Grape Supply Chain, Trade, and Consumption Implications of COVID-19

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Grape Supply Chain, Trade, and Consumption Implications of COVID-19

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Summary

The COVID-19 pandemic has shocked farm-to-food supply chains, market demands, and trade flows, as well as many analysts who study those topics. In this paper, we study how shocks on the labor market, consumer demand, trade, and policy interact. Focusing on the U.S. grape sector, we integrate a supply chain model with a market model to represent raisins and table grapes from farms to consumers. Application of this new approach generates results relating to the producer, consumer, and trade impacts of labor disruptions and market shocks associated with the pandemic.

Trade impacts of shocks to domestic demands can be greater than the trade shocks themselves, as a shock to the demand for a fresh product puts pressures on the trade of a processed product. Available data suggest that the pandemic placed downward pressure on table grape imports and exports, while increasing the export demand for raisins. The trade quantity impacts of these shocks to foreign demands and supplies are less pronounced than the trade effects of the reallocation of domestic demand. The data available at the time of analysis indicate more domestic demand for table grapes and lower domestic demand for raisins. While this reallocation of food demand seems neutral overall for the sector, there are important implications for trade of raisins, the processed product, and table grapes, the fresh product.

Labor cost increases raise overall consumer costs and reduce farm receipts, but market shares and labor shares in the supply chain complicate the relative effects on fresh and processed goods. In the case of a fresh product with a high share of labor in supply chain costs or a processed product with a lower labor share, a labor cost shock can depress farm-level demand substantially. The consumer price of the processed product could fall in this case if the demand for the fresh product pushes the farm price down enough to offset the higher labor cost of the processing sector. In this case, exports of the processed product rise and imports might fall. The fresh product sector still causes higher labor costs, which in turn drives domestic consumer expenditures higher and producer receipts lower, but the processed market response complicates or mitigates some of these impacts.

A labor constraint that reduces labor use at a fixed cost per unit can reduce the value-adding services provided along with the farm commodity and lead to a lower aggregate marketing margin. A labor constraint changes the mix of retail options as goods that embody more labor are curtailed. If people tend to maintain an overall level of consumption and substitute from goods with high labor cost share to goods with low labor cost share, then the aggregate marketing margin can decrease. This is not to say that consumers are better off. Indeed, current events might lead consumers to appreciate the value added by supply chain labor in such forms as consumption-ready meals or restaurant dining.

A constrained labor quantity without changing the per-unit labor cost can lead to greater food loss. At least in this case, supply chain adjustments to use less labor lead to a greater share of the farm commodity being lost between farm and consumer. With limited flexibility to adjust in the short run, this greater loss puts upward pressure on market prices. While this effect might not dominate other effects of the pandemic, either overall or for specific commodities, this finding suggests that an outcome of disruptions that force a reduction in workforce could be an increase in food loss for the sector. During the initial phases of the pandemic, there seemed to be instances when the supply chain was briefly severed, such as when livestock had to be destroyed for want of processing capacity. It is possible that the reestablished supply chains in those cases and the supply chains for specialty crops, at least, might lose a greater share of farm commodity inputs as they ration labor use.

The pandemic likely makes losers of consumers, producers, and workers, in aggregate. Consumers typically face some combination of higher prices and less value-added goods, although some consumers, including foreign buyers, see lower prices under certain conditions. Data available early in the pandemic suggest some positive results for producers if considering only the shifts in domestic demand. However, this effect is modest compared to the negative commodity producer effects of greater supply chain labor costs. Supply chain workers lose in all cases: a quantity constraint on labor means fewer workers; and an increase in labor costs reflects additional payments to offset safety concerns, such as paid sick leave, or complementary inputs required by the pandemic, such as testing and personnel protection measures.

Policies to offset some of these impacts can generate negative side effects. For example, a hypothetical policy-driven reduction in exports to pull consumer prices down and support consumers of the product in greater demand leads to market responses that work against this goal. The result of the export constraint tested here is a small increase in the use of the target good, at best, with a proportionately larger decrease in the producer price and partly offsetting impacts on trade of the good that is not targeted by the policy.

Supply chain innovations or policy interventions to reduce supply chain disruptions might mitigate the consumer price increases and producer price decrease. Of course, the economic and health effects of such innovations on workers would depend on the method used to alleviate labor cost pressures or constraints. While an assessment of all policy options and their impact on worker safety goes well beyond the scope of our representation of the table grape and raisin

market, we are unable to identify policy or business options that unambiguously help everybody during a global pandemic.

We identify limitations of our approach, including our reliance on certain data to define market shocks, the focus on short-run impacts, and the assumption that consumers readily substitute among different forms of a good with different value added by labor.

Introduction

The COVID-19 pandemic and its impact on agriculture, food trade, and value chains have stunned agricultural economists, policy makers, and the general public. The world seems to have changed as never before in living memory, and applied scientists have provided only piecemeal insights relating to agricultural supply chain, trade and policy.

