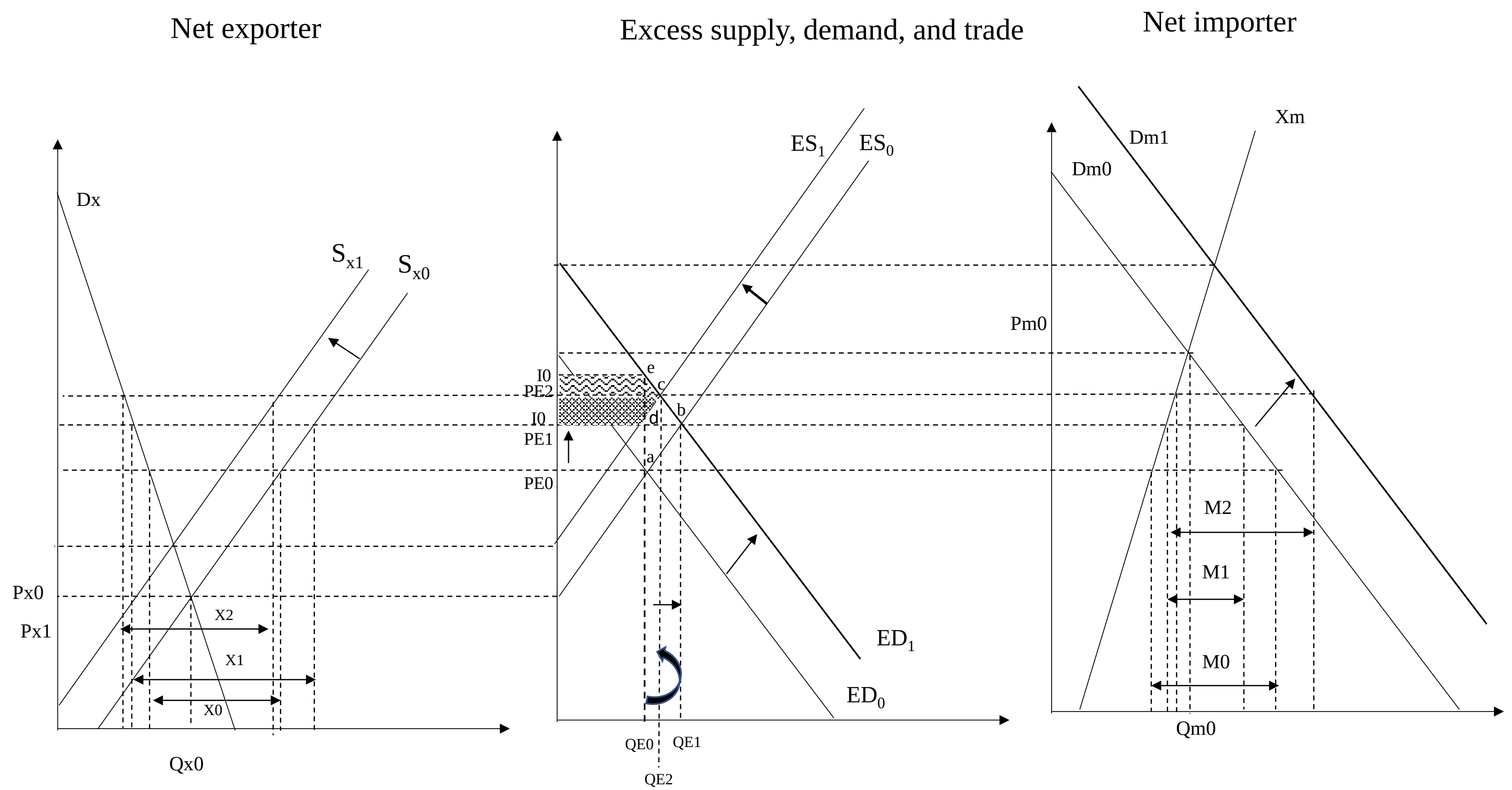



Figure 2. The Effects of the Covid-19 Pandemic on Shrimp Excess Demand and Excess Supply

