The Welfare Impacts of Covid-19 on the U.S. Salmon Sector

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Abstract

This research estimates the effects of Covid-19 on the U.S. supply and demand for the salmon market over two distinct periods. The short run reflects the first year (2020) since the Covid-19 outbreak, and the long run covers the second year (2021). The effects of Covid-19 on salmon prices, domestic production, and imports are analyzed using graphics and elasticities derived within spatial welfare economics using the results from the equilibrium displacement model of the U.S. salmon market. In the first year, Covid-19 caused a reduction in domestic demand. As a result, U.S. salmon producers and consumers lost $302 million, of which consumer loss accounts for 87% of this value. In 2021, however, domestic consumption recovered and its positive effect of $447 million outweighs negative impacts in 2020. Therefore, the domestic producers and consumers gained jointly approximately $512 million. Overall, the net market gain (a combination of the short and long-run effects) was $210 million. These results are subject to the magnitudes of change in demand and supply due to Covid-19 and transportation costs.

Keywords: Covid-19, consumption, supply, welfare, price, salmon

1. Introduction

The Covid-19 pandemic had multiple effects across the seafood demand and supply chains in the U.S. (Aday and Aday 2020; Hobbs 2020; Senten, Engle, and Smith 2021). Seafood is one of the crucial protein sources in most American diets[1]. Per capita consumption of fish and shellfish in the U.S. increased gradually to 19.2 pounds (lb) in 2019, from 16.8 lb in 2012 (Fisheries of the United States, 2019). The U.S. is one of the largest seafood importers globally; approximately 90% of total domestic consumption is from imports (National Oceanic and Atmospheric Administration, NOAA, 2021). Any events interrupting domestic and global seafood production and consumption have direct impacts on the welfare of the U.S. seafood industry. Consequently, the country's food security will be influenced by these events.

On January 20, 2020, the U.S. announced its first case of COVID-19. On February 2, the federal government suspended entry into the U.S. of "immigrants or nonimmigrants, of all aliens who were physically present within the People's Republic of China." On March 13, then President Trump declared the coronavirus a national emergency. Federal social distancing guidelines were announced on March 16. The food sector has experienced the most significant surge in prices, supply, and consumption (Akter, 2020). Initially, the pandemic negatively impacted food consumption in 2020 (Dong et al., 2021), which is consistent with personal consumption expenditures declining under the first stage of the Covid-19 pandemic.

In addition to the changes in seafood consumption habits, total seafood consumption decreased globally (Ruiz- Salmón et al., 2022). For seafood in the U.S., in 2020, domestic production decreased and restaurant sales declined; but retail sales increased significantly. Overall, both seafood consumption and domestic production significantly reduced due to Covid-

1 Meat, poultry, and seafood (fish and shellfish) accounted for 51%, 42%, and 7%, respectively, of the 143.9-pound total per capita consumption in 2017 (USDA ERS, 2020).

19 (Love et al., 2021; White et al., 2021; Froehlich et al., 2021). In addition, the demand for local and domestically sourced seafood increased significantly (Stoll et al., 2021). The losses of the U.S. fishing and seafood sector due to Covid-19 vary by sector, region, and industry (NOAA, 2021). In 2020, the first year during the Covid-19 pandemic, total seafood consumption decreased, and seafood consumption habits changed (Ruiz-Salmón et al., 2021). The decrease in seafood consumption in 2020 was due to several factors, including lockdowns, the collapse of the foodservice sector, consumers' working from home, and school closings. However, in the long run, seafood consumption is expected to increase because (1) at-home seafood consumption has risen unprecedently[2], (2) more people can afford cooking seafood at home instead of at restaurants, (3) consumers intentionally moved away from red meat to seafood as a healthier form of protein (Hagenbuch, 2021), and (4) prices of competing products such as beef increased relative to salmon. For example, in 2020, the price of Alaskan sockeye salmon decreased by 50% due to disruption in trade, air freight, and lower demand for fresh fish (White et al. 2021), whereas the wholesale price of beef increased by 24%, from $205/cwt to $255/cwt (Lusk et al., 2021).

The distinction between fresh and frozen seafood became more pronounced during the Covid-19 pandemic since frozen seafood had been a sales growth leader in the frozen department (Blank, 2021). Specifically, in March 2021, frozen seafood sales increased by 29% compared to March 2019, while fresh seafood sales rose 26% and ambient/shelf-stable items sales rose 2% (Blank 2021). Froehlich et al. (2021) determine that seafood consumers have been rapidly shifting from restaurants to retail sales and more convenient prepared products. As a result, seafood

[2] The annual report by Alaska Seafood Marketing Institute (Alaska Seafood 2021) indicates sales have surged for frozen seafood at retail and indirect to consumer online sales.

consumption at retail stores has increased significantly. Therefore, the revenue from seafood sales was anticipated to increase by 6.1% in 2021 (IBISWorld, 2021).

Salmon is the second most favorite seafood in the U.S., following shrimp. On average, Americans consume 2.23 lb. of salmon per year, accounting for 15% of total seafood consumption (Love et al. 2020). Globally, the USA and the EU are the largest consumers of salmon (Salazar and Dresdner, 2021; Kinnucan and Myrland 2005; Asche et al. 2005). In contrast to the EU, most of the domestic consumption of salmon in the U.S. is imported (75% of domestic consumption is from Canada, Chile, and Norway). Therefore, any events interrupting domestic and global seafood production and consumption directly impact the welfare of U.S. salmon consumers and producers. Specifically, in 2020, domestic production decreased and restaurant sales of salmon declined.

Although the total domestic salmon consumption in 2020, responding to the shock of Covid-19, decreased by 5% compared to the consumption in 2019, the domestic consumption in 2021 increased by 8% (Figure 1). The recovery and increase in consumption of salmon are based on a significant rise in imports, domestic production, and an increase in seafood consumption at home. The imports of salmon increased by 6% in 2020, while compared to the same period in 2019, imports increased by 13% in 2021. This trend is consistent with the Great Recession that began in December 2007, causing domestic salmon consumption to decrease by 18% compared to the consumption in 2006; however, the consumption recovered quickly and increased by 5% in 2009. Therefore, the aggregate effects over the first and the second year of Covid-19 are essential information to the policymakers and related stakeholders to implement appropriate support to salmon producers and consumers.

This research determines the impacts of Covid-19 on the U.S. salmon supply, demand, prices, and overall salmon consumer and producer welfare. First, an international trade framework is developed that incorporates classical welfare economics (Other recent papers that examine the effects of Covid-19 using a similar framework include Schmitz et al. (2020); van Kooten and Schmitz (2022); and Schmitz and Nguyen (2022). The welfare economic results are derived from an international trade equilibrium displacement model (EDM). The demand, supply, and welfare simulations in this research are for the first year (2020) of Covid-19 (short run). This analysis was also carried out for 2021 (long run). In the analysis, we determined the effects of Covid-19 on U.S. salmon consumption, considering the increase of transaction costs during the Covid-19 pandemic. The transaction costs from salmon producers to buyers increased due to higher freight rates, closed or shipping delays, restricted borders and customs, health inspection delays, and the large-scale cancellation of flights (FAO, 2020). Because the impact of Covid-19 on consumers' health behavior and food consumption is incomplete (Lawrence et al., 2021; Ammar et al., 2020), this research seeks to provide a better overview of the impacts of Covid-19 on food consumption and consumer welfare in the last two years. Moreover, seafood consumers showed a better nutrient intake profile than non-seafood consumers (Hu and Chan, 2020). Thi research contributes to the literature identifying the impacts of shifts in supply relative to demand on market price fluctuations that may affect consumer nutrient intakes.

2. Theoretical framework

2.1 Comparative statics

The comparative statics use figures to describe the trends and compare the welfare effects of domestic salmon producers and consumers over the short- and long-run during Covid-19 and the increase in transaction costs. In the short run, our models reflect a 5% decrease[3] in salmon consumption due to Covid-19. In the long run, the seafood consumption in the U.S. increased by 8%[4]. However, during the 2021 period, the higher transaction costs affected the imports, such as shipping delays, labor shortages, fees associated with port delays and equipment shortages, and higher freight rates. However, this research only focuses on the increase in higher freight rates or transportation costs due to higher fuel prices affecting the imports because the data of other cost increases are not available yet. Moreover, domestic salmon producers are experiencing difficulties in labor and other input shortages and transport difficulties. Therefore, domestic production has been decreasing as well. A fundamental theme of this research is that market price and volume are considered for the effects of shifts in both supply and demand curves (Brækkan, 2014).

