The effect of COVID-19 on U.S. pork exports to East Asia

by

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ABSTRACT

The motivation for this research was brought on by the COVID-19 pandemic and the supply chain disruptions it caused when the virus spread worldwide, infecting employees in manufacturing positions, causing production to slow. This was especially observed in the pork and pork products industry. As employees at processing plants fell ill, production decreased and, in some cases, halted entirely. This caused a shortage of pork products both domestically and destined to be exported. The research question is: What effect did the COVID- 19 pandemic have on U.S. exports to the four major East Asian destinations? The overall objective of this study is to determine the extent of COVID-19's effect on U.S. pork exports to East Asia.

Over the years, pork exports and profits have consistently increased. The sector earned a record $8.1 billion in revenue in 2021, which was a 5% increase from 2020. In 2021, China, Japan, and Mexico imported approximately $1.7 billion of U.S. pork, accounting for 63% of U.S. pork exports. Due to China and Japan being the top two international destinations for U.S. pork, and East Asia accounting for half of all U.S. pork exports by volume, this region will be the focus of how COVID-19 affected U.S. pork exports. The close contact of livestock processing led to rapid spread of the virus through these facilities. It was reported that between April and May 2020, 17,358 workers were diagnosed with COVID-19 at 264 processing plants in 28 states, and 91 workers died, slowing the production of pork products, and limiting the quantity available for export. Data for this research were collected primarily from the USDA's Economic Research

Service (ERS) and Foreign Agricultural Service (FAS) GATS (Global Agricultural Trade System).

The impact of COVID-19 was assessed by running a regression using the software program, Stata™. The study used monthly data from January 2011 through June 2022. It focused on pork and pork products in the consumer-oriented section of the database using both quantity and value of exports to the four focus countries – China, Japan, South Korea, and Taiwan.

Prior to COVID-19, U.S. pork exports were estimated to be 194,443 MT/month, while the amount exported during the COVID-19 era was 237,086 MT/month. In the COVID-19 era, the average export of U.S. pork was higher than in the previous era. This was true for East Asia as a whole and for China. However, the remaining countries saw a reduction in U.S. pork exports during the COVID-19 period. The impact of the COVID-19 virus did not have a statistically significant impact South Korea. However, it did have a statistically significant impact on China, Japan, and Taiwan. Therefore, the hypothesis that there was no COVID-19 effect on U.S. pork and pork product exports was rejected in three of the four cases. These results provide insight into the relationships between U.S. pork and pork product exports to the four East Asian countries and their imputed prices. Members of the pork industry and policymakers will be able to better prepare for future opportunities in pork export by understanding the growth in demand and the disruptions that a major global event might cause.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER I: INTRODUCTION

With 12% of the world's pork produced in the United States, pork and pork products have become a growing export industry for the nation. The pork industry has steadily increased the volume exported while achieving record profits from year to year. The sector earned a record $8.1 billion in revenue in 2021, a 5% increase from 2020, when a record profit was also reported. China, Japan, and Mexico are the top three importers of US pork in 2021, accounting for 63% of the exports of US pork, importing approximately $1.7 billion in total. China remains the top destination of U.S. pork exports despite declining shipments in 2020 (Pork and Pork Products Export Highlights 2021).

Table 1.1: Top 10 Export Markets for U.S. Pork by Value (U.S. $M)

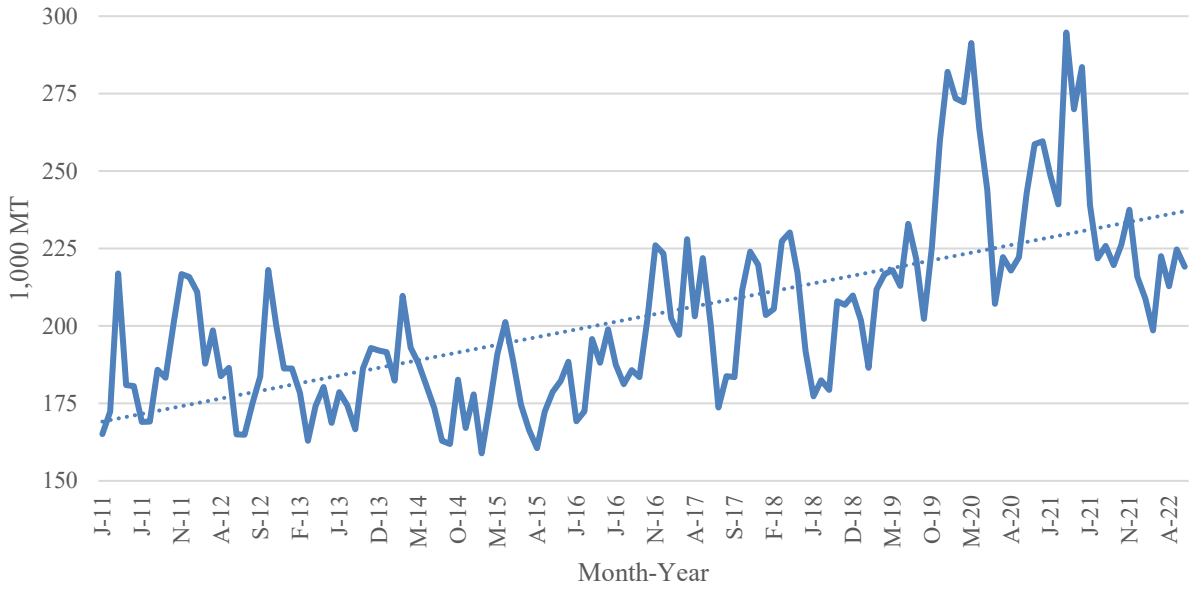
Country	2017	2018	2019	2020	2021	2020-2021 % Change	2017-2021 Average
China	662	571	1,300	2,280	1,698	-26%	**1,302**
Japan	1,626	1,631	1,523	1,623	1,694	4%	**1,619**
Mexico	1,514	1,311	1,278	1,153	1,675	45%	**1,386**
Canada	793	765	802	854	952	12%	**833**
S. Korea	475	670	593	453	557	23%	**550**
Colombia	163	215	221	147	258	76%	**201**
Philippines	98	116	93	114	204	78%	**125**
Australia	208	227	302	253	197	-22%	**237**
Dominican Republic	71	93	78	90	151	67%	**96**
Honduras	54	59	67	73	115	57%	**74**
All Others	821	745	694	670	607	-9%	**707**
Total	**6,485**	**6,403**	**6,951**	**7,711**	**8,107**	**5%**	**7,131**

(Pork and Pork Products 2021 Export Highlights 2021)

According to United States Department of Agricultural Services (USDA) Foreign Agricultural Service (FAS) data, the demand for U.S. pork continues to grow, resulting in an increase in the quantity of pork and pork products shipped each year. As a result of the

global pandemic SARS-CoV-2, also known as Coronavirus or COVID-19, the pork shipments in both value and quantity, like other shipments the world over, declined sharply in April 2020. Figure 1.1 and Figure 1.2 show the severe drop in U.S. pork exports in April 2020. Despite the positive trend shown in Figure 1.1 and Figure 1.2, it can be observed that the spread of the COVID-19 virus disrupted U.S. pork exports. For example, the average growth rate in U.S. pork exports from January 2011 to March 2020 was estimated at 0.2% per month while the growth rate from April 2020 through August 2022 was -0.6% per month. The uncertainty about the potential effect of the COVID-19 on public health caused virtually all countries to shutter their economies and contributed to the change in export demand direction (Alabi and Ngwenyama 2022).

Figure 1.1: Total Volume of U.S. Pork Exports (1,000 MT), January 2011 – June 2022
(FAS - Global Agricultural Trade System Online 2022)

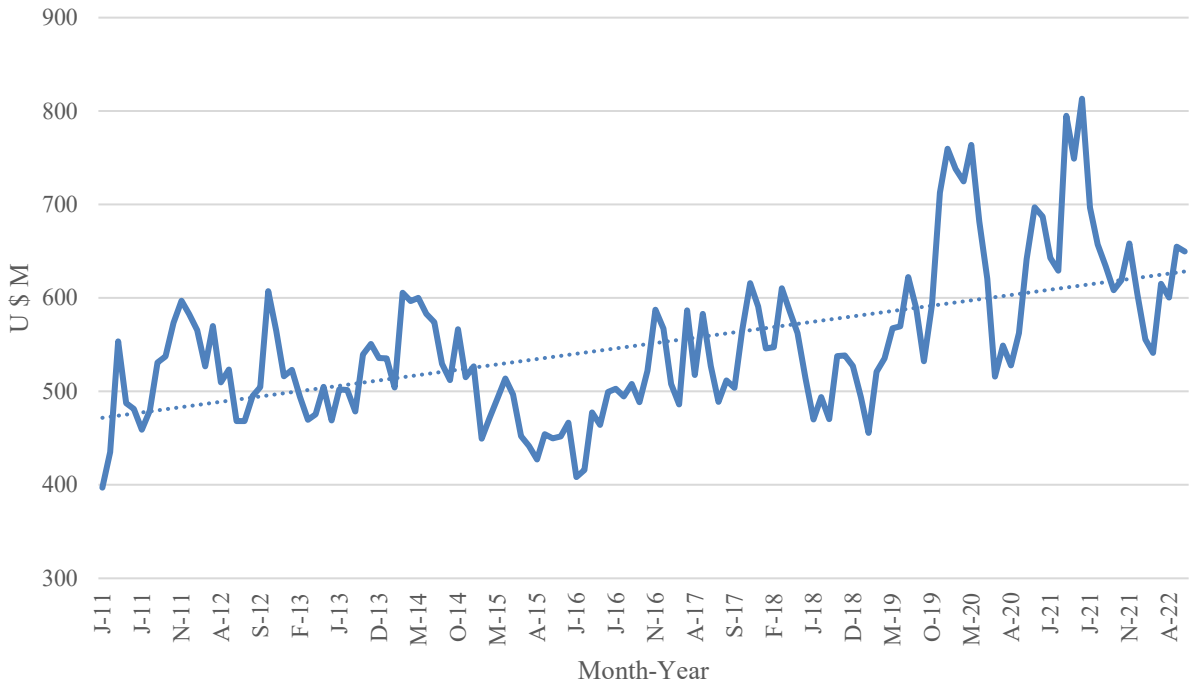


(FAS - Global Agricultural Trade System Online 2022)

The change in volume affected the value of exports since value is the product of volume and price. For example, while total value of U.S. pork exports grew at about

0.13% per month from January 2011 to March 2020, the growth rate after the World Health Organization pronounced COVID-19 as a global pandemic was flat. This means that with declining quantities value was flat only because prices increased slightly, at about 0.02% per month during that period.

