An Empirical Analysis of the Price Variance of Agricultural Commodities before and after COVID-19 in the USA

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Abstract

Using monthly price data of beef, pork, broilers, apples, strawberries, potatoes and tomatoes we compare and contrast price volatility before and after COVID-19 pandemic. We also compare and contrast the price volatility among meat, fruits and vegetables before and after COVID-19. Our analysis shows how COVID-19 induced disruptions affected these commodities' price. Our empirical results suggest that COVID-19 has a significantly positive impact on increasing prices of beef, pork and strawberries. On the other hand, COVID-19 has a negative impact on potatoes prices. COVID-19 has no significant effects on broilers, apples and tomatoes prices. We also tested how much gasoline price contributed to increase of prices of these commodities. The result suggested all three kind of meat prices have a positive relationship with gasoline price.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background

Coronavirus-2019 (COVID-19) first started in Wuhan, China in December 2019 and very quickly spread throughout the world. The first confirmed case of COVID-19 in the United States was on January 18, 2020, in Washington state. According to the World Health Organization, by June 16, 2022, there had been more than 536 million conformed COVID-19 cases and more than 6.3 million COVID-19 related deaths around the world. Just in the USA alone there have been more than 85 million conformed COVID-19 cases and more than 1 million COVID-19 related deaths. To stop spreading the virus, almost every country in the world mandated lockdowns. On March 13, 2020, the US declared a nationwide lockdown to stop spreading the virus. During the lockdown, all the restaurants, cafeterias, dining halls, schools, hotels, etc., were closed and people had to eat all the meals at home. Therefore, consumers had to shop for more groceries than at normal times. However, when a government mandates a lockdown, there are always economic consequences and the COVID-19 lockdown was no exception. The economic impacts of COVID-19 were very large. For example, the US unemployment rate hit almost 15% in April 2020, which was the highest unemployment rate since the Great Depression. The Gross Domestic Product (GDP) declined significantly (5% on annual basis) during the First Quarter of 2020 and dropped hugely during the Second Quarter (31.7% on annual basis). This was technically a recession, and the economy's resilience resulted in 33.4% GDP growth, on an annual basis, in the Third Quarter of 2020 followed by a small increase (4.1% on an annual basis) in the Fourth Quarter.

COVID-19 was disastrous on multiple levels in the whole US food industry. First, since COVID started record numbers of American became unemployed and therefore consumers lost their purchasing power. Second, food-away-from-home (FAFH) consumption went down by overall 19.5% (Zeballos et all 2021) because of lockdown and other behavioral changes of consumers. Third, total production volume of agricultural products was jeopardized by the pandemic and therefore there could be a shortage of supply instead of than demand. Fourth, international trade--imports and exports—was damaged because of adopting of border control policy.

1.2 Objective of the Study

Prices of agricultural commodities change hour by hour on commodities exchanges around the world and also did in the wholesale and retail environment during COVID-19 period. A large number of independent variables affect agricultural commodities prices, summarized as supply and demand. However, supply is affected by numerous variables such as weather, imports and exports, labor shortages, panic buying, transportation disruptions, and others. Demand is affected by unemployment rates, prices, imports and exports, changes in consumer consumption preferences and patterns, retail management decisions, and others. Even in relatively stable times, there are trends and disruptions in the supply and demand for agricultural commodities. Lusk et al (2021) wrote, “Meat and livestock prices and processing volumes were extraordinarily volatile during the COVID-19 pandemic.” They show that the extraordinarily volatile periods were short (two weeks to two months) but do not directly mention that prices and volumes are always volatile, which is clear from looking at any year’s USDA data.

Higher food prices exacerbated food insecurity not only in developing countries but also in the USA (Gregory et al 2013). Low-income households tend to spend less on healthy food when food prices increase (Leibtag 2007). It is critical to understand whether price increases of agricultural products because of COVID-19 cause food insecurity in the USA. Indeed, Gundersen et al (2020) projected an increase of 17 million Americans who were food insecure in 2020.

Economists are still investigating the changes in supply, demand, and therefore prices under extraordinary circumstances, such as during the current COVID-19 pandemic—which has now lasted over two and a half years and continues. Major disruptions in the supply and demand for agricultural commodities during the pandemic have included widespread temporary or permanent, partial or total closure of the country's approximately one million restaurants, and labor shortages from farms to factories to warehouses to grocery stores.

It will be useful to perform an analysis of the variance of agricultural commodity prices before and after the COVID-19 pandemic over time as various different independent variables have increased and decreased in their apparent effects on agricultural prices. Most research conducted in the early days of COVID-19 examined only the short-run impacts of COVID-19 lockdown. Most of the authors of these papers suggested that other academics should write about the long-run consequences of COVID-19 in the commodity markets. There is also a lack of research comparing and contrasting the meat industry with the vegetables and fruits industry. It is been more than two years since the early research was conducted and now it is appropriate as suggested to empirically analyze the impact of COVID-19 from beginning to the end of 2021.

There are two research questions of this paper. One research question is to compare and contrast the volatility in the prices of selected commodities before and after the start of the COVID-19 pandemic. And the second question is to compare and contrast the price volatility of selected meat with the price volatility of selected fruits and vegetables before and after the pandemic started.

The rest of the thesis is organized as follows. The following section discusses relevant literatures on how COVID-19 affects overall US agricultural markets. Sections 3 is about data and descriptive statistics. Section 4 is empirical strategy and results. And section 5 concludes the paper.

Chapter 2: Literature Review

The prices of agricultural commodities have historically been a major concern for economists, politicians and the general public because everyone needs them, and they also factor into inflation rates, government policies, scientific priorities, and other spheres. Commodity prices might seem to be straightforward, but a large number of factors, related and not, and easy to find out and not, affect agricultural commodity prices.

2.1 Historical Point of Views on Price of Agricultural Products

One frequently cited journal article from nearly 30 years ago, Tomek and Myers (1993), is dedicated entirely to their criticisms of, and suggestions for, agricultural price analyses by economists. (In short, they thought that most commodities price analyses by economists up until that time had been badly done.) They wrote that commodity price analyses are conducted for four reasons: "forecasting, policy analysis, improved understanding of agricultural markets including the stochastic properties of variables, and hypothesis generation." They also wrote that parameter estimates are "usually unstable (fragile)," changing with samples and models, and, unfortunately, the resulting "varying parameter estimates imply poor forecasts and are a questionable basis for policy analysis" (p. 195).