Short-run effects – 2020

The theoretical framework is given in Figure 1a. The salmon total supply curve in the U.S. (S_{TT}) is the sum of domestic production (S_D) plus imports (ES). The domestic demand curve for salmon before Covid-19 is D_{TT}. The initial equilibrium supply and demand volume, is Q_{TT}, at price, P_{US}. In the short run, the Covid-19 pandemic caused the domestic demand to decrease (5%). This reduction caused the U.S. demand curve to shift downward, from D_{TT} to D'_{TT}. The new intersection of the D'_{TT} and S_{TT} curves give the new coordinate (Q'_{TT}, P'_{US}). As a result, the U.S. producers sell less salmon and receive a lower price for each unit sold. The associated welfare loss from the U.S. producer perspective equals the area (P_{US}dcP'_{US}). Similarly, the domestic consumers lose welfare equal to the area (P'_{US}abP''_{US}).

[3] This 5% was based on the statistical data by NOAA presented in Table 1.
[4] This 8% was estimated based on the data of imports and exports in 2021 from NOAA and landing data in 2021 from Alaska salmon harvest updates end of season 2021 (https://www.alaskaseafood.org/industry/market-information/#2021).

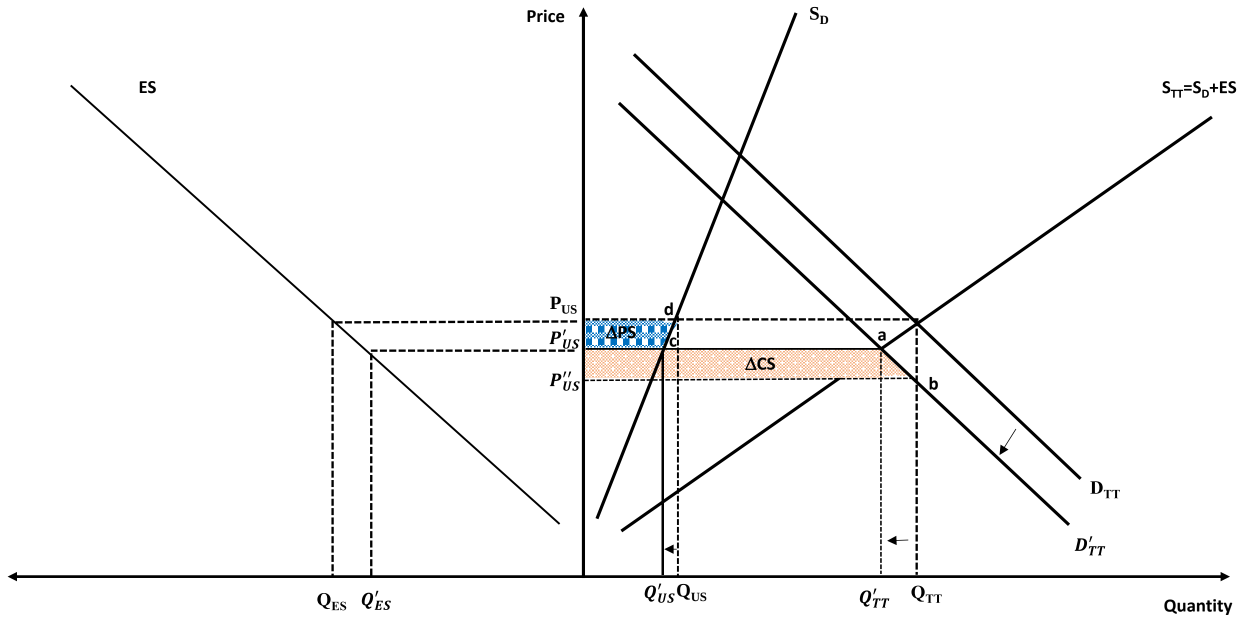

Figure 1a. The short-run welfare impacts of a decrease in demand

The areas (P_{US}dcP'_{US}) and (P'_{US}abP''_{US}) in Figure 1a are measured using the following formula (Just et al., 2004):

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

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

(3) Total change in economics welfare: TS= ΔPS + ΔCS < 0

where V_D is the decrease in market price when quantity is held constant (Q_{TT} does not change). Since $(V_D - P^*) < 0$, a decrease in demand decreases consumer and producer welfare even though price falls.

Long-run effects - 2021

In the second year of Covid-19, total demand recovered and increased in conjunction with increased transportation costs. The effects of transportation costs and Covid-19 on the U.S. salmon producer and consumer welfare in this period are shown in Figures 1b&1c. Figure 1b shows the Covid-19 impacts that led to an increase in salmon consumption in the second year.

Initial equilibrium is given the intersection of the S'_{TT} and D_{TT} where S'_{TT} represents the total supply in the U.S. market as a sum of domestic production and imports, and D_{TT} is the demand for salmon in the absence of Covid-19. At this level of demand, the supply by the domestic producer is Q_{US}, imports are $Q_{US}Q_{TT}$, the domestic market price is P_{US}. The Covid-19 pandemic caused the domestic demand curve to shift outward by a proportion of α. D'_{TT} is the demand curve of salmon in the U.S. under the Covid-19 effect. The intersection of the D'_{TT} and S'_{TT} curves give the coordinate (Q'_{TT}, P'_{US}). Thus, the U.S. producers sell more salmon (Q'_{US}) and receive a higher price for each unit sold (P'_{US}). The associated welfare gain from the U.S. producer perspective equals the area (P_{US}deP'_{US}). In addition, the domestic consumers gain (P'_{US}abP''_{US}) due to the higher consumption.