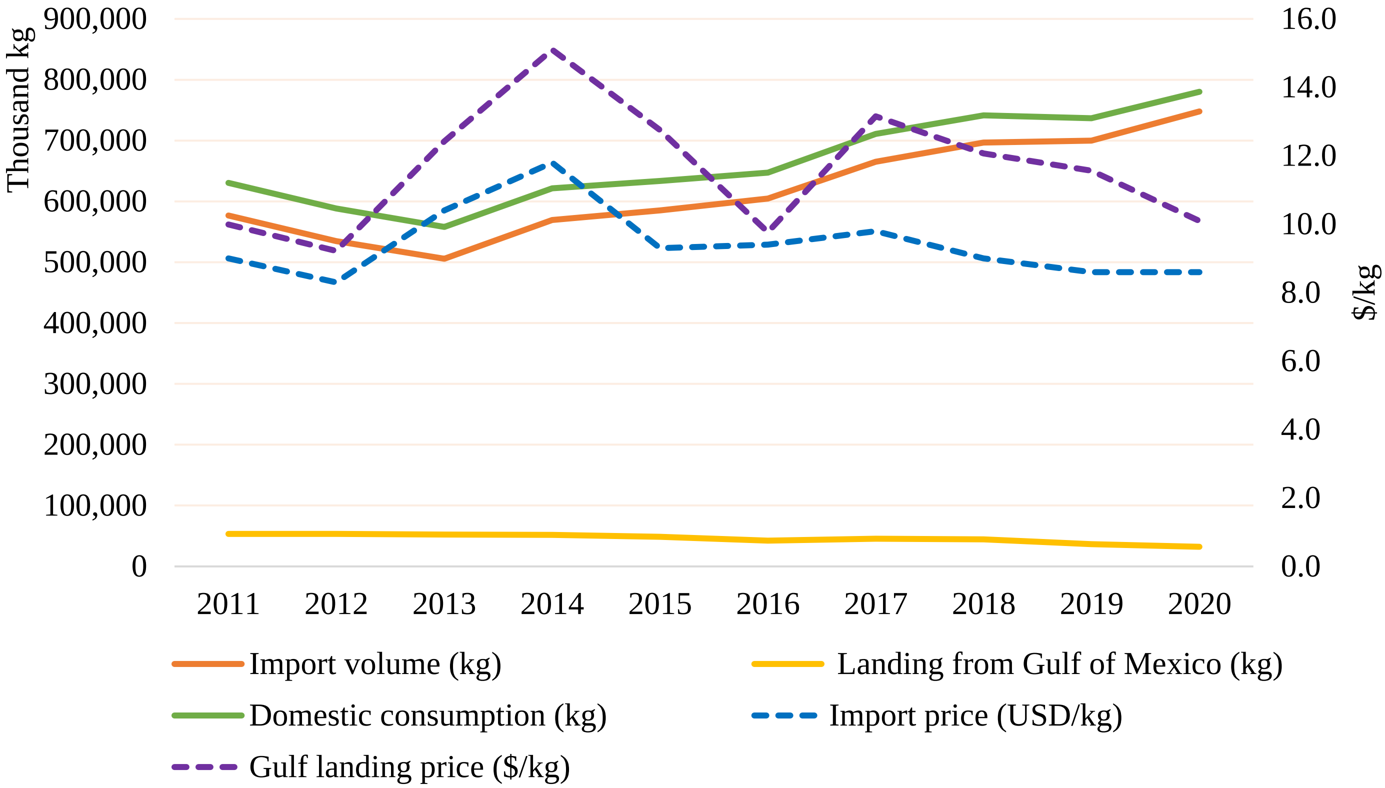



Figure 3. Shrimp Import Share in U.S. Domestic Consumption and Per-Unit Price (2011–2020).