Figure 1.2: Total Value of U.S. Pork Exports (U.S.$ Million), January 2011 – June 2022

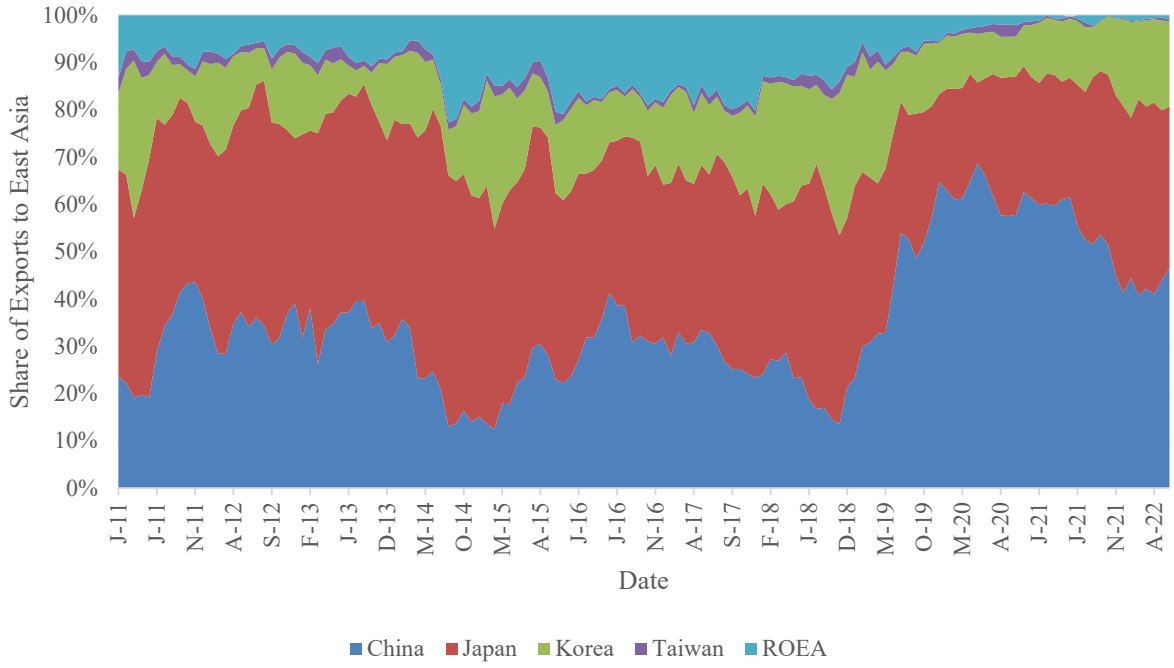


(FAS - Global Agricultural Trade System Online 2022)

In recent years, China has become the single-largest destination for U.S. pork exports, peaking at approximately 112,000 MT in April 2020. Between April 2019 and April 2020, Chinese demand for U.S. pork spiked, increasing by 54% in the volume. Japan is the second largest importer of U.S. pork, although its volume of U.S. pork imports has decreased slightly over the past decade. Yet, similarly to China, there was a sharp decline in Japan's imports in April 2020. China and Japan being the top two top

destinations for U.S. pork exports, and all East Asia accounting for nearly 50% of all U.S. pork exports by volume, makes the region an interesting subject area for analysis of how COVID-19 affected U.S. pork exports. The major destinations for U.S. pork exports in East Asia, apart from China and Japan, include Taiwan, and. South Korea. Like China and Japan, U.S. pork exports to South Korea and Taiwan experienced a significant decline in the period immediately following the declaration of the COVID-19 pandemic. These four countries accounted for about 98% of the population of East Asia in 2021 (UN Department of Economic and Social Affiars Population Division 2022). The volume of U.S. pork exports correlated closely with the relative shares of destination countries' population. The demand for U.S. pork by volume in these countries seems to follow their relative population shares. The distribution of U.S. pork exports to the East Asia region is depicted in Figure 1.3, with ROEA being Rest of East Asia.

Figure 1.3: Distribution of U.S. Pork Exports to East Asia by Principal Destinations, January 2011 – June 2022



(FAS - Global Agricultural Trade System Online 2022)

The value of pork exported to East Asia from the United States is another important factor to consider. However, in considering value, it is important to remember that the quality of pork going to the different countries are not the same. For example, the highest valued U.S. pork product are exported to Japan. In this product list, presented in Table 1.2, are different cuts of different value, such as carcasses and half carcasses of swine, fresh or chilled, which are higher value than chilled or frozen processed meat. For Taiwan, the highest value products are frozen unprocessed meat, and the lowest valued products are whole and pieces of bladders, and stomachs, prepared for use as sausage casings. The top three product groups exported to the four focus countries are summarized in Table 1.2.

Table 1.2: Top 3 Most U.S. Pork Product Exports by East Asia Country

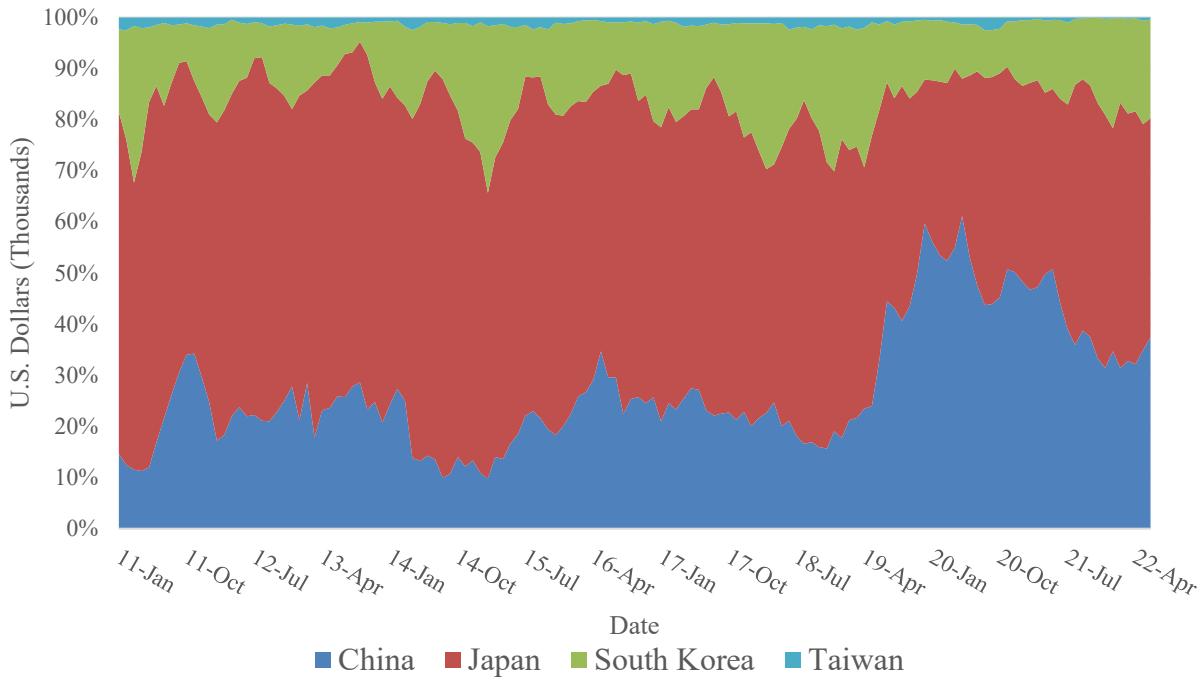
Country	Highest Value Pork Product	2nd Highest Value Pork Product	3rd Highest Value Pork Product
China	Meat except processed, frozen	Edible offal, (pork), frozen, feet	Hams, shoulders and cuts, bone in, except processed, frozen
Japan	Carcasses and half-carcasses fresh or chilled	Meat, except processed, frozen	Meat except processed, fresh, or chilled
South Korea	Meat, processed, frozen	Meat, except processed, fresh, or chilled	Hams, shoulders and cuts, bone in, processed, frozen
Taiwan	Meat, except processed, frozen	Edible offal, frozen, other	Hog guts, bladders and stomachs, whole and pieces, prepared for use as sausage casings

(FAS - Global Agricultural Trade System Online 2022)

Comparing the value of exported products shows that until recent years, Japan was by far the highest value destination for U.S. pork product exports. On average, it

remains the highest value destination, but China has been closing the gap over time. Figure 1.4 shows that from about July 2019 to about July 2021, the value of pork shipments to China exceeded that of Japan by an average of about 32%. This contrasts with the period prior when the value of U.S. pork exports to China was only about 32% of the value of its exports to Japan.

Figure 1.4: Value of U.S. Pork Exported to East Asia (U.S.$ Million), January 2011 – June 2022



(FAS - Global Agricultural Trade System Online 2022)

1.1 Research Question and Objectives

The research question was this: What effect did the COVID- 19 pandemic have on U.S. exports to the four major East Asian destinations? This question is motivated by the changes observed in the trend data and the fact that the pandemic's impact seems obvious. However, the extent of the impact is not visible and explaining it could position

the U.S. pork industry and U.S. Meat Exporters Federation to revamp its strategies to address future pandemics and trade disruptions.

The overall objective of this study is to determine the extent of COVID-19's effect on U.S. pork exports to East Asia. Because the exports are dominated by two countries in the region – China and Japan – the study included two smaller countries – South Korea and Taiwan – to provide some indications of the impact and assess if any differences existed between the larger countries and the smaller one.