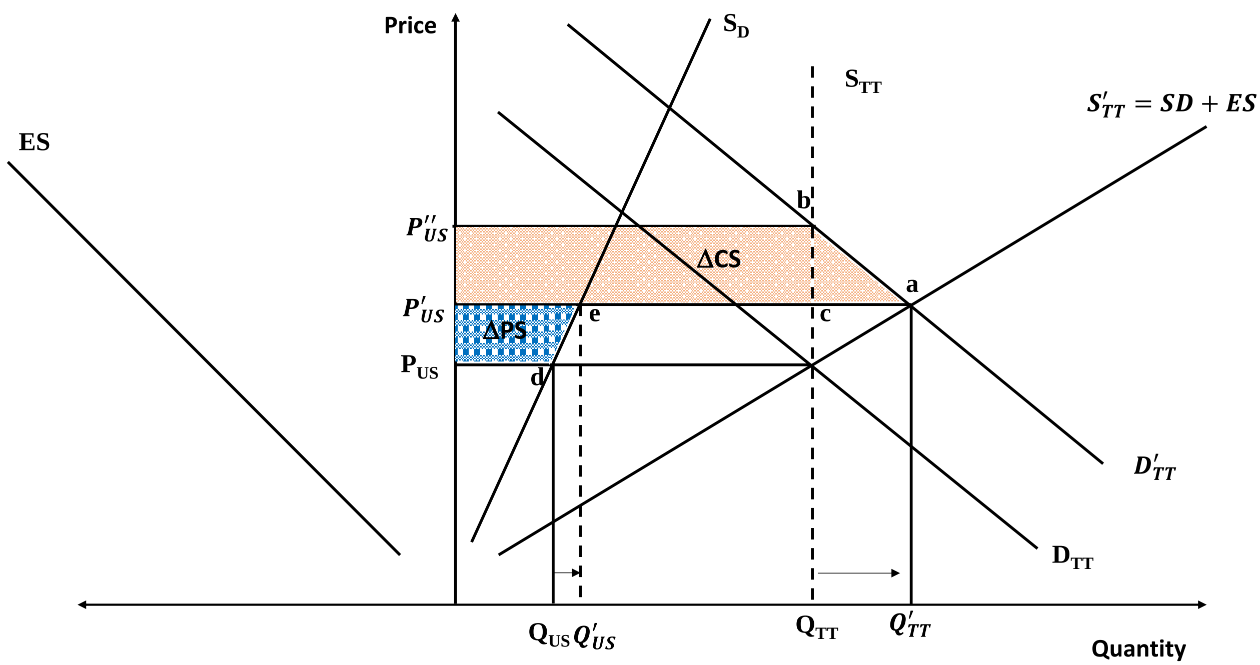

Figure 1b. Long-run welfare effects of Covid-19 caused demand to increase

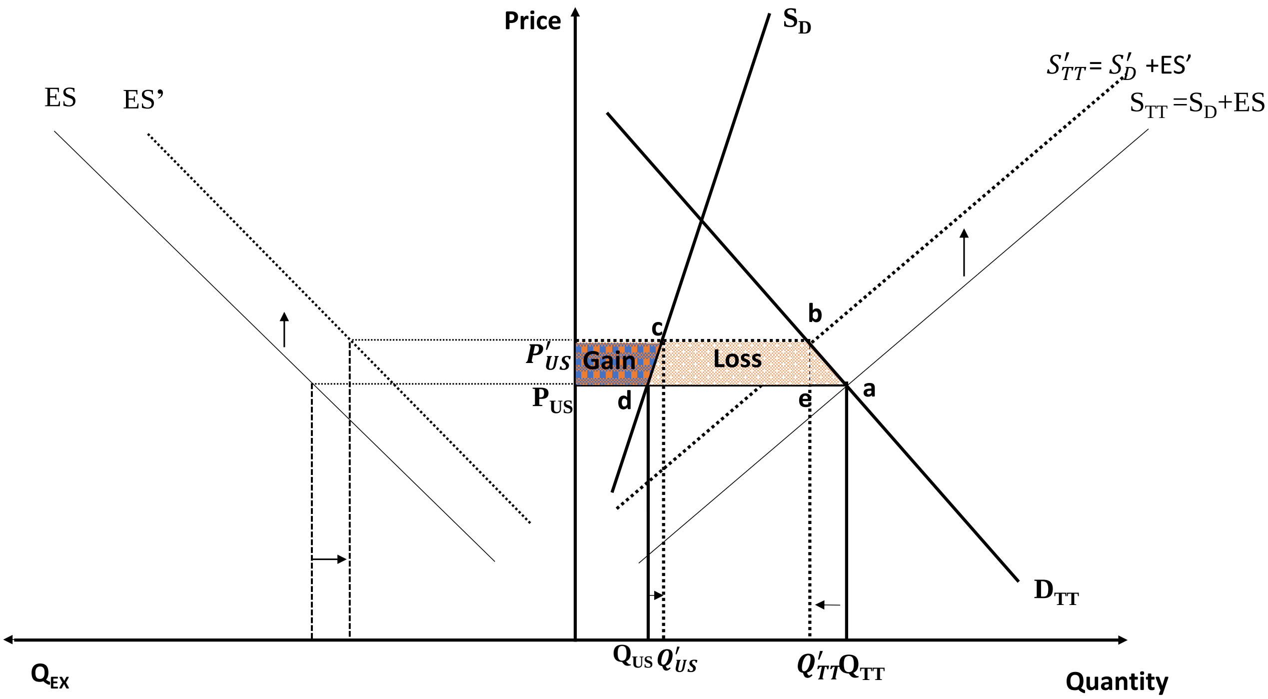

Figure 1c. Long-run welfare effects of an increase in transportation costs

The areas (P_{US}deP'_{US}) and (P'_{US}abP''_{US}) in Figure 1b are measured using the following formula (Just et al., 2004):

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

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

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

where V_D is the increase in market price when quantity is held constant (Q_{TT} does not change) Because $(V_D - P^*) > 0$, an increase in demand increases consumer and producer welfare.

Figure 1c shows the effect of transportation cost increase. In this figure, S_{TT} is the aggregate supply curve for the U.S. salmon before the transportation cost increased, D_{TT} is the domestic demand curve. The intersection of these curves finds the coordinate ($P_{US}Q_{TT}$) as the initial equilibrium of price and quantity. An increase in transportation cost shifted the unified supply curve from S_{TT} to S'_{TT}. In this model, we assume the transportation cost only affects the imports of salmon. Therefore, the total supply reduction due to transportation cost increase is levied on imports. The intersection of S'_{TT} and D_{TT} gives a new coordinate (Q'_{TT}, P'_{US}). An increase in transportation costs reduces the equilibrium quantity of U.S. salmon to Q'_{TT} and increases the equilibrium price per unit of salmon sold to P'_{US}. At this intersection, the U.S. producers benefit from selling more salmon (Q'_{US}) and receiving a higher price per unit sold (P'_{US}). The associated welfare gain from the U.S. producer perspective equals (P_{US}dcP'_{US}).

However, in reality, the gain by U.S. producers could be less than this area due to labor shortage and higher input prices. According to the Alaska salmon harvest updated by the end of seafood 2021, the 2021 Alaska sockeye and pink salmon increased on average by 31% compared to the harvest in 2020 by weight. Therefore, we assume that the U.S. domestic salmon production in the long run increased up to 31% and it is represented by the domestic production volume to increase from Q_{US} to Q'_{US}. This supply increase is the potential to substitute for the imports. Thus, the domestic producer welfare becomes (P_{US}dcP'_{US}). The higher market price due to the lower total supply caused the domestic consumer to lose (P_{US}abP'_{US}). However, in the long run, the effects of moving along the supply curve caused the domestic production to increase from Q_{US} to Q'_{US}. Therefore, the producer gained and consumer lost from supply rightward shift (parallel supply shift).

The areas (P_{US}abP'_{US}) and ($P_{US}dcP'_{US}$) are measured using the following formula:

(7) The benefit: (domestic producer surplus) $\Delta \text{PS} = \text{P}^0\text{Q}^0 P^*\left(1 + \frac{1}{2}Q^*\right) > 0$

(8) The loss (consumer surplus) $\Delta \text{CS} = -\text{P}^0\text{Q}^0 P^*\left(1 + \frac{1}{2}Q^*\right) < 0$

(9) Total change in economics welfare TS= ΔPS + ΔCS

Overall, during the Covid-19 pandemic, the increase in transportation costs and domestic consumption could benefit domestic producers due to higher market prices if there is not a significant reduction in domestic production due to other factors. However, its effects on salmon consumers are uncertain depending on the weight effects between an increase in transportation costs and consumption growth. Therefore, the simulations in the next part will show more accurate parameters of the effects.

2.2 Model simulation

The effects of the Covid-19 pandemic on the U.S. salmon are classified into two major components. First, the total demand for salmon decreased/increased, represented by a parallel inward/outward shift in the demand curve and an increase in transportation costs levied on the import price. Moreover, the long-run positive effect of Covid-19 on the domestic producers is an increase in domestic production due to higher prices.

A structural model to evaluate the effects of COVID-19 on the U.S. salmon industry in a partial equilibrium setting consists of eight equations as follows:

(10) $Q^D = D(P_{US}, C_v\ )$ Domestic demand

(11) $Q_{US}^S = S_{US}(P_{US})$ Domestic supply

(12) $Q_m^S = S_m(P_m)$ Import supply

(13) $P_{US} = P_m + T_m$ Price link between the U.S. market and imports

(14) $Q^D = Q_{US}^S + Q_m^S$ Market equilibrium

Where Q_D is the U.S. demand of salmon; Q_{US}^S and Q_m^S are the supply from U.S. domestic production and imports, respectively; P_{US} is the price of salmon in the U.S., P_m is the import price exclusive of transportation quantities cost; C_v is the shift variable to indicate the effects of COVID-19 on the U.S. demand for salmon; T_m is the per unit cost associated with shipping salmon from exporting countries to the United States.

In this model, the law of one price (LOP) is assumed, and other variables that shift the salmon supply and demand (e.g., consumer income and the prices of substitutes and complements) curves are suppressed. Supply is an increasing function of price ($\frac{\partial Q_{US}^{S}}{\partial P_{US}} > 0$ and $\frac{\partial Q_{m}^{S}}{\partial P_{m}} > 0$); demands are a decreasing function of price ($\partial Q^{D}/P_{US} < 0$); and COVID-19 shifts the demand curves to the left in the short run ($\partial Q^{D}/C_{v} < 0$) then to the right in the long run ($\partial Q^{D}/C_{v} > 0$).

Equations (10)-(14) can be converted to an EDM model (Piggott, 1992; Wohlgenant, 2011) by taking the total differential of each equation and converting absolute changes in the variables to relative changes to yield:

(15) $$\tilde{Q}^{D} = -\eta \tilde{P}_{US} + \alpha$$

(16) $$\tilde{Q}_{US}^{S} = \varepsilon_{US} \tilde{P}_{US}$$

(17) $$\tilde{Q}_{m}^{S} = \varepsilon_{m} \tilde{P}_{m}$$

(18) $$\tilde{P}_{US} = (1-\tau_{m})\tilde{P}_{m} + \tau_{m}\tilde{T}_{m} \qquad \tau_{m} = \frac{C_{m}}{P_{US}} < 1$$

(19) $$\tilde{Q}^{D} = k_{US}\tilde{Q}_{US}^{S} + k_{m}\tilde{Q}_{m}^{S}$$

where $X^{*} = dX/X$ is the relative change in variable X; η is the elasticity of domestic demand with respect to price; ε_{US} and ε_{m} are the price elasticity of domestic and export supply, respectively; $k_{US} = \frac{Q_{US}^{S}}{Q^{D}}$ is the share of consumption from domestic supply and $k_{m} = \frac{Q_{m}^{S}}{Q^{D}}$ is the share of consumption from imports; τ_{m} is ad valorem or proportional transportation cost associated with shipping salmon from exporting countries to the U.S. (plus any additional costs such as tariff imposed by the U.S. on the imported products) (per unit transportation cost divided by the U.S. price in initial equilibrium); α is a shifting parameter that indicates the proportional horizontal shift in the respective demand curve due to COVID-19, i.e., the shift in the quantity direction with price held constant.