Tomek and Myers also wrote that supply models have some common features, such as assumptions that must be made because of the time that passes between when production decisions are made and finished products are sold. Specifically, expected profits are based on expected yields and expected profits, while input prices are assumed to be known and exogenous when production decisions are made. But risks to prices and yields still must be factored into supply. The problems with this, Tomek and Myers wrote, is that supply functions

"differ markedly" among individual farm commodities for many different reasons, ranging from differing approaches by analysts, to varying government programs, to differences among products. For example, outputs of livestock and livestock products are "constrained in the short term by the size of the breeding flock of herd" (p. 183).

More proof that every commodity and every situation must be considered individually, Tomek and Myers pointed out that temporary changes in output when prices increase cannot be assumed to be the opposite of output changes when prices decrease. (For example, culling a breeding herd does not have the biological constraints that expanding a herd does.) When prices increase, farmers may make permanent investments (which analysts call irreversible functions) in new technologies in addition to any short-term changes.

Tomek and Myers also warned that perennial crops are difficult to analyze because farmers are limited by their available land, immediately increasing production in any way other than more land is difficult (and new trees take years to bear fruit, complicating discounted expected profit), and low prices may result in unharvested crops (p. 184). They added, "even supply analysis of annual crops is not easy" because of the influence of government programs on crops such as wheat, corn, soybeans, rice, and cotton (p. 184). They wrote that improved technology is "the single most important factor determining the level of supply" but technological change is "so pervasive and continuous that it is difficult to measure" (p. 185), resulting in ad hoc modeling by researchers.

Tomek and Myers (1993, p.185) also outlined why studying demand for agricultural commodities also is complex and difficult. They mentioned disagreements and difficulties in constructing demand equations, and then gave examples. For instance, "A key concept in modeling household data is the life cycle of the household, specifically, the number, sex, age

of the household members" (p. 187), but that many other factors affect demand, only two of which are income levels and changes in meat advertising.

Baffes and Haniotis (2016), in the World Bank paper, "What Explains Agricultural Movements?", focused on five major causes of price changes in commodities. Their analysis showed "that increases in real income negatively affect real agricultural prices, as predicted by Engel's law. Energy prices matter most (not surprisingly, given the energy-intensive nature of agriculture), followed by stock-to-use ratios and, to a lesser extent, exchange rate movements. The cost of capital affects prices only marginally, probably because it not only influences demand, but also evokes a supply response" (abstract). Baffes and Haniotis cautioned that their model was designed to capture long-term trends, not short-term price variability.

An important part of analyzing commodity prices is not just causes and effects of price increases and price decreases, but also the degrees and reasons for price volatility, which also can be small or large. The importance of price volatility has been the motivation for this thesis's study of price volatility in several agricultural commodities before and during the COVID-19 pandemic.

Volatility of prices of agricultural commodities is a long-term concern of some of the world's most important international agencies, think tanks, and others. For example, Bellemare (2014, p. 2) cites the Brookings Institution's Kharas (2011), who wrote, "the crux of the food price challenge is about price volatility rather than high prices per se…It is the rapid and unpredictable changes in food prices that wreak havoc on markets, politics and social stability." Bellemare wrote that the United Nations' Food and Agricultural Organization called a late 2010 meeting of its High-Level Panel of Experts on Food Security and Nutrition specifically to study causes and effects of food price volatility. Bellemare also analyzed the history of "food

riots" and "social unrest" connected to rising food prices and food shortages. (The United States did not have any food riot connected to COVID-19 or even any other social unrest like what has sometimes affected other countries.)

Focusing only on natural disasters ("all droughts, earthquakes, epidemics, episodes of extreme temperature, floods, insect infestations, mass movements [both dry and wet], storms, volcanic eruptions, and wildfires—in a given month" during 1990-2011) as causes of changes of food prices, Bellemare concluded that globally, social unrest could be caused by rising food prices, but not by food price volatility. He speculates, without evidence, that maybe highly volatile prices have a bigger impact on wealthy households, since they are more likely to be food producers, than on the much larger number of poor households, which are more likely to be only food consumers. Bellemare did not study causes of food price changes other than natural disasters, so this thesis adds to the literature about causes other than natural disasters.

2.2 Price of Agricultural Products during COVID-19

Several articles have been published on how price dynamics of agricultural commodities like beef, pork and chicken changed since COVID-19 started. These articles showed how this pandemic affected producers, consumers, retailers, and products themselves. Researchers discussed why beef prices went up while broiler chicken prices went down, why producers threw away potatoes instead of selling them, and other economics analyses. Also, supply chain issues became so prevalent and that caused many other problems in the agricultural industry. Next this literature review focuses on articles about prices of beef, pork and chicken in the United States during COVID-19.

Supply chain shocks

Researchers began addressing the issue of supply chain shocks during COVID, but they have differences in opinions. Some researchers believe that COVID-19 showed that food supply chains in the United States are too vulnerable and need to be changed before another major crisis. Hayes et al (2020) said, "The novel coronavirus has laid bare that the system is inefficient in the face of a large pandemic that impacts the production methods themselves as opposed to the supply of raw materials, in this case, commodity proteins". Hayes et al. were positive only about the country's food supply chains working well considering the size and speed of the COVID-19 pandemic's effects. They wrote, "Many supply chains designed to function efficiently were unable to respond fully to absorb the shocks, despite the impressive changes they did implement". (Their opinion is not based on past experience or studies, since Hayes et al wrote that studies on agricultural food chains were about other situations.) They wrote that previous studies did not address how supply chains are vulnerable when necessary large numbers of human or other assets are suddenly unavailable," concluding "We are in new territory in our understanding of the consequences of major shocks to supply chains, and it is imperative that we re-evaluate our understanding of food supply chain behavior in the face of a major pandemic".

Labor shortages on farms and in factories

According to a Washington State Department of Health report, agriculture, forestry, fishing, and hunting workers are the second most vulnerable group of people for getting COVID-19 because of a lack of infrastructure. Food and agriculture workers were essential workers. The result is apparent—workers infected by the virus. Operating packing plants throughout the

United States are not designed for employees to keep their distance from each other. When the federal government suddenly mandated social distancing in all packing plants, plants had to employ less employees than at a normal time. As a result, packing plants were running less efficiently and effectively than before. Social distancing contributed to making meat more expensive than at a normal time. Added factors like closedowns of packing plants, refrigerating empty buildings, paying employees who aren't at work, and paying for overtime made everything more expensive.