The specific objectives of this study are:

1. Describe trends in U.S. domestic consumption of pork and pork products and estimate the relative importance of exports to the U.S. pork industry.
2. Estimate the share of the top-four export destinations for U.S. pork in East Asia and assess their relative importance in the U.S. pork industry
3. Evaluate the factors influencing the trends in pork exports by country and assess these factors differences across the selected destinations.
4. Use the results to inform the pork industry and policymakers on how to deal with future disruptions in trade.

1.2 Thesis Organization

This opening chapter has described the background of this study, providing information on the demand for U.S. pork as a whole and to the specific region that will be analyzed in this research, East Asia. The discussion has included the quantity and value of U.S. pork and pork products exported, the quantity and values of U.S. pork and pork products exported into East Asia, and the difference in the products exported to the countries included in this study. A review of the literature covering additional factors affecting U.S. export is presented in Chapter 2. Chapter 3 presents the theory, data, and

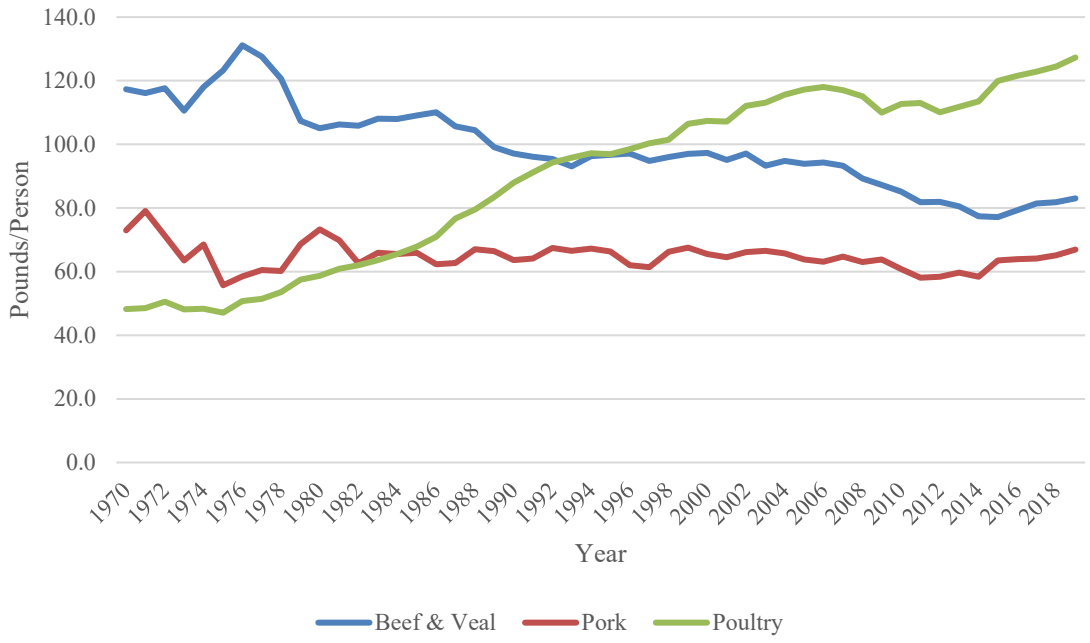
the model underlying the research. The study's results are presented and discussed in Chapter 4. Along with that are the summary, conclusions, and recommendations for further study.

CHAPTER II: LITERATURE REVIEW

2.1 Domestic Consumption

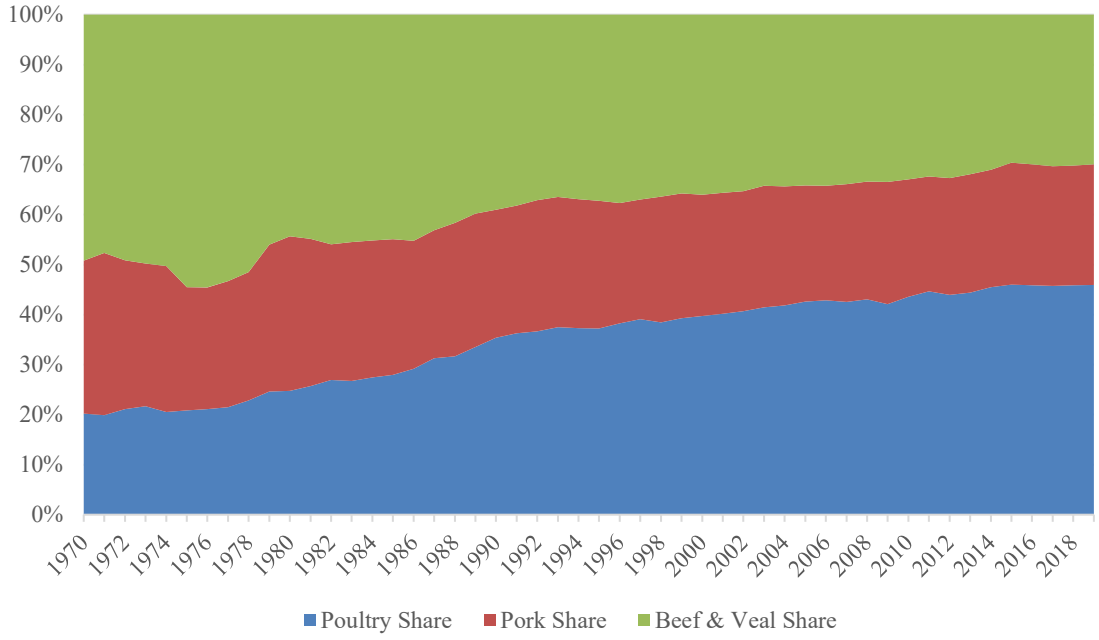
Even though pork is not consumed by all populations in all regions and countries, it is one of the most popular meats worldwide, including United States. It is the highest per capita meat consumed in the world and the third highest in the United States, and it is thus a dominant animal protein. (Davis and Lin 2005). Davis and Lin show that nearly 42 percent of the total consumption of red meats (beef, pork, lamb, and veal) in the United States in 2003 was derived from pork production, and approximately 50 percent of the total consumption of meat protein worldwide was associated from pork production. In 1960 in the United States, 150 lbs. of meat were consumed per capita, the majority of which was beef (64 lbs.), pork (59 lbs.), and chicken (28 lbs.). The per capita consumption of beef and pork were already on a downward trend in the 1970s, but chicken has continued to increase over several decades and does not show any signs of declining (Figure 2.1). Tonsor and Lusk (2021) estimated that U.S. per capita meat consumption has increased by 38% since 1960 and is expected to reach 207 pounds in 2021. They estimated the per capita consumption for beef, pork, and poultry at 59, 51, and 97 pounds, respectively for 2021. The distribution of total meat consumption per capita among the three main meats is presented in Figure 2.2, It shows that while beef and veal's share has been declining rapidly, poultry (chicken and turkey) share has been increasing. Pork share has been relatively stable over the years in the U.S. domestic market.

Figure 2.1: Annual Per Capita Meat Consumption, 1960–2021



(USDA Economic Research Service 2022)

Figure 2.2: Annual Per Capita Meat Consumption, 1960–2021



(USDA Economic Research Service 2022)

The average annual growth rates between 1970 and 2019 for the share of beef, pork, and poultry per capita consumption in total meat consumption per capita in the U.S. were, respectively, -1.2%, -0.5%, and 1.9%. The market conditions for beef especially, and for pork too, suggest that the only growth avenues are in the export market. Therefore, the U.S. Meat Export Federation has been very aggressive promoting meat exports to sustain the beef and pork industries. Indeed, the U.S. exported about 29.4% of its pork and pork variety meat production in 2021 (Pork Checkoff 2022).

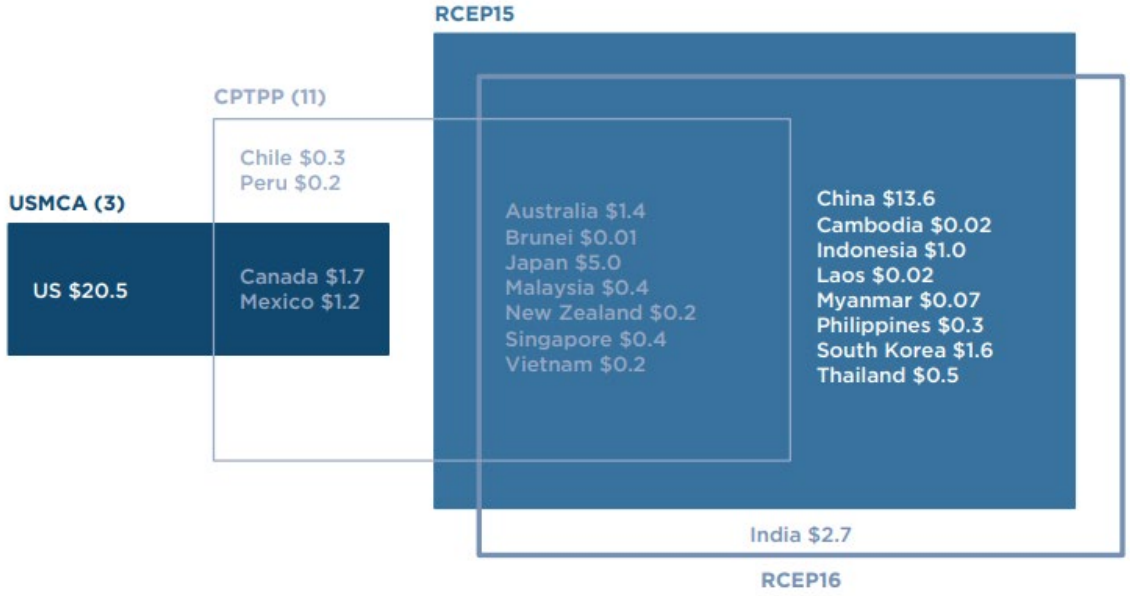
2.2 U.S. Trade leading up to COVID-19

The COVID-19 pandemic caused increased tension in an already strained relationship between the United States and East Asia. In January 2018, U.S. President, Donald Trump began imposing tariffs on Chinese goods in an effort to decrease bilateral trade deficits and increase jobs in the United States. Chinese companies had limited access to American technologies, which started a trade war between the two countries (Kapustina, et al. 2020).