The effects of changes in transportation costs and Covid-19 on equilibrium price and quantity of U.S. salmon and imports are determined by solving the model for the reduced-form equations for : $\tilde{Q}^D$, $\tilde{Q}^S_{US}$, $\tilde{Q}^S_m$, $\tilde{P}_{US}$, and $\tilde{P}_m$. Specifically, the effects of Covid-19 and transportation costs on the U.S. price are determined by solving equations (15) - (19) simultaneously for $\tilde{P}_{US}$ to yield:

(20) $$\tilde{P}_{US} = \frac{(1-\tau_m)}{k_m\varepsilon_m+(1-\tau_m)(\eta+k_{US}\varepsilon_{US})}\alpha + \frac{k_m\varepsilon_m\tau_m}{k_m\varepsilon_m+(1-\tau_m)(\eta+k_{US}\varepsilon_{US})}\tilde{T}_m$$

If we denote $\frac{k_m\varepsilon_m}{k_m\varepsilon_m+(\eta+k_{US}\varepsilon_{US})(1-\tau_m)} = \mu$

since $(\eta + k_{US}\varepsilon_{US})(1-\tau_m) > 0$ then $0 < \mu < 1$

(20a) $$\tilde{P}_{US} = \frac{\mu(1-\tau_m)}{k_m\varepsilon_m}\alpha + \mu\tau_m\tilde{T}_m$$

where $\frac{\mu(1-\tau_m)}{k_m\varepsilon_m}$ presents the effect of a shift in demand due to Covid-19 on the U.S. price and it is positive to α. Therefore, if the Covid-19 caused the U.S. demand to increase, the U.S. price would increase accordingly and vice versa.

Noting that $\tau_m = \frac{T_m}{P_{US}}$, the effect of transportation costs on the U.S. price can be expressed as:

(20b) $$dP_{US} = \mu dT_m$$

Equation (20b) shows that a one-dollar increase in transportation costs causes the U.S. price to rise by less than a dollar.

The effects of transportation costs and Covid-19 on the U.S. demand of salmon imported can be derived by deleting equation (17) and solving the remaining equations simultaneously for $\tilde{Q}_m^S$ in terms of importing price ($\tilde{P}_m$), transportation cost ($\tilde{T}_m$) and the Covid-10 effect (α) to yield:

(21) $$\tilde{Q}_m^S = \frac{(1-\tau_m)(\eta - k_{US}\varepsilon_{US})}{k_m}\tilde{P}_m + \frac{\tau_m(\eta - k_{US}\varepsilon_{US})}{k_m}\tilde{T}_m + \frac{1}{k_m}\alpha$$

where $\frac{(1-\tau_m)(\eta - k_{US}\varepsilon_{US})}{k_m} < 0$ is the U.S. demand elasticity of importing salmon with respect to import price; $\frac{\tau_m(\eta - k_{US}\varepsilon_{US})}{k_m} < 0$ and $\frac{1}{k_m} > 0$ are the effects of transportation costs and Covid-19 on the import demand.

Further, the positive effect of Covid-19 on the domestic demand causes the import demand to increase ($\frac{1}{k_m}$). An increase in the reduction of domestic production due to Covid-19 will magnify the imports. Therefore, the aggregate effects of transportation cost and Covid-19 on the import demand are either positive or negative depending on whether transportation costs or Covid-19 has a higher effect. Equation (21) also shows that the import demand depends on the degree to which U.S. consumption is made up of imports. Specifically, the import demand curve becomes less elastic when the share of the imports in total domestic consumption increases (larger k_m). In addition, the more sensitive domestic producers and consumers are to the price, the more elastic the import demand curve is.

2.3 Data and parameterization

The numerical values used to determine the effects of Covid-19 on market prices and volumes derived from the EDM model are given in Table 1. Accordingly, the shares of imports and domestic production in domestic consumption, k_m and k_{US}, are set to their average values of 2017-2019. The U.S. supply and demand elasticities are based on empirical estimates. For example, Herrmann and Lin (1993) and Steen et al. (1997) are the only known studies of supply elasticities. Empirical estimates of demand elasticities for salmon are more abundant (Asche et al., 1998; Asche et al., 1999; DeVoretz and Salvanes, 1993; Herrman et al., 1993; Bjorndal et al., 1992). However, these estimates lack the geographic coverage to be of much use here. Therefore, we set the salmon price import supply elasticity (ε_m) to equal 1.5 based on Steen et al.'s (1997) analysis. This study estimates the long-run supply elasticity for Norwegian farmed salmon to be 1.54. The U.S. salmon demand elasticity (η) is set to be equal to 1.2 based on Bjorndal et al.'s (1996) summary of the empirical literature, which is suggested by Wellman (1992) as a "best-bet" value for this parameter. Although demand for the various fish products is relatively inelastic (Wellman, 1992), it is reasonable to indicate salmon demand is elastic since it is one of the most expensive seafood commodities. The value of 0.39 for the domestic supply elasticity (ε_{US}) is based the estimate by Kinnucan and Myrland (2002).

In reality, the elasticity parameters may be different by geographic and sample characteristics. Therefore, we conducted both deterministic and scholastic simulations of Equations (15-19). In the deterministic simulations η, ε_{us}, and ε_m are set to baseline values as given in Table 1. In the stochastic simulations η, ε_{us}, and ε_m are treated as random variables that follow a triangle distribution in which the most-likely values are set to their baseline values, and the minimum and maximum values are set to 0.5 and 1.5 times the most-likely values. Using the package @Crystal Ball in Excel, mean values and confidence limits are computed based on 1,000 random draws.

Table 1. The U.S. Salmon Production, Imports, Exports, and Prices, 2016 - 2020

Variable definition	Value by year				
	2017	2018	2019	2020	2021
U.S. Production (MT) (Q_{US}^{S})	554,688	309,218	462,033	304,126	398,475
U.S. Imports (MT) (Q_{m}^{S})	603,594	661,089	695,627	735,492	782,686
U.S. Exports (MT) (Q_{X}^{S})	357,608	275,284	304,147	227,369	256,298
U.S. Consumption ($\tilde{Q}^{D}$=$Q_{US}^{S} + Q_{m}^{S} - Q_{X}^{S}$)	800,673	695,023	853,513	812,249	924,863
Quantity share of imports ($Q_{m}^{S}/\tilde{Q}^{D}$)	0.75	0.95	0.82	0.91	0.85
Quantity share of U.S. net production ($Q_{m}^{S} - Q_{X}^{S}$)/ $\tilde{Q}^{D}$)	0.25	0.05	0.18	0.09	0.15
Domestic price, farmed whole salmon ($/kg)	8.11	8.62	7.67	6.88	9.06
Domestic price, wild whole salmon ($/kg)	8.55	9.65	7.95	6.94	9.23
Import price, farmed whole salmon ($/kg)	11.4	11.6	10.4	11.6	10.1
Import price, wild whole salmon ($/kg)	8.9	8.7	7.9	8.3	8.6
U.S. supply elasticity for salmon ε_{us}			0.39		
Import supply elasticity to the U.S. ε_{m}			1.5		
US salmon demand elasticity η			1.2		
US's initial shipping rate (%) τ_{m}			15.0		
An increase in shipping cost (%) $\tilde{C}_{m}$in 2021			11.0 or 20.0		
A shift in U.S.'s demand for U.S. salmon due to COVID-19 (%) α_{2020}			-9.33		
A shift in U.S.'s demand for U.S. salmon due to COVID-19 (%) α_{2021}			14.9		

Source: NOAA Salmon Supply Data, 2021; authors' simulation, and literature review. Domestic price of whole salmon was based on the market prices from Urner Barry's Comtell and import prices were from NOAA Foreign Trade Data

3. Results

3.1 The short-run effects of Covid-19 on the U.S. salmon price and welfare

Covid-19 caused the domestic consumption of salmon to decrease by 5% in 2020. In response to this total consumption decrease, the vertical shift of the demand curve was 9.3% (α =9.3%). Other exogenous variables that affect the salmon market are suppressed.

Table 2. Model Parameters: Covid-19 Short-Run Effects (Decrease in Salmon Demand) – 2020

Endogenous Variable	$Covid - 19\ (\alpha = -9.33\%)$		
	2.5% limit	Mean	97.5% limit
$\tilde{P}_{US}$	-0.05	-0.04	-0.03
$\tilde{P}_m$	-0.05	-0.04	-0.03
$\tilde{Q}^D$	-0.06	-0.05	-0.04
$\tilde{Q}^S_{US}$	-0.01	-0.01	-0.02
$\tilde{Q}^S_m$	-0.07	-0.06	0.04

The effects of this inward shift of the demand curve on domestic production, imports, and prices are presented in Table 2. Accordingly, on average, a 5% decrease in domestic consumption caused the domestic and import prices to decrease by 4%. As a result, domestic production decreased by 1%, and imports decreased approximately 6%. Overall, in the short run, the reduction of salmon domestic consumption due to Covid-19 caused the market prices to decrease and domestic production and imports to decrease accordingly.

The consequent effects on the welfare of domestic producers and consumers are presented in Table 3. Overall, consumers and producers lost their benefits due to lower market volume and lower prices in which consumers bear most of the effects. Specifically, on average, U.S. salmon consumers lost $361 million in 2020, accounting for approximately 4% of total consumption value. Likewise, producers lost $34 million, equivalent to 3% of domestic production value, due to the reductions in demand and lower market prices. In all, a 4.5% reduction in demand due to Covid-19 caused the market welfare to lose $395 million.