The H-2A visa allows United States farm owners to hire temporary or seasonal agricultural workers from outside of the United States, but the H-2A visa program was temporarily shut down at the beginning of COVID-19. All these labor related problems helped cause price hikes during that time.

Ridley and Devadoss (2021, p. 329) wrote, "As one of the most labor-intensive sectors in agriculture (USDA-ERS 2020), fruit and vegetable production is one of the sectors with the most at stake in light of COVID-19's threats to the farm labor force." This is especially true considering how concentrated US fruit and vegetable production is, meaning that COVID-19 spreading in a heavy fruit or vegetable-growing area could have a large impact on an entire commodity. The researchers differentiated between fruit and vegetables they consider labor-intensive and those they don't consider labor-intensive. They observed that "40 counties alone account for nearly 75% of US acreage devoted to labor-intensive fruit and vegetable production (USDA-NASS 2020) and have almost uniformly experienced significant and protracted outbreaks" (Ridley and Devadoss, p. 330). They gave several examples: "outbreaks among 201 workers at a berry farm in Ventura County, California (Rode 2020); 90 cases on a watermelon farm in Alachua County, Florida (Sexton 2020); and 120 workers at an orchard in

Okanogan County, Washington" (Ridley and Devadoss, 2021, p. 331). They also argued that COVID-19 effects did not happen entirely by chance: "The wide variation in demographic and economic conditions across counties, policy responses from state and local governments of differing intensity and duration, and other unexplained factors have led to some regions experiencing widespread outbreaks, and others remaining relatively unscathed (Desmet and Wacziarg 2020)."

Their study, "The Effects of COVID-19 on Fruit and Vegetable Production," reported their econometric estimates of how much production was damaged, in an "extreme scenario": "major crop losses include $16 million in lettuce, $5 million in apples, and $4 million in grapes" (Ridley and Devadoss, p. 329). Relevant for this thesis, their extreme scenario losses were $3.5 million for strawberries and almost $1.7 million for tomatoes. (Their analysis did not include potatoes because it was not considered labor intensive.) Their "conservative scenario" figures were about one-quarter as much. Overall, they wrote, "Millions of dollars in losses for a multi-billion-dollar industry are not trivial, but neither are they cataclysmic" (p. 338).

Hayes et al. (2020) wrote that the pandemic did not affect the country evenly because COVID-19 rates were higher in some regions than others, and pork-processing plants also are not everywhere. "Early on, COVID-19 cases were more concentrated in coastal population centers, especially in the Northeast," and hog packing plants in New York and New Jersey process only .1% of the country's pork. They wrote, "As the pandemic spread, COVID-19 cases spiked in major pork processing regions such as Iowa, Illinois, Minnesota, and Missouri. These states contain 94 F1 hog plants which slaughter 56% of the annual volume".

Lack of flexibility in selling products

Chenarides et al (2021) argue that a big problem for the food industry during COVID-19 was that food producers had not prepared for the possibility of a huge drop in FAFH sales for any reason, and that some foods sold for food service (restaurants, cafeterias, etc.) is quite different than food sold for at-home consumption. FAFH sales dropped, at least temporarily, by 50%, leading to "onions, milk, meat, and other products destined for food service use being discarded, or donated to food banks" (p. 270), especially between March 2020 and May 2020, "in which severe disruption was clearly evident" (p. 271). Chenarides et al. point out that "moving between the food service and retail channels often involves a considerable investment—in packaging, transportation, product design, contract negotiation, and even plant varieties" (p. 271). They conclude that firms that can more easily move sales from FAH to FAFH, or from FAFH to FAH, will be more highly valued by investors in the capital markets, and that unprepared/inflexible firms should go out of business instead of being saved by "government support" (p. 277). However, their research, which was submitted for publication on July 15, 2020, is based on assumptions that the US food industry was in long-term chaos from COVID-19. Events since mid-2020 show that Chenarides et al. were far too critical and pessimistic about the food industry and they overreacted in their conclusions and recommendations.

Demand shocks: closures of restaurants and other demand changes

Zeballos et al (2021) noted that when the United States government mandated a stay-at-home order and all restaurants were closed due to COVID-19, eating at home drastically increased

compared to eating in restaurants. That study also pointed out that food consumption at restaurants and cafeterias decreased by 19.5% in 2020 compared to 2019.

There was not only an increase in eating at home, but also changes in grocery shopping (more online buying) and possible small changes in what Americans ate. Ellison et al (2021) surveyed 1,370 families four times in less than two months (mid-March to late April 2020) about grocery shopping. They concluded, "food values that we studied appear to be stable over the pandemic and align with the findings from other studies showing that taste is a driving factor of food purchases. However, the reductions in importance for nutrition and price, in particular, reveal the tradeoffs households are willing to make in times of scarcity (perceived or actual)."

Ellison et al (2021) conducted four surveys of 1,370 households during a short period early in the pandemic—mid-March to late April 2020. During that short period, they found that consumers of canned meat (they did not specify which meat) were less sensitive to both less nutrition and also higher prices as time went along. They said the results "reveal the tradeoffs that households are willing to make in times of scarcity (perceived or actual)" (p. 70) and that the tradeoffs consumers made during COVID-19 were larger than those made during the Great Recession. (Ellison et al also found significant increases in online shopping, not just large increases in buying for consumption at home.)

Specific factors beef prices during COVID-19

Lusk et al (2021) studied marketing margins and price spreads of beef (and pork) during the first few months of 2020 (they submitted their research in July 2020). They wrote about the first four months of the pandemic, "Meat and livestock prices and processing volumes were

extraordinarily volatile during the COVID-19 pandemic" (p. 5) due to an increase in demand at grocery stores followed by a collapse in demand at restaurants. Wholesale prices jumped to $255/cwt by the end of March from $210/cwt in mid-March right before the pandemic shutdown. Wholesale prices increased to $459/cwt for the week ending May 15, 2020. After that, wholesale beef prices decreased fairly quickly. Lusk found that wholesale price increases were only partially caused by an increase in live cattle prices, which were $124/cwt in January and declined to only $108/cwt by mid-March. Live cattle prices apparently were never higher than about $124/cwt during the entire January-June 2020 period. (The price declines during March and April 2020 were so "drastic" that the Coronavirus Food Assistance Program, announced in May 2020 by the US Dept. of Agriculture, included direct financial assistance to cattle producers, "especially those who had to move cattle during the lowest price periods" [Martinez et al., 2021, p. 312].)