In conjunction with the spread of the virus and tariffs imposed during the Trump administration, two megaregional trade agreements, the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) and the Regional Comprehensive Economic Partnership (RCEP), refocused East Asia's economic ties within the region (Figure 2.3). CPTPP and RCEP were China's response to the Obama era Trans-Pacific Partnership (TPP), which Trump scuttled when he assumed power in 2017. The CPTPP and RCPP are bringing nations that are friendly to China's global aspirations together in ways that secures China's access to the region's market even as they exclude the U.S. from any strategic partnerships. The agreements are projected to raise the participation countries' national

incomes in 2030 by between annual $147 billion and $186 billion. The values outlined in Figure 2.3 show the expected increase in income for each country. They will yield especially large benefits for China, Japan, and South Korea. Globally, $301 billion will be lost by 2030 as a result of the China-U.S. trade war. The regional trade agreements offset the adverse effect of the trade war for China effects. By strengthening East Asian interdependence, RCEP adds $428 billion in trade among its members and reduces $48 billion in trade among its nonmembers. The foregoing is summarized in Figure 2.3 (Petri and Michael 2020).

Figure 2.3: Regional trade groups involving the United States, Asia, and the Pacific and 2018 GDP (U.S. $ Trillion)



CPTPP = Comprehensive and Progressive Agreement for Trans-Pacific Partnership
RCEP = Regional Comprehensive Economic Partnership
USMCA = United States-Mexico-Canada Agreement
Source: World Bank, data.worldbank.org; authors' simulations.

(Petri and Michael 2020)

East Asian countries are importing pork products in a large quantity despite banding together under new trade agreements. Due to the rise in takeout orders during the pandemic, pork loin is became highly sought after in Japan (U.S. Meat Export Federation

2022). This inspired food service providers to develop new menu items. Specialty shops featuring Kara-age are one example of extreme growth in 2020 and 2021 with sales reaching $950 million, a 50% increase from 2019. Kara-age is a Japanese cooking technique in which various foods, usually chicken, are deep fried in oil. The United States Meat Export Federation (USMEF) sees U.S. pork loin as a viable alternative and has worked with leading chefs to develop fried pork recipes for the food service sector in Japan. (U.S. Meat Export Federation 2022)

In a similar effort, USMEF partnered with an importer/distributor in northern China to introduce new cooking concepts that are gaining popularity in southern China. The Autumn Chef's Table was hosted by the USMEF and Beijing Salate Trade Company to introduce U.S. beef and pork to local chefs, as well as to offer new menu ideas to current and potential food service customers. The popularity of yakiniku and Korean barbecue is growing throughout Asia, including southern China, where underutilized U.S. cuts are often used. In the demonstration, five cuts were used to expand the range of U.S. pork cuts: flank, tri-tip, bone-in short ribs, rib finger, and CT butt. (U.S. Meat Export Federation 2021)

With COVID-19 restrictions still lingering in South Korea, consumers are becoming more interested in cooking high-quality red meat at home. Consumer demand for beef is soaring, and retail chains are looking to expand their meat case options. One of Korea’s leading grocery chains is working to position its meat departments as year-round “steak specialty stores.” The increased demand for beef products in South Korea could lead to a decrease in the demand for higher-quality pork cuts. (U.S. Meat Export Federation 2022)

Taiwan is also experiencing increased demand for beef products. However, Taiwan's meat cuts are not of the same quality as South Korea's. U.S. beef exports to Taiwan were up 70% and reaching $378 million through May 2020. USMEF recently brought a celebration directly to Taiwan families. The celebration was hosted to increase the awareness of corn-fed U.S. beef and promote alternative U.S. beef cuts. Engagement was centered around two alternative cuts, U.S. beef knuckle and chuck flap. (U.S. Meat Export Federation 2022)

2.3 COVID's Effect on Food Production Supply Chain

As a result of COVID-19, there was significant disruption in every step of the food supply chain, including food production, processing, distribution, and demand. Consequently, COVID-19 restricted worker movements, impacted consumer demand, closed food production facilities, restricted food trade policies, and placed financial pressure on the food supply chain. Following appropriate social distancing protocols while maintaining a sufficient workforce to meet production demand was a challenge within the food industry. Governments around the world placed significant restrictions on the movement of goods and labor during that pandemic as they restricted the transportation of goods via land, water, and air.

Maritime supply chains were adversely affected by the Covid-19 pandemic. It led to a slowdown in maritime trade, reducing demand and port throughput. Maritime transport became less stable due to container shipping companies stopping certain services or canceling port calls. As a result of Covid-19-related restrictions, including lockdowns, port congestion, and delays in cargo handling were also experienced, weakening maritime supply chains and connectivity (Guerrero, Letrouit and Pais-Montes 2021).

Agricultural production is largely dependent on the seasons and weather, so a flexible schedule is necessary so that immediate actions can be taken when required. As all processes and stages in a supply chain are highly interconnected, a slight delay or glitch can have a significant impact on yield and production. As a result of this dependency, many farmers have been forced to burn or leave their products in the field because they could not transport their products profitably to processors. Due to interrupted supply, 14 million liters of milk were dumped daily, according to the Dairy Farmers in America Co-operative. In England, the chair of dairy farmers reported that approximately five million liters of milk are at risk in one week. Furthermore, it was reported that tea plants were being lost in India due to logistical challenges. Therefore, maintaining logistical efficiency is a key factor for the food industry, especially in a global crisis. A key challenge in the food supply chain is obtaining raw materials from suppliers and making sure food flows from manufacturers to consumers promptly. Food quality, freshness, and food safety can be negatively affected by these problems, and access to markets and affordability may be hindered (Aday and Aday 2020).

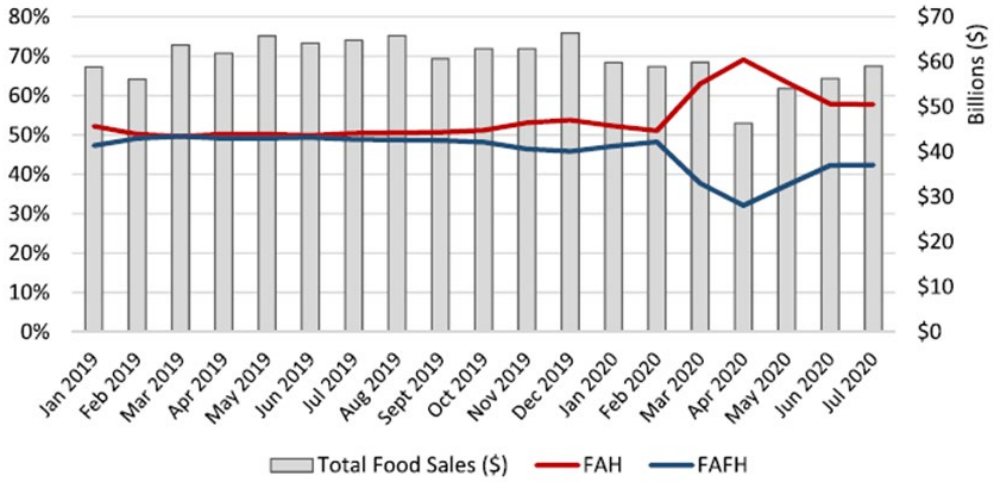
Food production includes a variety of products such as meat, fruit, vegetables, dairy, ready-to-eat foods, and other edible items. Food and agriculture chains can, however, be divided into two categories based on capital investment and labor. The first category consists of staples such as wheat, corn, maize, soybeans, and oilseeds, while the second category consists of high-value items like fruit, vegetables, meat products, and fisheries. Capital investments in staple products are substantial, and restrictions between cities, provinces, regions, and countries implemented during COVID-19 negatively affected their distribution. A large amount of labor is required for high-value products, as

opposed to staple products. When social distancing protocols were implemented into food production facilities, this negatively impacted high-value products that require a larger labor force (Aday and Aday 2020).

Consumers' eating/purchasing habits changed due to the closure of restaurants and limited options for dining out, resulting in an unusual shift from food service to retail. Consumption, shopping preferences, income level, sociodemographic, and price of foodstuffs all influenced demand. In addition, the number of visits to the grocery store and the amount of money spent on food per visit increased. During the COVID-19 lockdown, some types of food were less readily available to consumers. As home baking became more popular, flour, a staple product, was more difficult to find on store shelves, while bread and baked goods remained available. Consumers have focused on products with longer shelf life such as dried or canned foods, pasta, and frozen foods due to convenience and daily cooking at home.

According to surveys conducted over the past decade, food expenditures in the United States have been about evenly divided between consumption at home (food at home [FAH]) and spending away from home (food away from home [FAFH]), with some fluctuations during the holidays. Figure 2.3 shows FAFH and FAH expenditures, in U.S. dollars, from January 2019 through July 2020. As of January 2020, total dollar expenditures on food and beverages declined significantly, reaching the lowest point in April, as did the proportion of FAFH expenditures. Consumption at restaurants and schools, as well as food and drink expenditures at workplace cafeterias, hotels, and during travel, were restricted during COVID-19 shutdowns. During the same period, at-home food consumption (FAH) increased significantly (Hayes, et al. 2020).

Figure 2.4: January 2019 – July 2020 FAH vs. FAFH monthly sales



(Hayes, et al. 2020)

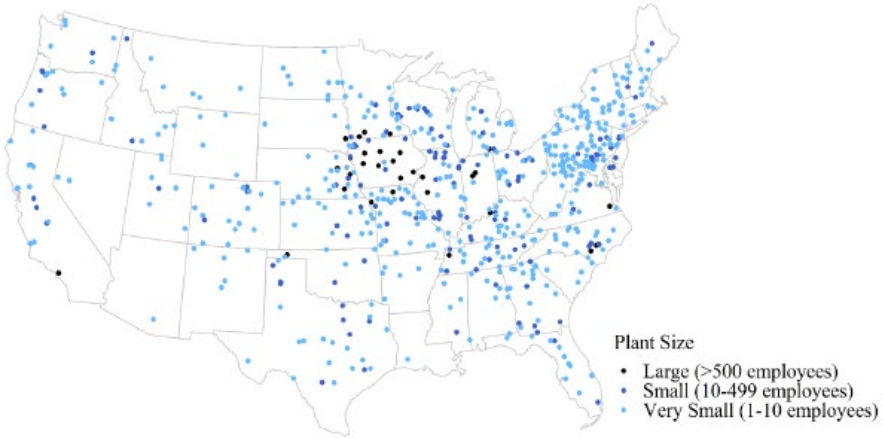
As a result of restaurant closures, home cooking rose, so food companies were forced to evolve their packaging from food service to retail standards. The shortage of eggs was not only due to increased demand but also a lack of packaging for retail (Aday and Aday 2020). Household egg consumption increased by 44% compared to the year before COVID-19 in the USA (Aday and Aday 2020). The U.S. Food and Drug Administration provided flexibility related to the packaging and labeling of eggs due to the insufficient availability of appropriately labeled retail packages to fulfill the demand and facilitate the distribution of eggs during the COVID-19 pandemic.