Table 3. Effects of A Decrease in Salmon Demand (5%) on the Welfare of U.S. Salmon Producers and Consumers in 2020

	Effect Values		
	2.5% limit	Mean	97.5% limit
Consumer welfare Effect (mil $)	-506	-262	-153
Producer welfare Effect (mil $)	-53.8	-40.1	-31.5
Total welfare Effect (mil $)	-560	-302	-185

3.2 The long-run effects of Covid-19 on the U.S. salmon price and welfare

The effects of an increase in consumption

Based on the preliminary data of Alaska salmon harvest end of seafood 2021 and the imports data from NOAA through November 2021, we assume the domestic consumption of salmon increased by 8% in 2021. The effects of a hypothetical increase in domestic demand due to Covid-19 on the U.S. market price and import demand, in the long run, are determined by using equations (15) to (19). The effect parameters of an 8% increase in domestic consumption on domestic price and supply are presented in Table 4.

Overall, the effects of Covid-19 on domestic consumption cause the highest impact on the market price, and a decrease in domestic production provides the most negligible impact on the market price. It is reasonable since domestic production accounts for only 10% of domestic consumption. A 10% increase in domestic demand increases the domestic market price by 7%, and its impact is similar to the import price. The higher domestic price causes domestic production and imports supply to increase by 3% and 13%, respectively. The response of domestic production to the growth of price is much less elastic than the response of imports. Therefore, any policy intervention given to domestic production would provide relatively small effects on the market supply, demand, and price than do the imports. These effects reflect a highly dependent supply of the salmon market on imports.

Table 4. Model Parameters: Covid-19 Long-Run Effects (Increase in Salmon Demand) – 2021

Endogenous variables	$Covid-19\ (\alpha = 14.9\%)^{*}$		
	2.5% limit	Mean	97.5% limit
$\tilde{P}_{US}$	0.05	0.06	0.08
$\tilde{P}_{m}$	0.05	0.06	0.08
$\tilde{Q}^{D}$	0.06	0.08	0.10
$\tilde{Q}^{S}_{US}$	0.01	0.02	0.04
$\tilde{Q}^{S}_{m}$	0.06	0.09	0.11

Note: * is the proportional value of outward shift in demand curve in responding to an 8% increase in domestic consumption.

The effects of an increase in demand due to Covid-19 on the welfare of salmon producers and consumers in the U.S. are given in Table 5. The impacts of Covid-19 on domestic producers and consumers were obtained by simulation of the EDM model with the shift of the demand curve parameter α equal to 19% reflecting the total demand increase by 10%. The results show a 10% increase in domestic demand due to Covid-19 increased U.S. producer surplus by $78 million on annual basic, equivalent to between 8%

of domestic production revenue. Similarly, a 10% increase in consumption increased domestic consumer welfare by $877 million, equivalent to 9% of salmon domestic consumption value. Overall, consumers received most of the benefits of demand growth due to the Covid-19 pandemic, and the total social welfare benefit is $955 million. An increase in demand for U.S. salmon created a relatively small benefit to the domestic producers because more than 90% of the salmon supply is from imports. Therefore, foreign salmon producers could increase their imports to fill in the gap.

Table 5. Effects of A Increase in Demand (8%) on the Welfare of U.S. Salmon Producers and Consumers in 2021

	Effect Values		
	2.5% limit	Mean	97.5% limit
Consumer welfare Effect (mil $)	258	447	873
Producer welfare Effect (mil $)	51.0	65.4	88.2
Total welfare Effect (mil $)	309	512	961

3.3 The effects of an increase in transportation costs

Transportation costs are a part of overall transaction costs in the salmon supply chain. These are included in the basic parameters underlined in the results in Tables 3 & 5, in which the transportation costs were set at 10% of the market price of salmon (the difference between FOB and CIF prices).

Fuel is one of the key inputs in salmon production and transportation (Ziegler et al., 2012). Specifically, more than one-fifth of salmon transportation costs are fuel (Salmonbusiness, 2021). Hence, total salmon production is related to fuel costs (Salazar and Dresdner, 2021). Therefore, the explosion in fuel prices at the beginning of 2021 is a critical challenge to salmon importers and exporters.

Several price observers said that the 10% transportation costs are too low. Therefore, we simulate the effects of higher transportation. In the first scenario, we increased the transportation costs by 11% relative to the base cost of 10%. In the second model, we increased the transportation costs by 20% compared to the base.

The parameters that show the effects of a transportation cost increase on the market prices and volume are presented in Table 6. The first three columns present the effects of an 11% increase in transportation costs (over the base of 10% transportation costs). The 11% increase was based on the gap between FOB and CIF prices from the USDA data in 2021 for salmon imports. This gap calculation is based on Haskel and Slaughter (2003), indicating the transportation costs are the difference between import valued costs, insurance, freight, and imports valued FOB all as a share of imports values FOB. The last three columns show the effects of a 20% increase in transportation costs.

Table 6. Model Parameters of Increased Transportation Costs

Endogenous variables	Transportation cost (τ_m = 11%)			Transportation cost (τ_m = 20%)		
	2.5% limit	Mean	97.5% limit	2.5% limit	Mean	97.5% limit
$\tilde{P}_{US}$	0.04	0.05	0.07	0.07	0.10	0.13
$\tilde{P}_m$	-0.07	-0.06	-0.04	-0.13	-0.10	-0.07
$\tilde{Q}^D$	-0.08	-0.07	-0.05	-0.15	-0.12	-0.09
$\tilde{Q}^S_{US}$	0.01	0.02	0.03	0.02	0.04	0.06
$\tilde{Q}^S_m$	-0.11	-0.08	-0.06	-0.19	-0.15	-0.11

Note: the changes in transportation cost is simulated in which the demand is fixed (i.e., the same demand shift as in Tables 3&5)

The results from Table 6 show that an 11% increase in transportation costs caused the domestic prices to increase by 5%, imports to increase by 8%, and domestic consumption to decrease by 7%. The decrease in imports and higher domestic demand resulted in a domestic production increase of 2%.

Overall, all other exogenous factors are suppressed; the increase in transportation costs caused domestic production and domestic price increases. Like import tariffs, the increase in transportation costs creates discrimination in domestic and import prices in which the domestic consumers have to pay for higher prices (Haskel and Slaughter, 2003; Sercu, 1992). Although the domestic producers gain from higher domestic prices due to the higher transportation costs, its benefit to domestic producers is much lower than the cost levied on domestic consumers

Table 7. Welfare Effects of Increased Transportation Costs on U.S. Producers and Consumers

Percent Change	Producer welfare Effect (mil $)			Consumer welfare Effect (mil $)			Total welfare Effect (mil $)		
	2.5% limit	Mean	97.5% limit	2.5% limit	Mean	97.5% limit	2.5% limit	Mean	97.5% limit
Transportation cost increase *(%)*									
11%	44.2	60.7	79.1	-458	-351	-258	-414	-290	-179
20%	80.7	111	146	-813	-620	-458	-732	-509	-312

Note: The base model assumes the proportion of transportation costs to market price was set as 10% (Table 5).

The effects of the increase in transportation costs on welfare are obtained by simulating the EDM model with transportation costs set to increase by 11% and 20% on average. These simulated results to determine the effects of an increase in transportation costs on the welfare of producers and consumers are presented in Table 7. The rise in transportation costs by 11% decreased the U.S. consumer surplus by $351 million, equivalent to 5% of the domestic salmon consumption value. Simultaneously, the U.S. producer surplus increased by $60.6 million, equivalent to 6% of the domestic production value.

Similarly, if the transportation costs increase by 20%, the U.S. consumer surplus will decrease by $620 billion, equivalent to 9% of domestic salmon consumption value. In addition, the U.S. producers gain $111 million, equal to 10% of domestic supply value.

4. Summary: total effects of Covid-19 and transportation costs

The summary of the total effects of the changes in demand and supply in the short and long run due to Covid-19 is presented in Table 8. Overall, salmon consumption in the U.S. decreased in the short run in responding to the shocks of the closure of restaurants and food service establishments, the implementation of social distancing policies, transportation delays, and labor force shortage. However, both domestic consumers and producers benefited from the Covid-19 pandemic in the long run. The salmon sector has quickly adapted and recovered in the long run because consumers switched to cooking seafood more often at home, and suppliers have changed to provide more convenient prepared products and a better delivery system. Therefore, the salmon sector benefited from the pandemic in the long run because the increase in domestic demand was higher than the decrease in consumption in the short run. Specifically, in the last two years, the domestic salmon producers and consumers gained $25 million and $185 million, respectively, for a total of $210 million. Overall, the net welfare measurements show that the changes in demand during Covid-19 increased domestic consumer and producer welfare by 3% and 2%, respectively.