They found that packing plants tried to run at near capacity because of worker safety concerns, to preserve food availability for the public, and because shutting down plants also would have had costs (p. 20). They also concluded that profits of publicly-traded meatpackers did not increase to "substantial windfalls" despite prices going up.

Overall, Lusk et al. wrote that the price spread in beef "has become increasingly volatile over the past five years, highlighting the need to better understand the determinants of change." Comparing volatility before and during COVID-19 possibly can help that understanding.

Ramsey et al (2020) focused their study on price transmission in US meat markets. They emphasized that by the end of March 2020, the beef industry already had been accused of "potential market manipulation and unfair practices" by Senator Charles Grassley of Iowa and legislators in the largest farm states. Ramsey et al wrote that COVID-19 began affecting

beef processing plants right after Grassley made his accusation, which apparently made investigating it more difficult. But Ramsey et al. (2021) also said that, overall, beef, pork and poultry "prices return(ed) to expected levels at a pace consistent" with prices before the pandemic, so "unexpected, large price movements in April and May of 2020" were "transitory" (p. 441). They also said that the "largest discrepancies" for beef and pork were in May and June, but were in April and May for chicken (p. 454). Lusk et al (2021) concluded that beef packers did not operate in a noncompetitive manner and that large profits can happen in competitive markets with large supply shocks.

Weersink et at. (2021) wrote, "The diversion of beef from the hospitality channel to grocery stores was not seamless, because of differences in distributional logistics, package size and meat qualities. Reallocation of beef tended to discriminate against the most expensive restaurant cuts whereas individual grocery shoppers tended to purchase cheaper cuts and hamburgers."

Specific factors to pork prices during COVID-19

Lusk et al (2021) studied marketing margins and price spreads of pork (and beef) during the first few months of 2020 (they submitted their research in July 2020). They wrote, "Meat and livestock prices and processing volumes were extraordinarily volatile during the COVID-19 pandemic" (p. 5). They concluded that "the overall pattern of price and margin movements…for pork is similar to that of beef…, albeit with less dramatic price movements" (Lusk et al., p. 9).

Like beef, Lusk et al wrote that the "significant increase in the price spread in May is more explained by the increase in wholesale pork prices than hog prices. The farm-to-

wholesale pork price spread averaged about $9/cwt in January and February 2020, reaching a peak of almost $44/cwt in early and mid-May, a 388%" (p. 9).

According to Lusk et al, hog prices by carcass weight (dressed) were about $62/cwt in January 2020, declined to less than $50/cwt in mid-April and went up to about $72 in mid-May before continuously declining until at least late June. The wholesale price cutout price for hogs were about $75/cwt in January, went up a little, then down a little, then up, hitting $80/cwt in late March, then went down again. But starting in late April, there was a quick increase to about $115/cwt in early May before a decline until at least late June.

Again, Ramsey et al. (2021) also said that, overall, beef, pork and poultry "prices return(ed) to expected levels at a pace consistent" with prices before the pandemic, so "unexpected, large price movements in April and May of 2020" were "transitory" (p. 441). They also said that the "largest discrepancies" for beef and pork were in May and June but were in April and May for chicken (p. 454).

Weersink (2021) wrote that another factor in pork prices was, "As market hog inventories rose and prices fell, producers tried to modify hog diets, adjust stocking densities, and find additional facility space to maintain pipeline hog supplies. However, the biological nature (i.e., gestation of finishing length) of hog production restricts producers from instantly responding to prices changes."

Specific factors to chicken prices during COVID-19

COVID-19 had a major impact on the broiler chicken industry but different than other agricultural products, according to Maples et al (2021). Chicken processing was "relatively unscathed by COVID-19" (Lusk et al, 2021, p. 5). Lusk et al said, "it is unclear exactly why

chicken processing was less affected than beef and pork, but possible explanations include greater use of automation, lower worker density, and differing geographic plant locations." Ramsey et al (2021) concluded that there are still unanswered questions about COVID-19's impacts on meat markets. They said one question like that is, "why were chicken prices mostly immune to labor related price increases when chicken processing plants were affected by COVID-19?"

Maples et al (2021) said that 70% of all US poultry production is broiler chickens. They concluded that the effects of COVID on broiler chicken farmers cannot be known due to a combination of a decrease in consumer demand, processing disruptions, and insufficient data from the farmers, which is partially because farmers who raise chickens do not own them. (99% of US broiler chickens are grown under contract.)

In February 2020, the US Department of Agriculture predicted 45.8 billion pounds of 2020 broiler chicken production at an average of 87 cents per pound. In August 2020, the same report was updated to only 44.7 billion pounds, a decrease of only 2.4% but with a 19% decrease in prices to only 70.4 cents per pound on average.

The Unusual case of dairy Prices

Commodities prices generally increase due to all kinds of different demand side and supply-side shocks. But it should not be assumed that this happens to all commodities or in every case of a shock. Liu & Rabinowitz (2020) studied eight different dairy products, using weekly data from June 2019 to June 2020. They expected that all eight dairy products would experience price increases after the COVID-19 pandemic started for predictable reasons. However, overall prices of the eight products declined by 8%. When they broke that down into different sizes of

products (e.g., half a gallon of milk vs. gallon of milk), they showed that some prices declined while other prices remained steady. Their conclusions were speculative: "Prices can often be sticky, that is, grocery stores may prefer to respond more slowly to the situation. This can also be an effort by retailers to maintain good customer relations by not being seen as taking advantage of the consumer by raising price. Alternatively, retailers may be concerned about being seen as violating anti-price gouging laws. It is also possible that the impacts are implemented over a longer-term and thus not immediate at the time of the initial shock, which would indicate that we have not captured the impact in our analysis. This may depend on the length of time that restrictions are in place, how consumers respond, and the severity of the supply chain disruptions. There is also the potential that economic conditions were such that an extremely elastic section of the demand curve was reached at that time" (p. 119). Again, Liu and Rabinowitz's conclusions are consistent with economic theory but not supported by data.