Consumer behavior, a key component of the food supply chain, greatly affects food supply chains. In response to the COVID-19 outbreak, lockdown restrictions, panic buying, and disruptions in supply chains caused food prices to rise significantly. As a result of changing consumer demands, packaging materials and designs, delivery options, and storage conditions also had to change.

2.4 Pork Plant Shutdowns Disrupt Supply Chains

There were 64,871 hog operations in the United States in 2017. This consisted of 55,739 independent growers with annual sales of 79 million head, 8,557 contract growers with annual sales of 101 million head, and 575 contractors or integrators with annual sales of 55 million head, respectively, according to the 2017 Census of Agriculture (Figure 2.4).

Figure 2.5: Location of Federally inspected pork packing plants in the U.S.



(USDA-Food Safety and Inspection Service's (FSIS) Meat, Poultry and Egg Production Inspection Directory 2020)

Throughput is achieved by a highly efficient and coordinated process in which hogs are finished and transported to processors for prescheduled slaughter “slots.” In 2017, there were 8,386 operations with production contracts and slaughtering of almost 130 million hogs. Market-ready hogs leave finishing buildings to be replaced by feeder pigs from sow barns or nurseries. The challenge facing the industry during COVID-19 originated at the slaughter and processing level of the supply chain and caused major disruptions in both directions. As a result, the growers upstream of processors had no outlet for their finished hogs, and there was no space left for growing pigs. Food

distribution markets suffered as well as processed pork availability declined sharply as packing plants shut down dramatically, making it harder for them to meet consumer demand (Hayes, et al. 2020).

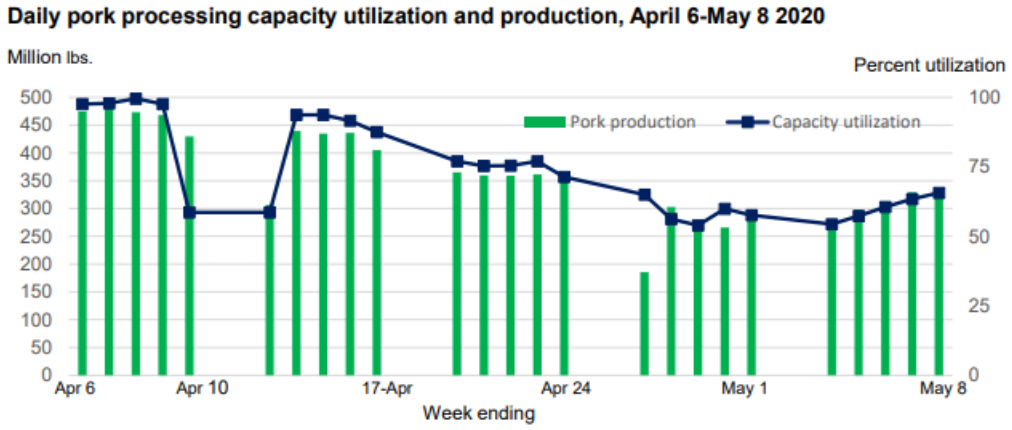
While the lockdown was in effect, meat processing facilities continued to operate. An executive order signed by President Trump on April 28, 2020, requires meat and poultry processing companies to ensure continuous production and supply to Americans during the pandemic. The presence of COVID-19 nevertheless brought challenges to meat processing plants. The close contact nature of the work performed by meat processing workers led to outbreaks of COVID-19 among workers at Tyson Foods Inc, Kraft Heinz Company, and Seaboard Corporation. (Nguemging and Sant'Anna 2021). The CDC reported that between April and May 2020, 17,358 workers were diagnosed with COVID-19 at 264 processing plants in 28 states, and 91 workers died (Waltenburg 2020). The disruptions in the meat supply chain led to an excess of livestock for slaughter and a shortage of meat for consumers.

COVID-19 has posed new challenges to meat processing plants. There are several challenges the company faces, including the following: 1) Its design prevents workers from distancing themselves from each other. Work is done in close proximity to each other in these factories; 2) In the processing facilities, there are constant cold temperatures, which make viruses easily spread; 3) Workers must shout information over the noise generated by the machinery to be heard, and most workers do not wear face shields or masks to protect themselves from infection via saliva. In the industry, workers from dormitories, production lines, and collective transportation are in constant contact, which makes outbreaks more likely. As a result, migrant workers with limited or no

insurance benefits are more likely to conceal their infection to preserve their jobs. People were poorly prepared for the spread of the virus, personal protective equipment was not available, and disinfection guidelines were not implemented effectively, contributing to its rapid spread. Many workers showed up to work despite being in contact with someone who tested positive for the virus due to economic challenges and incentives offered by meat processors at the time (Nguemging and Sant'Anna 2021).

Worker availability is critical to the efficient and effective operation of packing plants. According to a report by the Federal Reserve Bank of Kansas City, from April to June, 2020, more than 80 beef and pork packing plants reported confirmed cases of COVID-19 and at some plants, as many as 30%–70% of the workforce was affected (Hayes, et al. 2020). Absenteeism and illness rates among plant employees greatly reduced the available labor force causing some facilities to close for days and others for more than a week. Many plants that did not close or that returned to operation after a temporary closure experienced a slowdown in operations due to worker availability and engineered controls like workstation alignments and modifications, as well as social distancing measures that slowed line speeds (Figure 2.5).

Figure 2.6: Daily Pork Processing Capacity Utilization and Production (April 6- May 8, 2020)

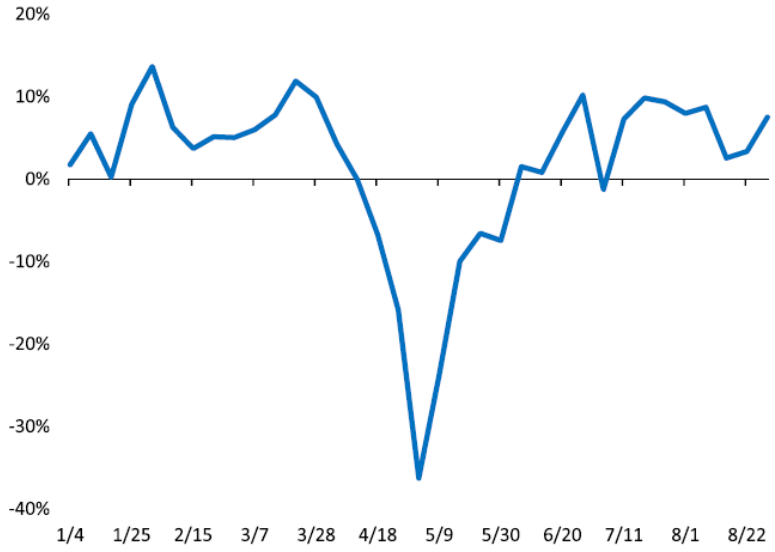


(United States Department of Agriculture Economic Research Service 2020)

The impact on hog slaughtering and processing capacity was significant. Early on, COVID-19 was more prevalent in coastal population centers, especially in the U.S. northeast. Although New York and New Jersey have 38 of the 619 federally inspected (FI) hog packing plants in the U.S., they account for less than 0.1% of the slaughter volume (USDA-NASS 2020). As the pandemic spread, COVID-19 cases increased in major pork processing regions such as Iowa, Illinois, Minnesota, and Missouri. 56% of the annual volume is slaughtered by 94 FI hog plants in these states (USDA-NASS 2020). A comparison of the weekly slaughter of FI barrows and gilts for the first eight months of 2020 is provided in Figure 2.7 to provide context on the dramatic fluctuations in pork processing volumes. Market analysis is often based on year-over-year comparisons because seasonality is taken into account, a key factor in hog slaughter levels, and tells us what is "normal" compared to recent slaughter capacity (2019 in this instance). Although it is an imperfect measure, because we do not know the true U.S. barrow and gilt slaughter capacity in 2020, and slaughter inventories were predicted to be

higher in 2020 than in 2019, it can still serve to identify trends and deviations. (Hayes, et al. 2020)

Figure 2.7: 2020 Percentage Change in U.S. FI Barrow and Gilt Slaughter



(Hayes, et al. 2020)

Due to the sharp decline in hog slaughter, the farm-to-whole pork price spiked from $9/cwt in January and February 2020 to almost $44/cwt in early and mid-May, a 388% increase. However, hog markets fell from nearly $84/cwt in February 2020 to $37/cwt. in April 2020, a 44% decrease, due to surpluses of hogs ready for slaughter (Lusk, Tonsor and Schulz 2021). A price increase in wholesale meat while livestock prices fall may seem contradictory, but the law of supply and demand can explain these price movements. As a result of shutdowns or illnesses at packing plants, packers' demand for hogs may decline. As a result, packers have more livestock than they can process due to a plant closure. The closure of plants reduces demand for hogs, resulting in lower livestock prices. As a result, packers have more livestock than they can process due to a plant closure. The closure of plants reduces demand for hogs, resulting in lower

livestock prices. As a result of a plant closure, fewer hogs enter food production, resulting in fewer shipments of meat. Meat prices rise as supermarkets, restaurants, and exporters compete for a smaller supply of meat.