Table 8. A Summary of Short and Long-Run Effects of Covid-19 on the U.S. Salmon Sector due to the Changes in Demand

Welfare effects	Transportation costs: 10%		
	Short run (Decrease in demand)	Long run (Increase in demand)	Total of short-and long run
Producer	-40.1	65.4	25.3
Consumer	-262	447	185
Total effect	-302	512	210
	Increase in transportation costs (11%)		
Producer	0	60.7	60.7
Consumer	0	-351	-351
Total effect	0	-290	-290
	Increase in transportation costs (20%)		
Producer	0	111	111
Consumer	0	-620	-620
Total effect	0	-509	-509

Note: In the long run, the total welfare was based on the assumption of a 10% increase in consumption

Simultaneously, the 11% increase in transportation costs reduced consumer welfare by 5% and increased the welfare of domestic producers by 6%. Although the demand changes benefited domestic consumers in the long run, adding the increase in transportation costs caused negative effects on the U.S. consumers because the negative impact of transportation costs on consumers is more significant than the net effects of the demand changes. These effects could be higher if the transportation costs increase by 20%. The sum of short- and long-run demand changes and the increase in transportation costs caused the domestic demand to decrease by 2% and domestic production to increase by 4%. As a result, the net welfare effects on domestic producers gained $86 million. Conversely, domestic consumers lost $166 million. Therefore, the net social welfare effects lost approximately $80 million. Overall, the Covid-19 pandemic benefits domestic producers and consumers due to the demand changes. However, when the increase in transportation costs is accounted for, domestic consumers lose in all because the negative effect of transportation costs on consumers is larger than their gains.

5. Conclusions

For the short run, our results indicate that the reduction in domestic consumption of salmon caused the market price to decrease, along with salmon supplies from domestic production and imports. In the long run, the increase in domestic consumption and the rise in transportation costs caused the market price to increase. The higher market price and higher demand, in the long run, benefit both domestic producers and foreign producers. Because of the increase in imports and the corresponding increase in domestic demand, foreign producers benefit from most domestic demand and price because 80% of domestic consumption was from imports. Overall, although both domestic producers and consumers experienced negative effects in the short run, they all gained from demand and market price growth in the long run. However, these gains could not compensate for the negative effects of the increase in transportation costs. In aggregate, domestic producers gained from the changes in domestic consumption and the increase in transportation costs. However, consumer net welfare effects were negative when the rise in transportation costs was added to the total effects in the short and long run.

Although production costs grew during the Covid-19 pandemic, domestic producers benefited because of the higher market price. This sector is expected to increase profitability when the effects of Covid-19 decrease further in the future. However, this profitability to domestic producers is much lower than the loss by consumers because the share of domestic production in domestic consumption is relatively small. Moreover, the negative effects of the higher production costs of salmon due to rising feed costs, the cost of logistics, packing, handling, storage, and waiting at the harbor, delay of shipping, labor cost, and energy cost could be reduced through industry innovation, such as the use of optimal feeding rations and increase in farm size (Iversen et al., 2020; Kumar and Engle, 2016). It would also be a gain for the seafood industry if salmon suppliers and retailers could provide more convenient products and services to cook at home (Adhikari et al., 2021; Rolfe et al., 2021).

Salmon producers and consumers also benefited from the increase in consumption of salmon during the pandemic. Past research has argued that the percentage of salmon consumption growth was partly the result of home-cooked meals. Competing items such as beef and pork were also cooked at home. Even so, the salmon sector benefited because of the sharp increase in beef and pork prices (during the pandemic, beef and pork prices skyrocketed relative to salmon). Further research is needed to determine the extent to which cooking at home and the change in relative commodity prices played a role in increased salmon consumption.

Unfortunately, data are limited for transaction costs for salmon, including domestic transportation costs. Therefore, we demonstrate our results change with the changes in transportation costs. Our results may show that overall, the Covid-19 could negatively impact total welfare depending on the size of transportation costs. Further research is needed to obtain more accurate estimates of transaction costs for salmon and many other agricultural products.

Although more than one factor caused the disruptions in salmon supply and demand during the Covid-19 pandemic, this research focuses only on increasing transportation costs representing the increased transaction costs of imports. Therefore, we suggest that future research include other factors pressuring the salmon imports and exports such as farmworker illness, labor shortage, and other factors increased transaction costs, including port delays, equipment shortages, and environmental fees.

Figures

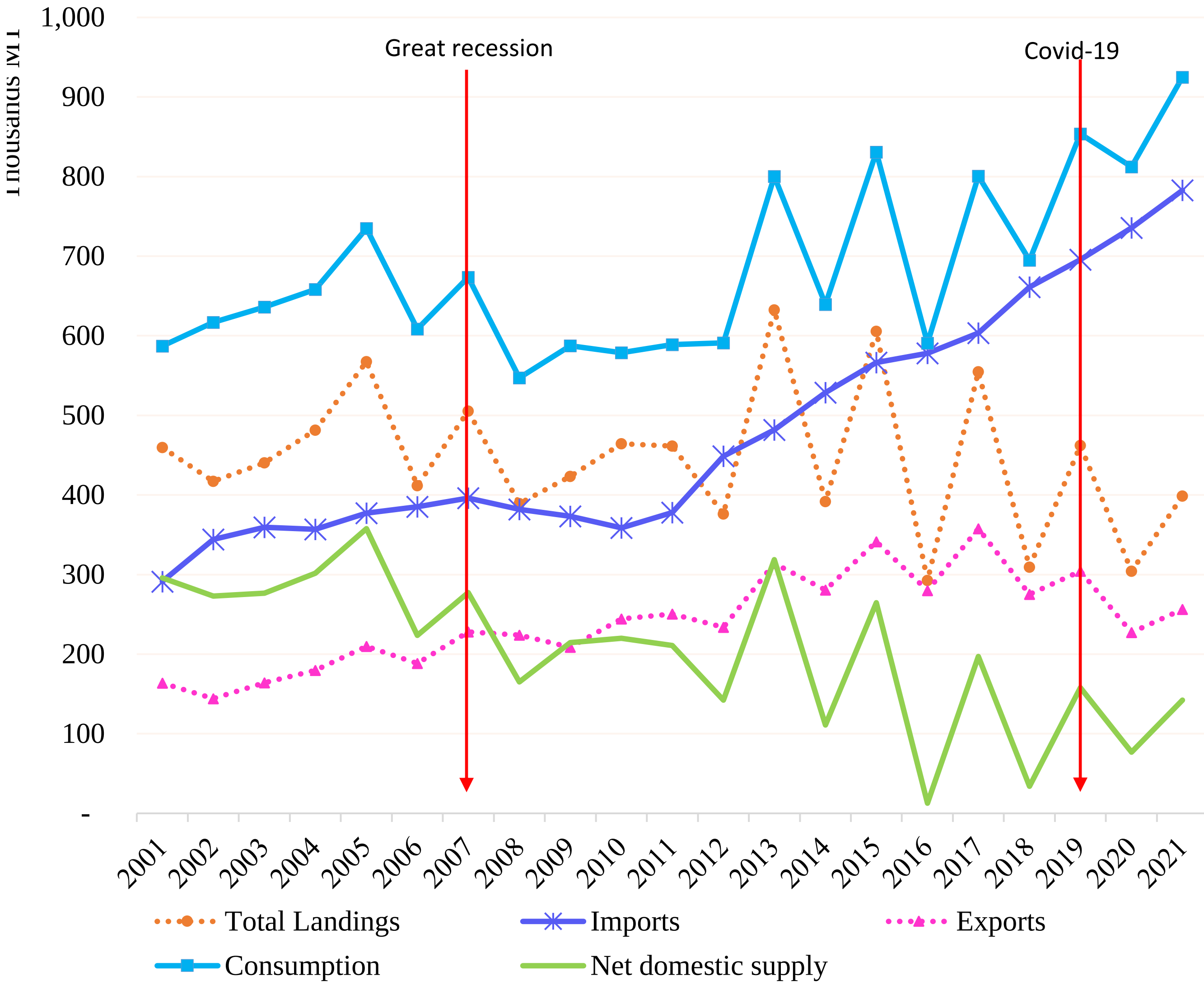

Figure 1. U.S. Salmon consumption, imports, and domestic production 2001-2021 (Thousand MT)
Note: Net domestic production = domestic production – exports; consumption = domestic production + imports – exports
Source: Data from 2001 to 2020 was collected from NOAA data, 2022. Data for 2021 were estimated using the import and export data to convert to round weigh the equivalent of the whole salmon in which 1.6 weight of the whole salmon is equivalent to 1.0 weight of salmon fillets. Domestic landing data in 2021 was estimated based on the Alaska salmon harvest updates in 2021 retrieved from (https://www.alaskaseafood.org/industry/market-information/#2021)