Policy makers in many developed countries agreed to vast spending packages and additional interventions as the disruptions of the pandemic persist. In the United States, concerns about the food supply might be one reason for the subsidies provided to the agricultural sector. Indeed, when combined with expenditures on other programs, payments to producers sum to the highest on record (Westhoff et al., 2021).

Anecdotes, along with data on infection rates in the food sector (Douglas, 2020) and on livestock processing quantities and margins, indicate that the impacts of the pandemic on food supply chains are consequential. Guidelines for meat processors speak to personnel equipment and habits, distances between workers, duration and nature of contact among people (at work and in transit), monitoring, and other considerations (CDC, 2020). Some firms or representatives of firms have sought liability waivers to reduce risks (New York Times, 2020). While supply chains have endured the strain of sudden plant closures and instances when short-run capacity limits were tested by spikes in farm commodity output, the present shock to the modern food system might have no precedent that is sufficiently recent, significant, and broad from which to draw insights that can be applied to the present case.

A pandemic can complicate supply chain economics

Labor disruptions have affected supply chains in general and can affect the U.S. grape supply chain in particular. Agricultural and applied economists have long studied the relationship between retail foods, farm commodities, and other inputs necessary for the movement of farm output and its transformation into consumer goods in shopping carts and food on the plate. The applicability of these lessons to this case might be limited by the nature and magnitude of the impacts of the COVID-19 pandemic, however.

Supply chain services have been represented as a derived demand as part of a food processor's or wholesaler's operation (Gardner, 1975). In this representation, agricultural products are combined with other inputs to generate food for retailing. Placed in the context of farm supply and consumer demand, these profit-maximizing intermediaries are a critical part of the food system, and their purchases of other inputs to supplement or displace agricultural inputs depend on the prices of those inputs, farm commodities, and retail goods. Seen over an adequate period

of time or at an adequate level of aggregation, one might expect that these intermediaries will combine varying quantities of farm and other inputs to generate an array of goods and will substitute over time among these inputs. If this framework is applied, then labor disruptions that increase the price of labor could cause a shift to other inputs. The implications for farm commodity demand could be positive or negative, depending on whether these goods substitute for or compete with labor over time and in aggregate.

A short-run representation with greater focus on specific goods might instead consider a production process that has little flexibility. This structure, too, has been developed and leads to a farm-to-retail margin that is separate from farm commodity prices (Heien, 1980). The marketing margin in this representation would depend on the prices of other inputs. A higher marketing margin would unambiguously reduce the demand for the farm commodity, and labor disruptions, represented as a higher cost for an input into the processes between farm and retail, would lower the farm price and increase the consumer price. The incidence of these price changes would be affected by the relative elasticities.

The focus of this work on margins might not be entirely applicable to the current event. First, the scope to substitute between agricultural inputs and other inputs for any product might be constrained in the short run. Setting aside long-run effects, such substitution might only be possible through changes in the retail product composition. For example, if labor disruptions are severe, then a sectoral response might be to shift from processed goods that have high labor input to fresh goods with less labor embodied in them. Moreover, the potential for such a shift might vary across commodities and be limited in some cases. Second, the labor market disruption caused by this pandemic might not be well represented by an increase in wages. Nonetheless, some effects might be approximated by a change in the wage. In this case, greater costs per worker to protect the health of workers might be represented as a wedge between the price that employers pay for labor and the returns to labor. However, concerns expressed recently go beyond the higher cost of labor and raise the potential of short-run constraints on labor quantity. Given plant sizes and structures that are fixed in the short run, including the limited ability to reorganize and expand the size of facilities to distance workers, labor quantity might have to be reduced relative to past practices and below the unconstrained optimal choice.

What to expect

In this paper, a supply chain model and a market model are integrated to allow for labor disruption to be represented as either a wage-related cost increase or an outright constraint on labor quantity. Moreover, we allow for responses that seem appropriate for the immediate effects of a pandemic: a supply chain response allows for shifts among a given set of modes and options for inputs and operations, but innovations are more difficult to achieve in the short time frame. Commodity producers have no ability to respond on this timeline as demand and trade shocks play out.

We apply an analytical tool to estimate labor disruption impacts on the U.S. table grape and raisin supply chain, market quantities and prices, trade, consumers, and producers. Our results link labor cost increases and even outright labor constraints in this supply chain to sectoral