2.5 Effects of COIVD-19 on Other Industries

Similar to the meat industry, many produce growers had nowhere to sell their crops due to a sudden decrease in demand. The highly perishable nature of most fresh fruits and vegetables limited growers' ability to adapt quickly to other marketing channels. In response to the lack of food service demand, some growers plowed under their fields to avoid harvesting, cooling, and packaging costs. The U.S. produce sector is highly streamlined and specialized. Producers cannot readily switch from one marketing channel to another when selling perishable produce items that are pre-sold and packaged in bulk according to certain specifications. According to a University of California study, most produce is grown, harvested, packed, and shipped in a precise schedule to replenish stores' inventories "just in time." Consequently, market disruptions are difficult to respond to (Johnson 2020).

Agricultural labor concerns further compound the challenges facing the U.S. produce industry. Perishable fruits and vegetables are handled labor-intensively and with few automated/mechanized options. On April 15, 2020, to lessen labor disruption impacts on the industry, the Department of Homeland Security and USDA announced a temporary final rule to change certain H-2A visa requirements. There was concern about what would happen if farmworkers and other produce industry workers became ill from the virus, like what happened in some U.S. meatpacking plants. This major disruption was avoided due to less intimate working conditions than those of meat processing (Johnson 2020).

U.S. soybeans and corn for the 2019–2020 crop year were harvested before the pandemic hit, so there were no pandemic-related production disruptions. Despite the Phase One trade agreement signed on January 15, 2020, which included China's promise to increase purchases of U.S. soybeans (over half of all US soybean exports were exported to China before the trade war), U.S. soybean exports in February and March 2020 were at the lowest levels of the period studied. Neither the virus nor the US lockdowns appear to have affected soybean exports in March, April, and May 2020. Exports in the U.S. typically experience seasonal lows during these months (Mallory 2020).

It was less disruptive for poultry production in the US in April and May than it was for pork, with April production down 5% and May production down 6% from average production levels from January, February, and March 2020. Despite modest declines from the three-month average, April and May's productions were still within the typical range, and higher than February 2020. The beef production in April decreased by 21% compared with January, February, and March of 2020. However, beef production for May was still 19% below the previous year. As a result of the pandemic shutdowns which began in June, July, and August 2020, production levels were near their peak levels before the shutdowns (Mallory 2020).

2.6 Other Issues Impacting the Pork Industry

While the pork industry was recovering from the disruptions caused by COVID-19, African Swine Fever (ASF) was confirmed in late July 2021 in the Dominican Republic. ASF was also reported in neighboring Haiti in September 2021. The disease spreads fast through direct or indirect contact and has a high mortality rate. China experienced an

outbreak of ASF in 2018, greatly reducing the pig population. As a result, U.S. pork production increased to meet China's demand.

Although not a threat to human health, the USDA's Animal and Plant Health Inspection Service (APHIS) implemented steps to keep the virus from spreading into the U.S. In spite of the fact that the virus has never been confirmed in the United States, the pork industry feared that the World Organization for Animal Health might sanction U.S. pork, even if it is found in Puerto Rico, a U.S. territory hundreds of miles off the mainland, because when determining ASF status, the organization does not distinguish between a country and its territories. This would prevent the export of pork and pork products to foreign countries which had already experienced a decline in the amount of product shipped due to the COVID-19 outbreak. Luckily, U.S. pork was not sanctioned due to the virus and biosecurity measures were increased to prevent the spread of the virus into the U.S.

Thousands of pigs were destroyed on farms across the U.S. because of reduced slaughter capacity at processing plants caused by ill workers during COVID-19. Compared to poultry or beef, the pork industry had more problems compromising animal welfare for multiple reasons. There were thousands of pigs at market-ready weights in April and May 2020 without a place to go when livestock processing plants were at reduced capacity. A ruminant's diet can be switched from a grain-based to a forage-based diet, so slowing down growth and waiting for the plants to reopen was much easier. Although pigs have a monogastric digestive tract, some rations can be used to slow their growth, but they are not as effective as dietary changes for cattle. The addition of fiber and reduced energy in the diet will slow the rate at which pigs will reach market weight, but this will only provide an additional four to seven days before they should be marketed. There may only be a four to a

seven-day extension of this time. Poultry has a shorter life cycle than pigs and it is easier to stop production by hatching fewer eggs (Grandin 2021).

It was reported by Minnesota Pork Producers that 350,000 pigs were euthanized, and another 250,000 were sold, slaughtered, or given away. In the case of pigs that had to be culled, they were transported to a large slaughterhouse where the standard stunning equipment was used to kill them, which required only a few people. The carcasses were disposed of in landfills or composted. In terms of welfare, this option was preferable to killing pigs on the farm with a captive bolt or gunshot.

2.7 Conclusion

After COVID-19 infected employees many large pork processing plants had to close or operate at reduced production. This reduced pig prices as processors could not take in any livestock because they were closed from COVID-19 impacts. This lower supply of pork and pork products increase prices for consumers even as it reduced producer prices. The supply tightness affected both domestic and international export markets. The purpose of the research, remember, was to assess the extent to which COVID-19 affected these disruptions in exports to East Asia.

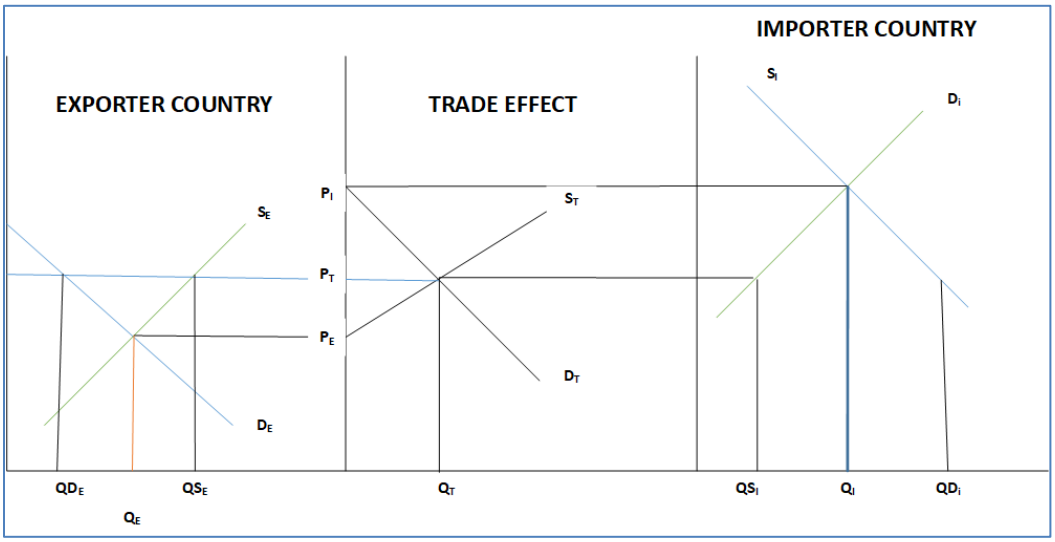
CHAPTER III: MODEL

This chapter examines the relationship between pork exports from the United States to East Asia, as well as the impact of COVID-19 on the industry. It is organized into three sections. The first presents the theory and the hypothesis of the study. The second covers the data – source and nature, the final section presents the model.

3.1 Theory

Exports occur because the price of the exported product is lower in the importing country than the price of the product produced in the importing country, and higher in the importing country than in the domestic market of the exporting country. Figure 3.1 shows that the supply and demand conditions in the export country are such that the equilibrium price is low (P_E) and the supply and demand conditions in the importing country are such that the equilibrium price (P_I) is high in the absence of trade. When trade occurs, the demand conditions allow consumers in the importing country to pay a higher price than they were paying without trade while suppliers in the exporting country get to charge a higher price than they were charging prior to trade. This is the trade price, P_T. As a result of the opportunity presented by trade, supply in the exporting country increases to QS_E from Q_E while demand in the importing country increases to QD_I from QD_E. The graph shows that trade makes consumers in the importing country better off than they were before and suppliers in the exporting country better off than they were before. The consumer and producer surplus resulting from are assumed to be high enough for the suppliers in the importing country and consumers in the exporting country to be *technically* compensated for their losses from trade.

Figure 3.1: Theoretical Framework Explaining Why Trade Happens



(Amanor-Boadu 2022)

Therefore, in our case, East Asia pork producers lose when U.S. pork products are imported but consumers gain from the lower prices the American exporters can charge. Unlike the example used to articulate the genesis of trade, the domestic U.S. market consumes different products than what is exported. Therefore, the exports do not have much impact on the domestic pork market. However, in the absence of trade, then U.S. pork producers suffer because they are unable to market their whole production, which could force them to increase prices to cover the unsold parts of the pig that American consumers do not want. Should that happen, and the price may increase enough to offer an advantage for another country to serve American consumers.

In this study, China, Japan, South Korea, and Taiwan are the four East Asian countries analyzed between the years 2011 and 2022. The principal hypothesis of the study was that COVID-19 had no impact on U.S. pork exports to East Asian countries including China, Japan, South Korea, and Taiwan. The alternative hypothesis was that

COVID-19 adversely affected U.S. pork exports to East Asian countries being focused on in this study.

3.2 Data

The data used for the study were obtained from USDA's Foreign Agricultural Service's GATS (Global Agricultural Trade System) database. The database covers all U.S. agricultural trade with the world at the individual country and regional level. The database is rich in that it has monthly, quarterly, and annual disaggregation as well as disaggregation by product type. The three product types are bulk, intermediate, and consumer-oriented product types. The products in the bulk category cover commodities, such as wheat and corn that are unprocessed and raw. The intermediate category covers good that are semi-processed and are often sold to manufacturers and processors for further processing. The consumer-oriented goods are those that can be sold directly to retailers and restaurants and institutions to be prepared for consumer consumption. These products may also be sold to processors who may be doing secondary or tertiary processing. For example, they might sell a ham to a deli which will process it into deli meat.