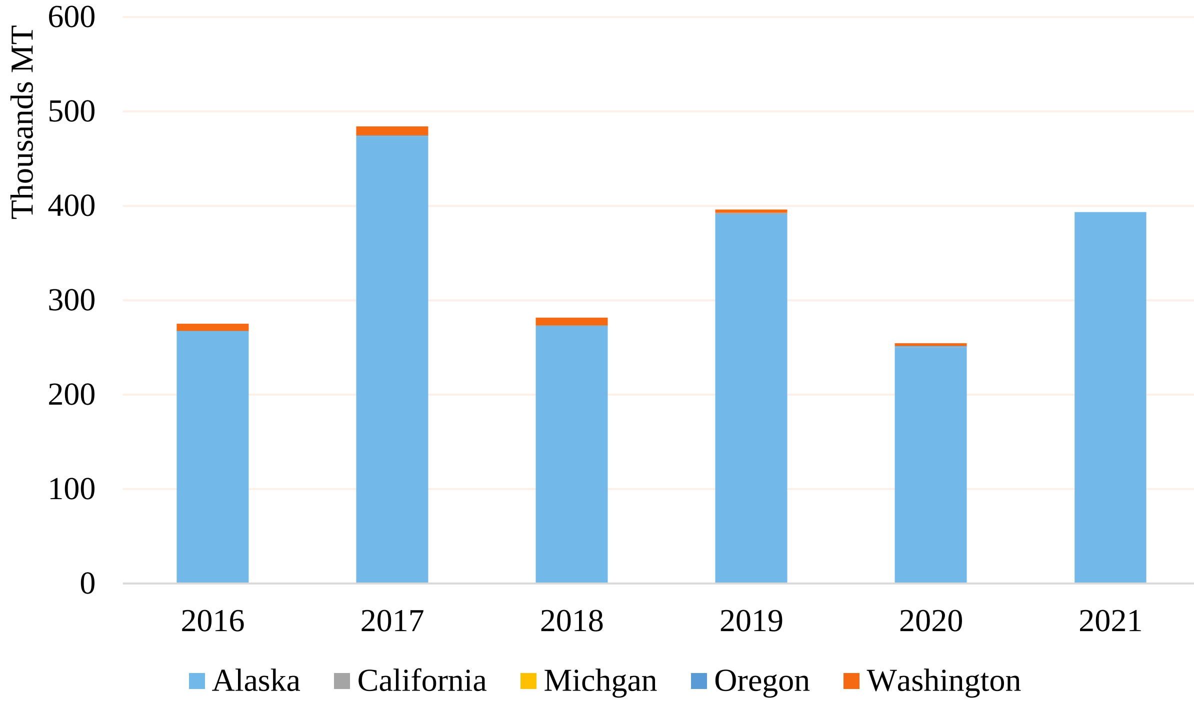

Figure 2. The US Salmon Production Volume by State 2016-2021

Note: The production volume in 2021 is only available for Alaska; other states have not updated yet.

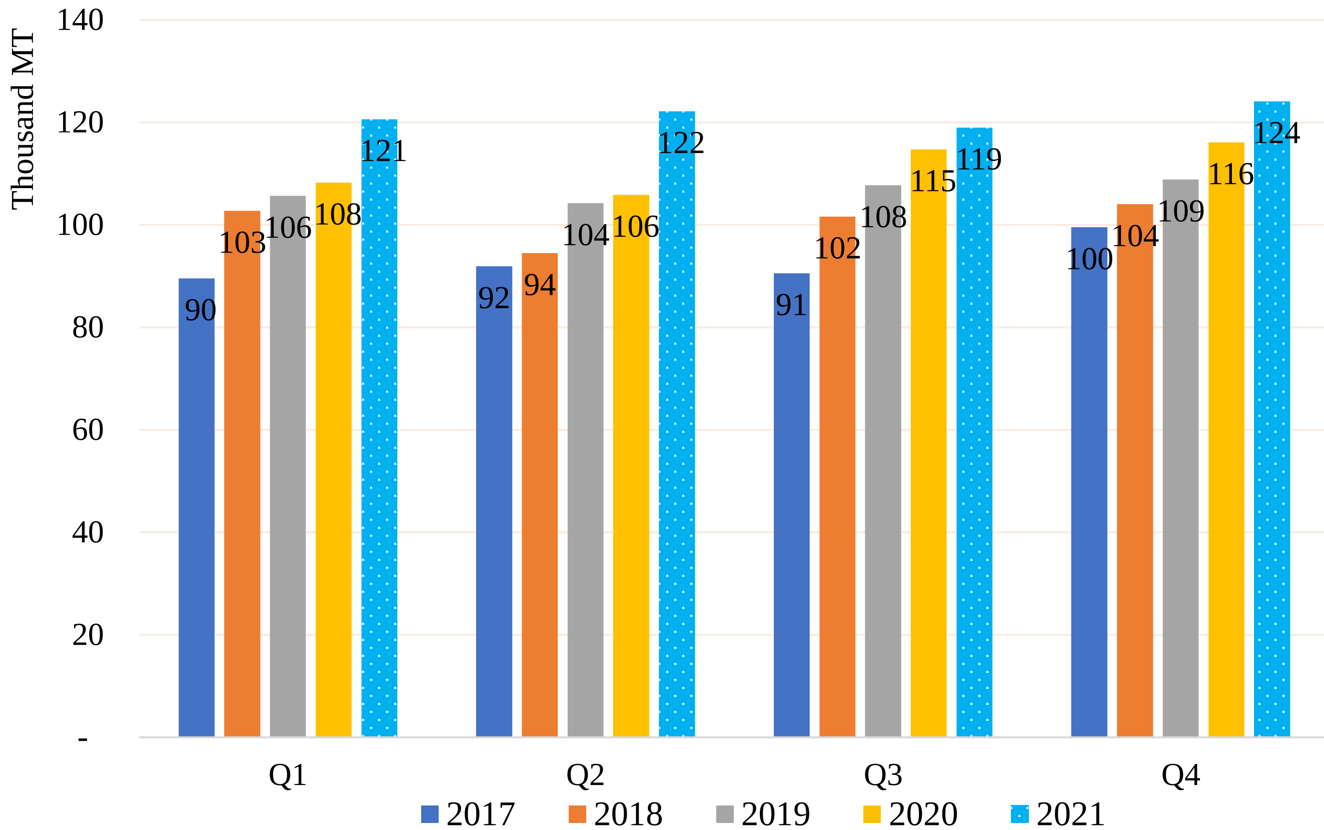

Figure 3. Quarterly Salmon Import, 2017-2021, thousand metric ton (MT)