Other factors

Lambert et al. (2010) researched "The sources of variability in U.S. food prices" following the Great Recession. They investigated an American Farm Bureau claim from 2008 that fuel prices were the largest reason for increases in domestic food prices. They also investigated other possible causes, such as global commodity demand, global inventories, the weakening of the U.S. dollar, packaging costs, and farmland being changed to other uses. But they concluded that "innovations in farm prices and manufacturing wages" were more responsible for price increases, not "consumer incomes or the price of other food production inputs including fuel…" Price increases during COVID-19 also should be researched for connections to

manufacturing wages, consumer incomes, fuel prices, global demand, and foreign exchange rates.

Chapter 3: Data and Descriptive Statistics

3.1 Data

This purpose of this study to analyze the whole prices of total seven different agricultural commodities. These commodities are beef, pork, broilers, apples, strawberries, potatoes and tomatoes. Data have been collected from various sources to do an empirical analysis that would show price variances in agricultural products before and after COVID-19. Historical monthly wholesale prices and production data on federally inspected meats (e.g., beef, pork, broilers) have been collected from the United States of Department of Agriculture website and can be founded in that website. Historical monthly total grocery sales data has been collected from the Federal Reserve Bank of St. Louis website and can be founded in that website. Real disposable personal income data has been collected from the Federal Reserve Bank of St. Louis website and can be founded in that website. Monthly U.S. regular conventional retail gasoline price has been collected from the Energy Information Administration website and can be founded in that website. Weekly spot prices per carton and spot shipment data for apple, strawberry, potato and tomato have been collected from Agriculture Marketing Service under specialty crops. Because of data unavailability--fruits and vegetables average spot price is used as a proxy of wholesale prices and average spot shipment data are used as a proxy of production data. Spot price and spot shipment of fruits and vegetables data are converted weekly to monthly to match up meat data and other variables timeline.

All the wholesale meat (e.g., beef, pork, broiler) price data are in cents per pound. The fruits (e.g., apple and strawberry) and vegetables (e.g., potato and tomato) average spot price data are in dollars per carton. Federally inspected each kind meat production data are in billion

of pounds. Spot shipment for apple, strawberry, potato and tomato data are in million of pounds. Total grocery sales data are in billion of dollars. Real disposable personal income data are in trillion of chained 2012 dollars. Regular conventional retail gasoline price in dollars per gallon.

Each of these products and variables are in time series data. Each of these variables are in same timeline except fruits and vegetables prices and shipments data. The timeline is January 2015 to December 2021 which is intentional for the analysis. This timeline would help to compare and contrast the affects of the pandemic before and after COVID-19.

3.2 Descriptive Statistics

Descriptive statistics for all products prices are reported in Table 1 with graphical plots of the monthly average wholesale prices for meats and spot prices for fruits and vegetables. To calculate price differences before and after COVID-19, historical monthly average wholesale prices for three kinds of meat and average spot prices for all fruits and vegetables were used.

From Table 1—beef prices before COVID-19 mean price was 333.790 cents per pound and after COVID-19 the mean price was 401 cents per pound. Not surprisingly, even expectedly, the maximum price in the beef data is noticeably higher during the COVID-19 period than in the before-COVID period. The monthly percentage changes in beef wholesale prices were very volatile from the very beginning of COVID-19. The wholesale price of beef went up, per pound, from 348.9 cents to 402 cents, which is a 15.22% increase in April 2020 compared to the March 2020 price. Within just a one-month spread, from April 2020 to May 2020, the price per pound went up from 402 cents to 638.6 cents, which is a 58.86 % increase-

-the biggest jump during the COVID period and the biggest jump since some time before 2015. Beef wholesale prices were less volatile during 2021, during which high prices persisted.

Before COVID-19, pork had a mean price of 146.650 cents per pound, while after COVID-19 the mean price was 178.95 cents per pound. Again, not surprisingly, the maximum price in the pork data is noticeably higher during the COVID-19 period. The monthly percentage changes in pork wholesale prices were also very volatile, which is similar to beef prices from the very beginning of COVID-19. The wholesale price of pork did not change significantly until May of 2020. That month, the price increased from 121.6 cents per pound to 200.7 cents, which is the biggest jump, a 64.98% price increase, since a jump in 2017. Pork wholesale prices have been trending upward since the beginning of COVID-19, through the end of 2021, with persistent increases. Price levels have not come down to the pre-COVID level.

Broilers prices before COVID-19 had a mean price of 78.381 cents per pound and after COVID-19 the mean price was 76.72 cents per pound. Surprisingly, the maximum price of 99.14 cents per pound in Table 1 is before the COVID-19 period. In fact, the broilers' wholesale price went significantly down right after COVID started. For example, in May of 2020 the price went down 11.28% while beef and pork prices went significantly up. The scatter plot of broilers' prices can give a better picture about price trends.

Apples' mean price per carton before COVID-19 was 24.80 dollars and after COVID-19 was 26.84 dollars, not a big difference. The maximum price of apples was before the COVID-19 period, which was 34.93 dollars per carton. The monthly percentage changes in apple spot prices are usually very volatile regardless of COVID. The overall price pattern for apples is regular with seasonal trends before and after COVID.

Strawberries' mean price per carton before COVID-19 was 14.62 dollars and after COVID-19 was 15.68 dollars. The maximum price of strawberries was in the before COVID-19 period, which was 28.59 dollars per carton. The monthly percentage changes in strawberries' spot prices are usually very volatile regardless of COVID. Overall price patterns for strawberries have regular seasonal trends before and after COVID.

Potatoes' mean price per carton before COVID-19 was 11.83 dollars and after COVID-19 the mean price was 14.39 dollars. The maximum price of potatoes was in the after COVID-19 period, which was 18.20 dollars per carton. The monthly percentage changes in potatoes' spot price are usually very volatile month-to-month regardless of COVID. The overall price pattern for apples is regular seasonal trends before and after COVID.

Tomatoes' mean price per carton before COVID-19 was 13.25 dollars and after COVID-19, the mean price was 14.48 dollars. The maximum price of tomatoes was in the before COVID-19 period, which was 25.05 dollars per carton. The monthly percentage changes in tomato spot prices are usually very volatile month-to-month regardless of COVID. The overall price pattern for apples is regular with seasonal trends before and after COVID.