The study used monthly data from January 2011 through June 2022. It focused on pork and pork products in the consumer-oriented section of the database. It used both quantity and value of exports to the four focus countries – China, Japan, South Korea, and Taiwan. The database does not collect prices due to the different individual customers and products exported. Therefore, prices were imputed from the value and quantity of products exported. COVID-19 was assumed to start in March 2020 even though it was recognized that products recorded in March had probably shipped before the declaration of the pandemic. The pandemic was coded as a dummy variable where 0 is the period before the

pandemic and 1 is the period of the pandemic. The study assumed that the pandemic has not ended since there has been no official declaration of the end of the pandemic.

The trade data were downloaded into a Microsoft Excel® and organized for analysis by estimating the imputed price of exported product by month and country. The dummy pandemic variable was also developed and included in the data. This was then exported to Stata™ 19 for analysis.

3.4 Model

The variables used in the analyses are summarized in Table 3.1. The subscripts *t* and *i*, running from 1 to 4, represent the time period for the observation (months) and the country of focus, respectively, in a particular analysis. The variables Q and P represent the logarithm of quantity exported by the U.S. and the imputed price of the product in the importing country. The time variable T is included as a proxy for all other variables that may have affected exports other than those specified.

Table 3.1: Theoretical U.S. Pork Export Model Coefficient

Coefficient	Variable
$\mathbf{Q_{it}}$	Quantity of Exported U.S. Pork to East Asian Country of Interest
$\mathbf{P_{it}}$	Price of U.S. Pork Exported to East Asian Country of Interest
$\mathbf{Q_{jt}}$	Quantity of Exported U.S. Pork to Countries Other Than Country i
$\mathbf{P_{jt}}$	Price of Product in Countries Other Than Country i
D	COVID-19
T	Time

The impact of COVID-19 was assessed by running a regression with the endogenous variable as the quantity of pork and products exported by the U.S. to Country *i* and the exogenous variables as pork price in Country *i* and pork and pork product prices

in the other countries, time, and the COVID-19 dummy variable. This is presented as follows:

$$Q_{it} = f(P_{it}, P_{jt}, T_t, D) \quad \forall\, i, j = 1,2,3,4 \text{ and } i \neq j$$
$$D = \begin{cases} 0 = \text{ Before COVID-19} \\ 1 = \text{ COVID-19} \end{cases} \tag{3.1}$$

The model is specified for estimation as follows:

$$Q_{it} = \alpha_i + \beta_i P_{it} + \sum_{j=2}^{4} \gamma_i P_{jt} + \lambda_i T_t + \theta_i D + \phi_i P_{it} D + \varepsilon_{it} \tag{3.2}$$

The Greek letters represent the estimated regression coefficients. The last but one term in Equation (3.2) explores the interaction effect between pork and pork product price and the COVID-19 dummy variable and the last term is the regression error term. If the coefficient ϕ_i is statistically significant, then it means that the pandemic affected the effect of price. The total effect of own price on quantity exported would be $\beta_i + \phi_i$. The model was estimated as a double logarithm for the quantity and price variables. This implies that the regression coefficient on the prices measure the price elasticity of export quantity.

The hypothesis testing required that if the null is rejected, that is COVID-19 does affect the quantity of pork and pork products exported to Country *i*, then θ is statistically significant. If we fail to reject it, then it is not statistically significant.

CHAPTER IV: RESULTS

This chapter is organized in three sections. The first reports the summary statistics for the variables used in the regression analyses. The second section reports the results of the regression analyses. The final section presents the summary, conclusions, and recommendations for further studies emanating from the results.

4.1 Summary Statistics

Table 4.1 presents the summary statistics of the quantity exported to the four countries as well as total exported to the world and to East Asia. The table shows that the average pork and pork products exported to the world was 203,095 MT per month over the duration of the study, i.e., from January 2011 through June 2022. The average porl export prior to COVID-19 was estimated at 194,443 MT per month compared to the COVID-19 era at 237,086 MT per month. Thus, the average U.S. pork and pork product exports during the COVID-19 era was higher than prior to the COVID-19 era. This was true for East Asia as a whole and then for China. However, the other countries all experienced a reduction in the COVID-19 era. For example, the average exports to China increased by about 54.4% between the pre-COVID-19 era and during the COVID-19 era.

Table 4.1: Summary Statistics for Pork and Pork Product Export Quantities in MT by Country and COVID-19 Situation

Export Destination	Average	Std. Dev.	Minimum	Maximum
Before Covid-19				
World	194,443	24,073	158,895	282,048
East Asia	89,303	17,328	61,463	157,769
China	28,550	15,995	8,366	102,220
Japan	35,137	4,652	27,808	48,526
Korea	13,939	5,952	2,751	41,119
Taiwan	1,450	642	532	3,511
Covid -19				
World	237,086	25,757	198,545	294,729
East Asia	110,996	27,317	77,812	172,752
China	62,615	23,709	32,113	112,078
Japan	32,268	3,611	23,896	40,745
Korea	13,712	2,987	8,793	18,067
Taiwan	917	874	68	2,833
Total				
World	203,095	29,800	158,895	294,729
East Asia	93,704	21,509	61,463	172,752
China	35,462	22,436	8,366	112,078
Japan	34,555	4,596	23,896	48,526
Korea	13,893	5,473	2,751	41,119
Taiwan	1,342	724	68	3,511

Table 4.2 shows the summary statistics of the imputed prices for pork and pork products exported to the focus countries in addition to East Asia and the world. The table shows that average imputed prices increased in all countries and was unchanged in the world. For example, while average imputed prices increased from $3.05/kg across all East Asia in the pre-COVID-19 era to $3.06/kg, it increased from $2.14/kg to $2.37 in China, an 11% increase. The increase in the imputed price in South Korea and Taiwan was 13% and 26%, respectively. Japan's imputed prices between the two periods increased only modestly, about 3%. It was interesting to note that the standard deviation decreased between the two periods in China and Japan but increased in the other countries. It increased by about 28% across East Asia, 45% in Taiwan, and by almost 30% in South

Korea. But the decline in the dispersion around the mean imputed price in China was almost 36% compared to 33.8% in Japan and 20% in the world.

Table 4.2: Summary Statistics for Imputed Pork and Pork Product Prices in $/kg by Country and COVID-19 Situation

Export Destination	Average	Std. Dev.	Minimum	Maximum
Before Covid-19				
World	$2.71	$0.18	$2.41	$3.31
East Asia	$3.05	$0.22	$2.58	$3.57
China	$2.14	$0.32	$1.46	$3.37
Japan	$4.12	$0.23	$3.57	$4.65
Korea	$2.84	$0.27	$2.20	$3.74
Taiwan	$2.33	$0.32	$1.57	$3.24
Covid -19				
World	$2.71	$0.15	$2.42	$2.97
East Asia	$3.06	$0.29	$2.64	$3.59
China	$2.37	$0.21	$2.02	$2.73
Japan	$4.25	$0.15	$4.07	$4.59
Korea	$3.21	$0.35	$2.65	$3.72
Taiwan	$2.94	$0.47	$2.44	$4.59
Total				
World	$2.71	$0.18	$2.41	$3.31
East Asia	$3.05	$0.24	$2.58	$3.59
China	$2.19	$0.32	$1.46	$3.37
Japan	$4.15	$0.22	$3.57	$4.65
Korea	$2.92	$0.32	$2.20	$3.74
Taiwan	$2.45	$0.43	$1.57	$4.59

4.2 Regression Results

The regression results are presented by country. They are presented in the following order: China; Japan; South Korea; and Taiwan.

4.2.1 China Regression Results

The F-value for the China regression model was 23.82, and it was statistically significant at the less than 1% level. The R-squared is 56.2%, implying that more than 56% of the variability in the quantity exported is explained by the variability in the exogenous variables. The model results, presented in Table 4.3, shows that the regression coefficient

for the log of imputed U.S. pork and pork products prices in China was approximately -0.98, indicating that a percentage increase in the imputed U.S. pork and pork products price in China leads to about 0.98% per month decrease in the quantity of pork and pork products exported to China by the U.S. This was statistically significant at the less than 1% level. The model results also show that being in a COVID-19 era instead of not increased the quantity shipped to China by more than 1.54% per month and it was statistically significant at the less than 10% level. Therefore, we reject the hypothesis that COVID-19 did not have any impact on U.S. pork and pork product exports to China. It did have a positive and statistically significant impact. While the change in the imputed price in Japan had no effect on the U.S. exports of pork and pork products to China, both South Korea and Taiwan prices did have an effect. A 1% increase in South Korea price decreased the quantity shipped to China by about 1.71% but a 1% increase in Taiwan price increased the quantity shipped to China by about 1.73%.

Table 4.3: Regression Results for U.S. Pork Products Exports to China (January 2011-June 2022)

China Quantity	Coefficient	S.E.	t	P>t	[95%	C.I.]
China Price	-0.98***	0.29	-3.41	0.001	-1.54	-0.41
COVID Era	1.54*	0.80	1.92	0.057	-0.04	3.13
COVID-China Price Interaction	-0.96	0.94	-1.02	0.309	-2.83	0.90
Japan Price	0.96	0.69	1.39	0.166	-0.40	2.33
South Korea Price	-1.71***	0.41	-4.17	0.000	-2.52	-0.90
Taiwan Price	1.73***	0.29	5.95	0.000	1.16	2.31
Period	0.00	0.00	-1.02	0.311	0.00	0.00
Intercept	17.82**	7.66	2.33	0.022	2.67	32.98

***, **, * represents statistical significance at the 1%, 5%, and 10% levels, respectively.

4.2.2 Japan Regression Results

The F-value for the Japan regression model was 5.91, and it was statistically significant at the less than 1% level. The R-squared is 24.2%, implying that more than 24%

of the variability in the quantity exported is explained by the variability in the exogenous variables. The model results, presented in Table 4.5, shows that the regression coefficient for the log of imputed U.S. pork and pork products prices in Japan was approximately -0.26, indicating that a percentage increase in the imputed U.S. pork and pork products price in China leads to about 0.26% per month decrease in the quantity of pork and pork products exported to Japan by the U.S. This was statistically significant at the less than 1% level. However, the imputed price of U.S. pork and pork products in Japan was not statistically significant in explaining the quantity of pork and pork products exported to Japan by the U.S. The model results also show that being in a COVID-19 era instead of not increased the quantity shipped to Japan by about 2.31% per month and it was statistically significant at the less than 5% level. Therefore, we reject the hypothesis that COVID-19 did not have any impact on U.S. pork and pork product exports to Japan. It did have a positive and statistically significant impact.