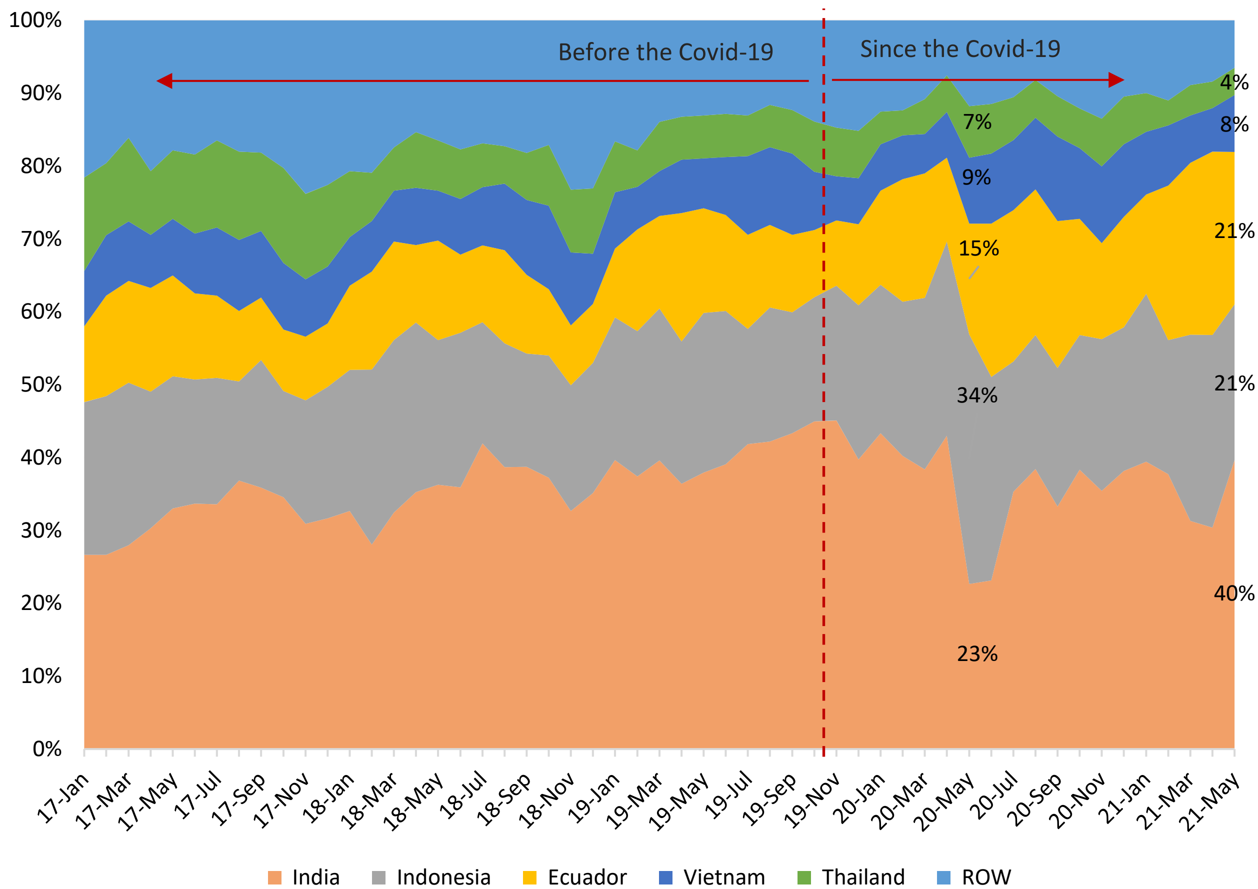



Figure 4. The Market Share of Major Exporters in U.S. Shrimp Imports, from 1/2017 to 5/2021

**dix 1. Price, Quantity, and Quantity Shares for Imported Shrimp in the United States, 2015–2019**

| | Price ($/MT) | Quantity (MT) | Quantity Share (%) | Price ($/MT) | Quantity (MT) | Quantity Share (%) | Price ($/MT) | Quantity (MT) | Qu Sha |
|---|---|---|---|---|---|---|---|---|---|
| | | **2019** | | | **2020** | | **The first six months of 2** | | |
| | 8,628 | 300,672 | 42.96 | 8,663 | 271,736 | 36.48 | 8,470 | 143,143 | 3 |
| ia | 8,506 | 133,163 | 19.02 | 8,831 | 160,714 | 21.99 | 8,689 | 88,883 | 2 |
| r | 6,660 | 82,968 | 11.85 | 6,265 | 125,839 | 12.22 | 6,751 | 90,289 | 2 |
| n | 9,790 | 42,503 | 6.07 | 10,534 | 66,154 | 10.80 | 10,106 | 31,998 | 7 |
| d | 11,009 | 43,272 | 6.18 | 11,208 | 41,449 | 7.20 | 11,083 | 15,956 | 3 |
| World | 8,566 | 97,383 | 13.91 | 8,940 | 81,694 | 11.32 | 9,672 | 33,399 | 8 |
| | --- | 699,962 | 100.0 | --- | 747,587 | 100.0 | --- | 403,668 | 1 |