To reiterate from Table 1 and calculations above, mean prices for beef and pork are significantly higher during the COVID-19 period than before the COVID-19 period except for broilers' mean price was higher before the COVID-19 period. On the other hand, the mean prices differences are not significantly different before and after COVID-19 for fruits and vegetables other than during the COVID-19 period they were higher than before. Also, for all meat prices, standard deviations are significantly smaller before the COVID-19 period than during the COVID-19 period. That means price volatility before COVID-19 was less than after COVID-19. On the other hand, all fruits and vegetables prices' standard deviations were

smaller during the COVID-19 period than before the COVID-19 period. That means price volatility before COVID-19 was less than after COVID-19.

Table 3.1: Summary statistics-price by products before and after COVID-19

Ag. Products	**N**	**Mean**	**St. Dev.**	**Min.**	**Max.**
Beef Price before COVID-19 (¢/lb)	62	333.79	26.68	280.20	397.60
Beef Price after COVID-19 (¢/lb)	22	401.01	78.49	311.30	638.60
Pork Price before COVID-19 (¢/lb)	62	146.65	13.70	115.40	186.50
Pork Price after COVID-19 (¢/lb)	22	178.95	35.58	121.60	241.40
Broiler Price before COVID-19 (¢/lb)	62	78.38	8.04	63.54	99.14
Broiler Price after COVID-19 (¢/lb)	22	76.73	11.54	62.61	94.74
Apple Price before COVID-19 ($/carton)	62	24.81	2.78	19.64	34.93
Apple Price after COVID-19 ($/carton)	17	26.85	2.66	22.26	29.48
Strawberry Price before COVID-19 ($/carton)	62	14.63	5.44	6.22	28.59
Strawberry Price after COVID-19 ($/carton)	14	15.69	3.69	9.28	22.24
Potato Price before COVID-19 ($/carton)	62	11.84	2.11	8.77	17.57
Potato Price after COVID-19 ($/carton)	17	14.39	2.05	11.93	18.21
Tomato Price before COVID-19 ($/carton)	62	13.25	3.94	7.92	25.06
Tomato Price after COVID-19 ($/carton)	17	14.49	3.14	9.40	20.21

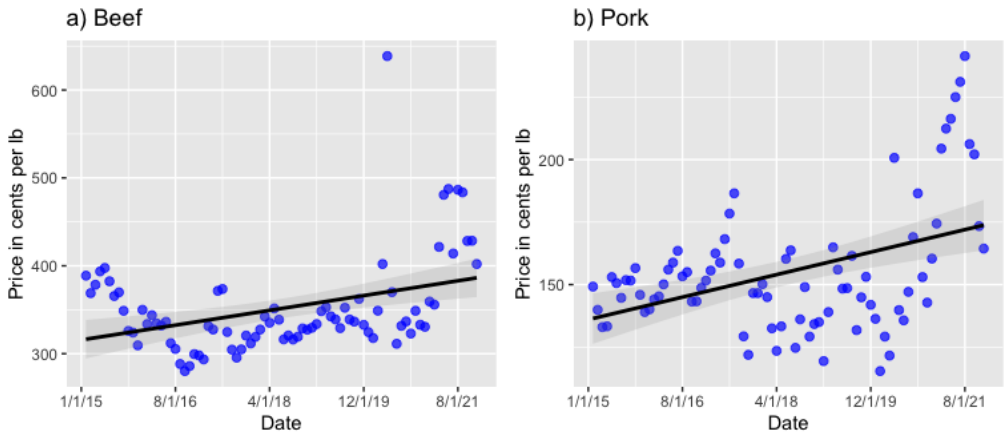

Figure 3.1: Price over time of beef and Pork

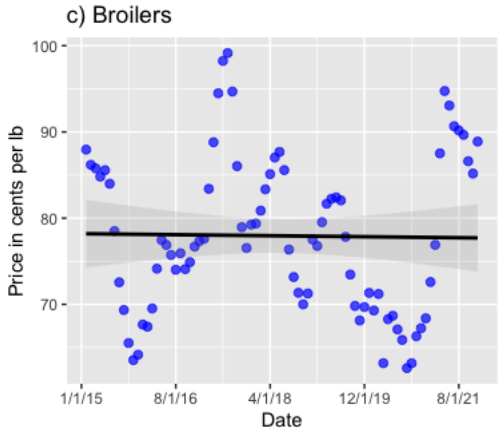

Figure 3.2: Price over time of broilers

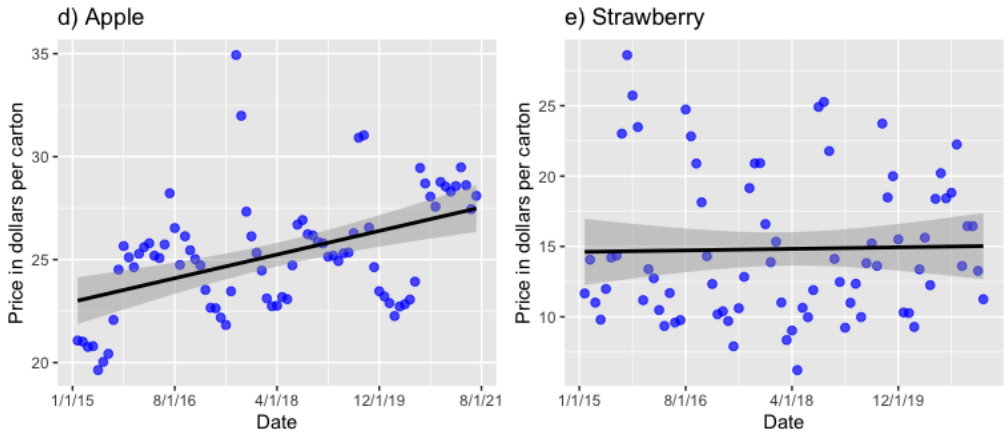

Figure 3.3: Price over time of apple and strawberry

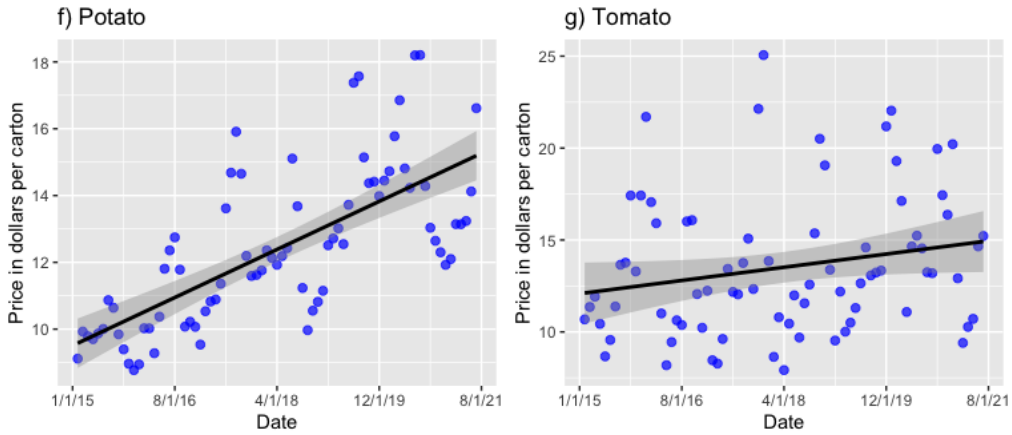

Figure 3.1: Price over time of potato and tomato

Looking at the summary statistics and graphs of different commodities prices over time gives a clear idea of what happened to prices of each commodity before and after COVID-19. It is necessary to analyze empirically what variables cause these prices fluctuation.