Table 4.4: Regression Results for U.S. Pork Products Exports to Japan (January 2011-June 2022)

Japan Quantity	Coefficient	S.E.	t	P>t	[95%	C.I.]
China Price	-0.26***	0.08	-3.10	0.002	-0.42	-0.09
Japan Price	0.11	0.21	0.50	0.616	-0.31	0.53
COVID Era	2.31**	0.95	2.42	0.017	0.43	4.19
COVID-Japan Price	-1.64**	0.66	-2.48	0.014	-2.94	-0.33
South Korea Price	0.36***	0.12	3.10	0.002	0.13	0.60
Taiwan Price	-0.18**	0.09	-2.03	0.044	-0.35	0.00
Period	0.00	0.00	-0.52	0.606	0.00	0.00
Intercept	11.47***	2.28	5.03	0.000	6.96	15.99

***, **, * represents statistical significance at the 1%, 5%, and 10% levels, respectively.

The change in the imputed prices in both South Korea and Taiwan prices had negative and positive effect on U.S. exports to Japan. A 1% increase in South Korea price increased the quantity shipped to Japan by about 0.36% but a 1% increase in Taiwan price

decreased the quantity shipped to Japan by about 0.18%. They were statistically significant at the less than 1% level and at the less than 5% level, respectively. The results also showed that Japan price effect was affected by the COVID-19. As a result, a 1% increase in the imputed price in the COVID-19 resulted in a 1.64% decrease in the quantity of pork and pork products exported to Japan by the U.S. during the COVID-19 era compared to the pre-COVID-19 era.

4.2.3 South Korea Regression Results

The F-value for the South Korea regression model was 10.12, and it was statistically significant at the less than 1% level. The R-squared is 35.3%, implying that more than 35% of the variability in the quantity exported is explained by the variability in the exogenous variables. The model results, presented in Table 4.6, shows that the regression coefficient for the log of imputed U.S. pork and pork products prices in South Korea was approximately -1.14, indicating that a percentage increase in the imputed U.S. pork and pork products price in South Korea leads to about 1.14% per month decrease in the quantity of pork and pork products exported to South Korea by the U.S. This was statistically significant at the less than 1% level. Similarly, the coefficients of the imputed price of U.S. pork and pork products in China and Japan were both statistically significant at the less than 1% level. For example, increasing prices in Japan by 1% is estimated to decrease exports to South Korea by more than 3.65% per month while increasing the price in China by 1% results in about 0.65% per month increase in exports to South Korea, both statistically significant at less than 1% level. Likewise, a 1% increase in the imputed price in Taiwan increased exports to South Korea by about 0.53% per month. COVID-19, however, did not have any statistically significant impact on exports to South Korea given that neither the coefficient on the COVID-19 alone or its interaction with the imputed price

in South Korea were statistically significant. Therefore, we are unable to reject the hypothesis that COVID-19 did not have any impact on U.S. pork and pork product exports to South Korea.

Table 4.5: Regression Results for U.S. Pork Products Exports to South Korea (January 2011-June 2022)

South Korea Quantity	Coefficient	S.E.	t	P>t	[95%	C.I.]
China Price	0.65***	0.24	2.66	0.009	0.17	1.13
Japan Price	-3.65***	0.61	-5.96	0.000	-4.86	-2.44
South Korea Price	-1.14***	0.39	-2.94	0.004	-1.91	-0.37
COVID	-1.17	0.79	-1.48	0.142	-2.74	0.40
COVID-South Korea Price Interaction	1.11	0.70	1.58	0.117	-0.28	2.49
Taiwan Price	0.53**	0.26	2.04	0.044	0.01	1.04
Period	0.00***	0.00	-3.23	0.002	0.00	0.00
Intercept	37.07***	6.70	5.53	0.000	23.82	50.32

***, **, * represents statistical significance at the 1%, 5%, and 10% levels, respectively.

4.2.4 Taiwan Regression Results

The F-value for the Taiwan regression model was 17.59, and it was statistically significant at the less than 1% level. The R-squared is 48.6%, implying that more than 48% of the variability in the quantity exported is explained by the variability in the exogenous variables. The model results, presented in Table 4.7, shows that the regression coefficient for the log of imputed U.S. pork and pork products prices in Taiwan was approximately -0.86, indicating that a percentage increase in the imputed U.S. pork and pork products price in Taiwan leads to about 0.86% per month decrease in the quantity of pork and pork products exported to Taiwan by the U.S. This was statistically significant at the less than 10% level. However, the coefficients of the imputed price of U.S. pork and pork products in China and Japan were both statistically not significant. The coefficient on the South Korea price was about -1.88, and statistically significant at the less than 1% level. The coefficient on the COVID-19 variable was 2.09 and statistically significant at the less than

5% level, indicating that the pandemic did have an influence on the quantity of U.S. pork and pork product exports to Taiwan. The Taiwan price-COVID-19 interaction showed that a 1% increase in pork and pork product price in Taiwan during COVID-19 decreased U.S. pork and pork product exports to Taiwan by about 2.34% per month, statistically significant at the less than 1% level. Thus, COVID-19 not only affected U.S. exports to Taiwan, but it also affected its imputed price in Taiwan.

Table 4.6: Results for U.S. Pork Products Exports to Taiwan (January 2011-May 2022)

Taiwan Quantity	Coefficient	S.E.	t	P>t	[95%	C.I.]
China Price	-0.38	0.39	-0.98	0.331	-1.15	0.39
Japan Price	-0.38	0.97	-0.39	0.698	-2.30	1.54
South Korea Price	-1.88***	0.55	-3.40	0.001	-2.97	-0.79
Taiwan Price	-0.86*	0.45	-1.92	0.057	-1.74	0.03
COVID	2.09**	0.85	2.47	0.015	0.42	3.76
COVID-Taiwan Price Interaction	-2.34***	0.82	-2.85	0.005	-3.96	-0.72
Period	0.00	0.00	0.74	0.460	0.00	0.00
Intercept	2.64	10.60	0.25	0.803	-18.32	23.61

***, **, * represents statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3 Conclusion

As well as experiencing an increase in domestic consumption, the demand for pork exports in the United States is also increasing. China and Japan are the two top global importers of U.S. pork and pork products with others in East Asia falling into the top ten. The demand for U.S. pork is growing as a result of changing trends within these countries. Members of the pork industry and policymakers will be able to better prepare for future opportunities in pork export by understanding the growth in demand and the disruptions that a major global event might cause.

The impact of the COVID-19 virus did not have a statistically significant impact on South Korea. However, it did have a statistically significant impact on China, Japan,

and Taiwan. Therefore, the hypothesis that there was no COVID-19 effect on U.S. pork and pork product exports was rejected in three of the four cases. The results also showed that the pandemic affected prices in Japan and Taiwan but not in China and South Korea. The results also show that price changes in other countries affect exports into the target country in some cases. For example, South Korea was a complement market for U.S. pork and pork product exports destined for Taiwan as were Japan for South Korea. The relationship between South Korea and Taiwan was opposite to the relationship between Taiwan and South Korea. This indicates that relationship between U.S. exports to South Korea and U.S. exports to Taiwan is not commutative. This is true for most of the relationships. In fact, Japan and Taiwan were the only pair that was commutative but while the Taiwan price effect on exports to Japan was statistically significant (at less than 5% level), the Japan price effect on exports to Taiwan was the same sign but not statistically significant. The summary of the regression results is summarized in Table 4.7. Finally, the table shows that the hypothesis that COVID-19 had not impact on exports was rejected in all cases but in the case of South Korea.

As a result of this information, the pork industry and policymakers can be informed as to how easily the supply chain can be disrupted, as well as how crucial it is to maintain a constant supply to prevent the happening of another catastrophe like the one that occurred during the COVID-19 pandemic. The importance of food manufacturers having disaster plans in place to ensure a continuous supply of food only highlights the importance of preparing for such an event during the production process.

Table 4.7: Summary of the Cross Price Effects, COVID-19, and Quantity Exported to East Asian countries

	China Price	Japan Price	S. Korea Price	Taiwan Price	COVID-19
China Quantity	-***	+	-***	+***	+*
Japan Quantity	-***	+	+***	-**	+**
Korea Quantity	+***	-***	-**	+*	-
Taiwan Quantity	-	-	-***	-*	+**

*** 1%; ** 5%; * 10%

4.4 Implications and Future Research

The foregoing results are interesting in illuminating the relationships between U.S. pork and pork product exports to the four East Asian countries and the imputed prices in those countries. The research assumed that the only influencing variables were prices, COVID-19, and time. The time variable was not statistically significant in all countries except South Korea. However, variables such as trade policy (tariffs, quotas, etc.) could have illuminated the results a lot more. Therefore, it is suggested that future research on the subject addresses the policy effect.

Products were aggregated at the HS-10 level. Thus, the imputed price had inadequate meaning because it was at a very aggregated level. Future work should disaggregate the products and explore exports of the same products to the different countries. This will allow the cross-price effects to have better meaning. The reason this was not done in this research was the differences in product components into the different countries and the research question of the effect of COVID-19 on exports to the selected countries. Framing a research question that focuses on a specific product, e.g., cooked hams, would provide more comparable results.

The prices used in the study are imputed from quantities and values. Therefore, they reflect the demand price and not the supply price. Therefore, the demand responses

are accurate: As prices increase, quantity demanded decrease. Future studies should explore these relationships in more detail from the supply perspective to see if economic theory of supply holds. The substitution effects across countries in the study may also be overstated because of the fact that products were aggregated but different countries demand different product mixes. Therefore, future studies might want to conduct this analysis at the specific product level.

Finally, including the domestic U.S. market conditions so that the effects of domestic conditions on exports could be explored. This may be done in general for all countries and all products as was done in this study. However, as noted above, conducting such a study on specific products and by country could probably produce more information to influence the pork industry's strategies and policy advocacies for exports. They could help minimize the impact of global or even regional catastrophic events, such as COVID-19, on U.S. pork and pork product exports.

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