Source: NOAA, 2022

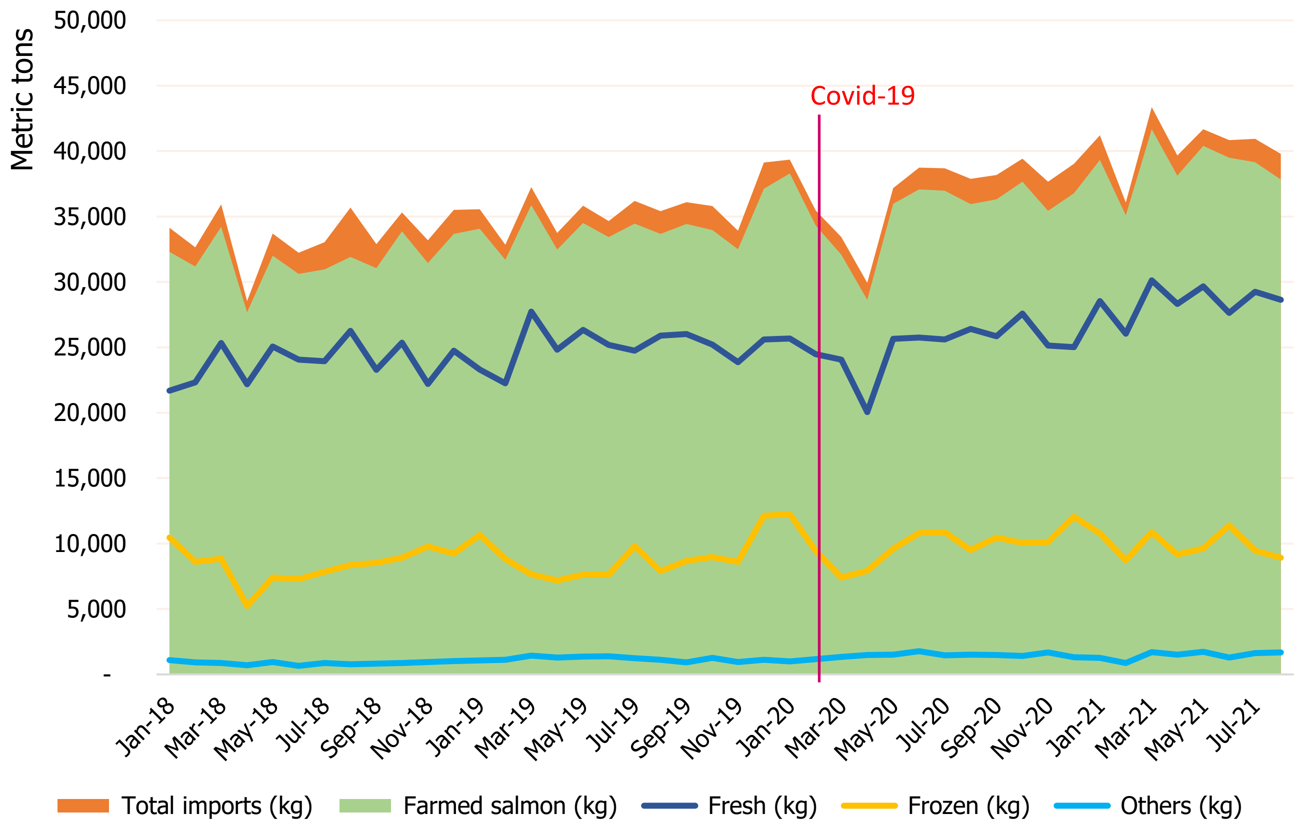

Figure 4. U.S. salmon monthly imports by product forms and production methods,

January 2018-August 2021

Source: NOAA, 2021

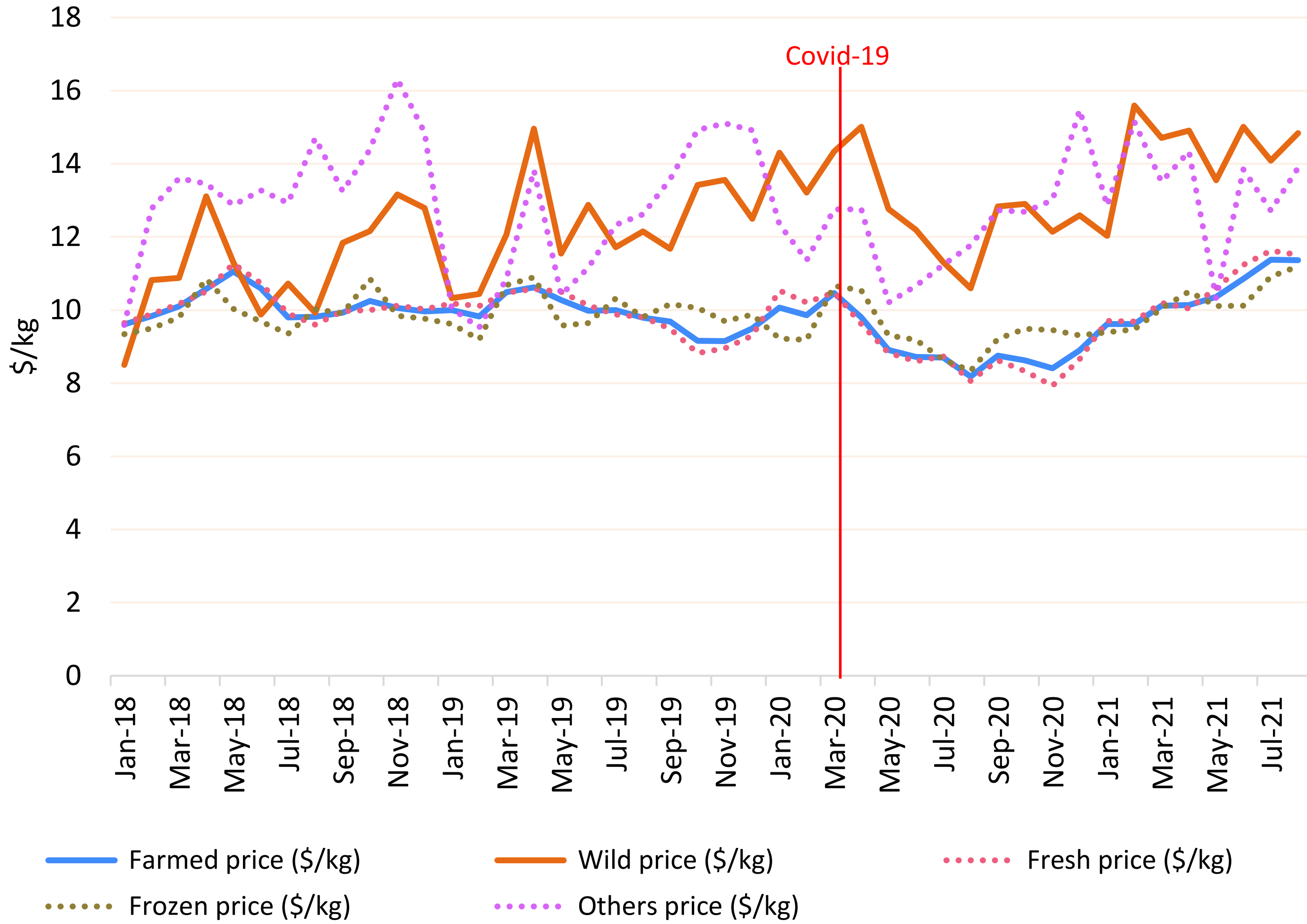

Figure 5. The market prices of salmon monthly before and after Covid-19

Source: Urner Barry's Seafood Market Data, 2022.

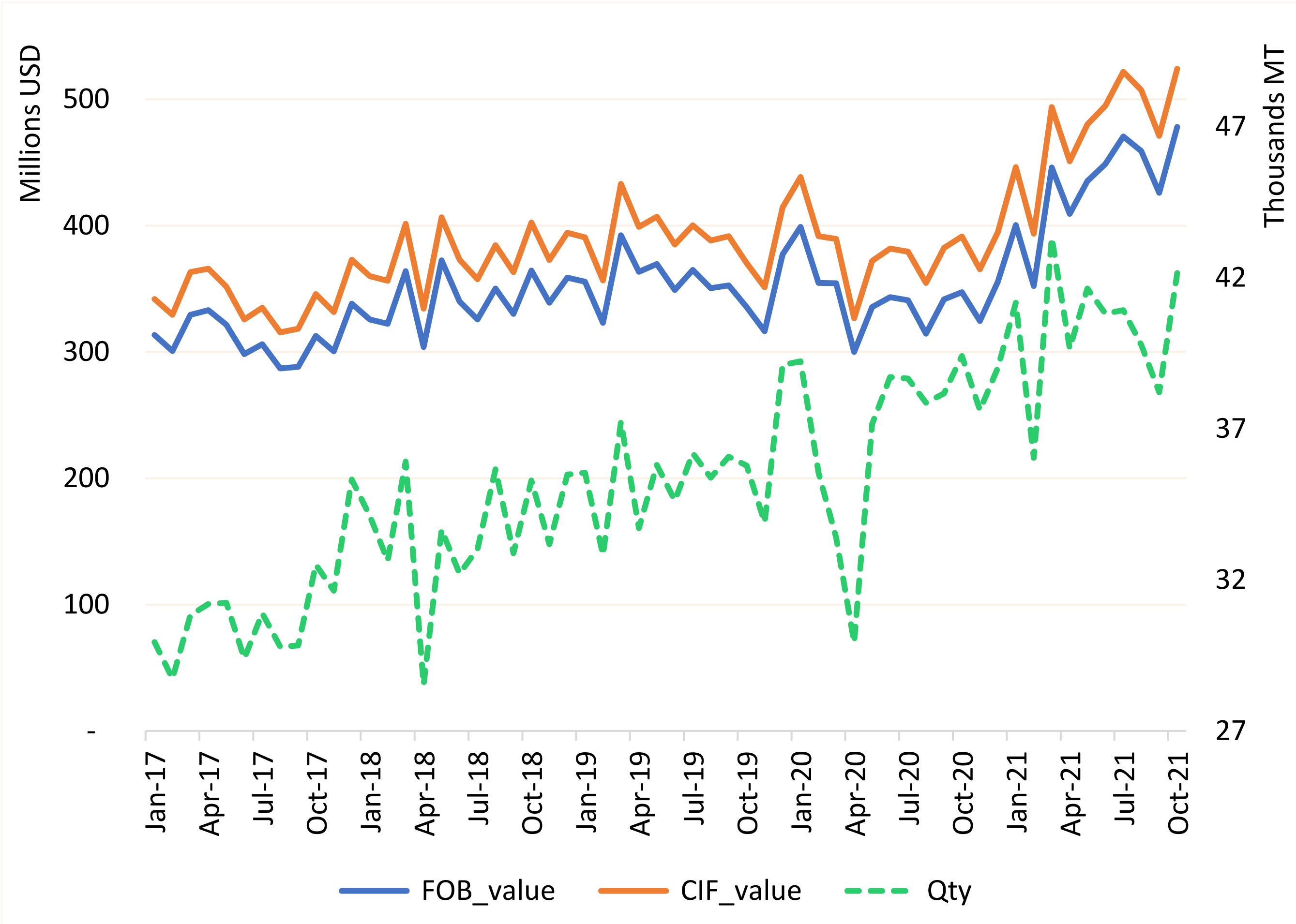

Figure 6. U.S. Salmon Imports Monthly in FOB and CIF Values and Quantity, 1/2017-10/2021

Source: USDA Foreign Agricultural Service retrieved from https://apps.fas.usda.gov/GATS/default.aspx

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