Chapter 4: Empirical Strategy and Results

4.1 Empirical Strategy

The nationwide lockdown in the United States was a policy to contain the COVID-19 virus. One major assumption of this thesis is that prices of agricultural products would change because of the combination of the nationwide lockdown and COVID-19. Prices changes do not necessarily mean they always change in the same direction for all commodities. The magnitudes and directions of the changes depend on the nature of the products.

The ideal model to use in that situation would be a Difference-in-Difference model or other natural experiments where a control group and a treatment group can be compared to identify the causal relationship of price changes. But COVID-19 in the USA was nationwide and no state was immune from COVID-19. Therefore, the causal inference model is not a feasible way to find out the effects of COVID-19 on price variances of agricultural commodities.

The ordinary least squares (OLS) estimation model would serve to address the research questions. All the relevant variables that are used here to run regressions are time-series data as already introduced in the data section. It is important to note that as already discussed in the literature review Baffes and Haniotis (2016), traditionally food prices movements happen because of high energy prices, stock-to-use-ratios, and personal incomes. Therefore, we are using gasoline prices, total production of each commodity, and personal disposable income to run regressions. During the pandemic, grocery sales—another variable—increased extremely high because all the restaurants and cafeterias were closed. Therefore, this thesis's analysis also added monthly grocery sales data in regression equation.

Here price is a dependent variable and COVID-19, production, shipment, grocery sales, personal disposable income and gasoline price are independent variables. The prices are converted into logarithmic form so that the effect can be interpreted as percentage change in price. It is important to notice that the cutoff point is March of 2020 when COVID-19 started. For three kinds of meat the ordinary least squires (OLS) estimation equation is

$$\ln(\text{Price}) = \beta_0 + \beta_1 COVID-19 + \beta_2 Production + \beta_3 Grocery\ Sales + \beta_4 Personal\ Disposable\ Income + \beta_5 Gasoline\ Price + \beta_6\ Adjusted\ for\ Seasonality\ by\ Month + \epsilon$$

For fruits and vegetables, the ordinary least squires (OLS) estimation equation is

$$\ln(\text{Price}) = \beta_0 + \beta_1 COVID-19 + \beta_2 Shipment + \beta_3 Grocery\ Sales + \beta_4 Personal\ Disposable\ Income + \beta_5 Gasoline\ Price + \beta_6\ Adjusted\ for\ Seasonality\ by\ Month + \epsilon$$

Where ln (Price) is the monthly average wholesale price in logarithmic value of meat products; For fruits and vegetables ln (Price) is the monthly average spot price in logarithmic value of fruits and vegetables products; β_0 is the intercept; COVID-19 is a dummy variable equal to 1 if the time is after March 2020 (including March—the cutoff-point) and otherwise the dummy variable is equal to zero; Production is the total amount of meat production; Shipment is the total amount of shipment of fruits or vegetables; Personal Disposable Income is the seasonally adjusted real disposable personal income; Gasoline Price is monthly averages U.S. regular conventional retail gasoline price; Dummy variables for all the months (considering January as a base month) has been included in the regression model in order to control seasonality and ϵ is the error term.

4.2 Results

Table 2 presents the results of OLS regression estimates for all the seven (beef, pork, broilers, apples, strawberries, potatoes and tomatoes) agricultural commodities. There are 18 out of 35 parameters in all seven models are statistically significant and different than zero without taking consideration of constant terms.

The regression results for beef in Table 2 indicates on average COVID-19 lockdown effect on beef price is about 9.4% increase in price. Grocery sales and gasoline price have a positive relationship with beef price. The positive relationship between grocery sales and beef price can be explained by 19.5% decrease in food-away-from-home sales and 4.8% increase in food-at-home sales (Zeballos et al 2021). The positive relationship between gasoline and beef price relationship can be explained recent price increase of gasoline. There is a negative relationship between beef price and beef production which can be explained by the COVID-19 related production disruptions such as labor shortage, supply chain shock and so on.

The regression results for pork in Table 2 indicates on average COVID-19 lockdown effect on pork price is about 26.7% increase in price which is the highest increase among all the commodities. There is a positive relationship between pork price and gasoline price and that account about 17.4% increase. There is a negative relationship between pork price and pork production. Grocery sales and disposable income have no statistically significant effects on pork price. However, controlling the effect of these influencing variables, which are controlled for seasonality, on pork prices, COVID-19 impact on the price of pork in the post-COVID period on average has been a 26.7% increase ($p < .01$) compared to the pre-COVID

period. The reason for the huge pork price increase during COVID-19 could be the same factors as the beef price increase.

The regression results for broilers in Table 2 indicates that price of broilers is unaffected by COVID-19 lockdown. Lusk et al (2021) explained that chicken processing was less affected than beef and pork, indicating that broilers' prices should be stable. Unaffected broiler prices during COVID also could be simply low consumer demand for broilers. There is a positive relationship between broilers price and gasoline price which is account 22.2% increase. There is a negative relationship between broilers price and disposable income.

The regression results for apples in Table 2 indicates that price of apples is unaffected by COVID-19. There is a negative relationship between apples price and shipment of apples. All other parameters such as grocery sales, disposable income, and gasoline price results are not statistically significant.

The regression results for strawberries in Table 2 indicates that price of strawberries is affected by COVID-19. There is a negative relationship with strawberry price and grocery sales. Other variables such as shipment, disposable income and gasoline price were statistically insignificant. However, controlling the effect of these influencing variables, which are controlled for seasonality, on strawberry prices, COVID-19 impact on the price of strawberries in the post- COVID period on average has been a 22.79% ($p < .05$) increase compared to the pre-COVID period.

The regression results for potatoes in Table 2 indicates that price of potatoes is negatively by COVID-19. This relationship can be explained by the closure of fast-food chains and restaurants during the lockdown which resulted in lower demand and lower consumption

of potatoes. Around 60 percent of potatoes are consumed in fast-food chains. Grocery sales and disposable income have a positive relationship with potatoes price. There is a negative relationship between potatoes price and gasoline price. The reasoning is that relationship is unclear. However, controlling the effect of these influencing variables, which are controlled for seasonality, on potatoes price, COVID-19 impact on the price of potatoes in the post-COVID period on average has been a 31.9% decrease ($p < .01$) compared to the pre-COVID period.

The regression results for tomatoes in Table 2 indicates that price of tomatoes is unaffected by COVID-19. There is a positive relationship between tomatoes price and grocery sales. There is a negative relationship between tomatoes price and gasoline price. Shipment and disposable income have no relationship with tomatoes price.

The value of R square ranges from 0.54 to 0.86 which indicates overall a good explaining capacity for all seven regression models. F-statistic coefficients for all seven models are statistically significant at the 99 percent confidence interval.

Overall, regression result shows if we keep everything constant, COVID-19 has a significantly positive impact on increasing prices of beef, pork and strawberry. On the other hand, COVID-19 has a negative impact on potatoes' price. Beef and pork production were significantly disrupted and packers processed 40% less in volume than in 2019 during COVID-19 period (Lusk et al 2020). However, demand for meat products increased significantly because food-away-from-home places were closed that reflects price increase and volatility in the meat markets. In contrast, fruits and vegetables consumption among food-insecure consumers decreased (Litton et al 2021) during pandemic which indicates lower demand and lower price for fruits and vegetables.

Baffes and Haniotis (2016), already mentioned in the literature review, showed that gasoline prices (energy price) have a significant impact on agricultural commodities' prices, and here Table 2 shows similar results except vegetables. For beef, pork and broilers prices, there is a positive relationship but for potatoes and tomatoes, there is a negative relationship with gasoline prices.

Table 4.1: OLS Regression Estimates of Seven Agricultural Commodities

Independent Variables	Beef	Pork	Broilers	Apples	Strawberries	Potatoes	Tomatoes
Covid-19	0.094**	0.267***	0.011	0.050	0.264**	−0.319***	−0.130
	(0.045)	(0.066)	(0.045)	(0.043)	(0.104)	(0.046)	(0.119)
Production	−0.553***	−0.347**	−0.059	NA	NA	NA	NA
	(0.086)	(0.13)	(0.074)				
Shipment	NA	NA	NA	−0.0001***	−0.000	0.000	0.000
				(0.001)	(0.000)	(0.000)	(0.000)
Grocery Sales	0.013***	−0.008	0.003	0.005	−0.491**	0.040***	0.036***
	(0.005)	(0.007)	(0.005)	(0.004)	(0.204)	(0.004)	(0.012)
Disposable Income	−0.004	0.019	−0.041**	−0.007	−0.002	0.059***	−0.039
	(0.016)	(0.024)	(0.016)	(0.017)	(0.010)	(0.017)	(0.043)
Gasoline Price	0.142***	0.174***	0.222***	0.034	0.139	−0.098***	−0.186*
	(0.031)	(0.044)	(0.031)	(0.034)	(0.101)	(0.035)	(0.094)
Constant	5.992***	5.542***	4.464***	3.665***	3.500***	−0.525	1.671***
	(0.213)	(0.313)	(0.225)	(0.270)	(0.444)	(0.325)	(0.579)
R2	0.731	0.5470	0.6182	0.6508	0.7675	0.8642	0.5389
Adj. R^2	0.6668	0.4388	0.527	0.5606	0.7045	0.8291	0.4200
Num. obs.	84	84	84	79	76	79	79
Residual Std. Error	0.079	0.115	0.079	0.074	0.183	0.076	0.204
df	67	67	67	62	59	62	62
F Statistic	11.382***	5.056***	6.779***	7.220***	12.174***	24.654***	4.530***
df	16; 67	16; 67	16; 67	16; 62	16; 59	16; 62	16; 62

Note: *p<0.1; **p<0.05; ***p<0.01

Chapter 5: Conclusion and Discussion

Using the ordinary least squares (OLS) estimation method, this thesis empirically measured the impacts of COVID-19 on seven important agricultural commodities (beef, pork, broilers, apple, strawberry, potato and tomato) prices in the USA. The analysis concludes that prices of beef, pork and strawberries are significantly increased because of COVID-19 pandemic. And price of potatoes is significantly decreased due to COVID-19 related disruptions. Our analysis also suggests that COVID-19 has no significant effects on broilers, apples and tomatoes prices.

From the analysis it has been apparent the ambiguous results of heterogeneous effects of COVID-19 related disruptions on different commodities price. For example, the effects of pandemic on meat products are higher compared to fruits and vegetables. Every product is different than others in terms of demand, supply, substitutability and so on. On the supply side during the pandemic there was disruptions in production which resulted in less than the expected amount of goods. These disruptions include labor shortages, transportation and so on. On the demand side, at least in the short-run, there was high demand for food commodities at home that previously was covered by restaurants and cafeterias. The equilibria market price of a particular good is determined by the supply and demand of that good. If demand for a good increase, then the price is also supposed to increase and vice-versa.

There are some data limitations of this thesis. Most businesses use freight trucks to ship agricultural products. Freight trucks movement data would show true indicators about supply chain disruptions that are induced by COVID-19. But unfortunately, because freight trucks movement data is unavailable, we cannot use that variable in our analysis. Production costs

such as animal feeds, transportation cost, and labor cost data were not used in the analysis which could give more accurate analysis. Since COVID-19 started, animal feed, transportation costs and labor costs also increased.

Prices of commodities are still high in the market and getting higher every month even though the COVID-19 situation is getting normal. Consumers do not see prices are coming down to pre-COVID levels, which is concerning especially for low- and middle-income households because low-and middle-income households are more vulnerable. The domestic and global supply chain problems are also returning to pre-pandemic levels. Future work should analyze the stickiness of commodities prices, especially meat products, to find out why prices are not coming down to the pre-pandemic level.

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