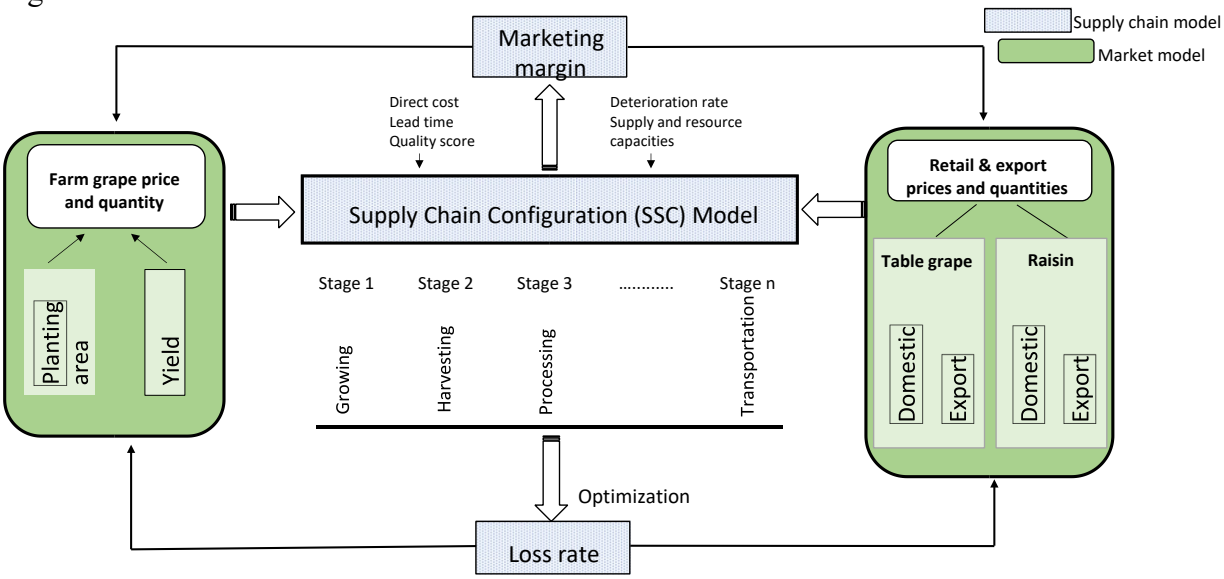
markets, trade volumes and values, grape product consumption and prices, and grape producer receipts. Our results also relate shocks to demands and trade to these same indicators of market impacts. By introducing each shock in turn, as well as together, we can decompose the impacts of these shocks on this market. After considering the circumstances of this case relative to other specialty crops, we speak to broader implications for specialty crop markets, and the impact of labor disruptions and other shocks of the pandemic.

Method

Our integrated supply chain and market models are applications of known economic methods tailored to the study at hand. To the best of our knowledge, this hybridization of these two approaches has not been attempted previously.

The models are built for an integrated and internally consistent representation that relates labor disruption to its implications for prices, and market quantities to their consequences for supply chain costs (Figure 1). The supply chain takes as given the quantities that are to be sold and the price levels of final goods and raw commodity, then optimizes operations by selecting among options at each node along the supply chain. The market model takes as given the margin required to cover the supply chain costs, then determines the market-clearing prices and corresponding quantities of farm grapes, raisins, and table grapes, taking domestic demand and trade responses into account using elasticities drawn from the literature.

Figure 1. Model Overview.



The *supply chain configuration model* extends existing supply chain configuration approaches (e.g., Graves and Willems, 2005; Li and Womer, 2012) to examine the impact of labor disruption, in both the forms of a capacity shortage and a higher cost of labor, on the optimal configuration of a food supply chain. The model minimizes the system-wide total supply chain costs under limited available labor capacity and budget, a decision need that has not been addressed in the literature before. Having been applied to the case of the grape supply chain (Li

et al., 2020) and in other contexts such as rice (Nie and Li, 2020), a modeling framework is readily available that can prescribe the optimal supply chain configuration from farm grapes to table grapes and raisins, for domestic and export uses, with the prices of grape inputs and outputs taken from the market model.

The supply chain configuration model consists of the stages and nodes required to move, store, transform, package, and otherwise process farm grapes in order to deliver table grapes and raisins to domestic and foreign buyers. The optimization problem determines the option/mode at each node and the system-wide safety stock placement to maximize supply chain profits. It takes final demand in terms of price and quantity as given; also taken as given are other input prices, technical constraints, loss and quality effects of choices, storage, and transportation operations. The solution reflects the combination of option selection and the amount of safety stock for each node that minimizes a nonlinear cost function of these decisions. In this application, we use the labor requirement of each option at each node as a means to introduce labor-related cost increases or labor-related constraints associated with the pandemic. End results will relate how these shocks cause a new pattern for delivering products, including new levels of labor use and different supply chain costs.

The *market model* is an equilibrium model that represents the farm grape market, table grape market, and raisin market. The raw product is fixed in the short run, whereas the domestic demands, foreign demands, and imports are represented with behavioral equations. Standard methods of commodity market analysis with a long lineage are applied; these methods are consistent with the behavioral equations and market conditions used in the context of supply chain and commodity market analysis (Gardner, 1975; Heien, 1980), as well as in partial and general equilibrium modeling more generally.

Methods for building economic models focus on equations that are the basis of the structural representation and the parameters. Equations are either behavioral equations or identities. Identities relate prices and quantities across a given market or vertically among markets. Behavioral equations capture the economics of producers, consumers, and others, typically resting on microeconomic principles. Parameterization relies on an existing body of literature, although some parameters had to be specified in the absence of empirical evidence, as is sometimes the case with such models (OECD-FAO, 2015). The relevant literature typically suggests inelastic domestic demands for fruit, including grapes when studied (Alston et al., 1997; Arnade and Pick, 2000; Brant et al., 2005; Brown, 1986; de Gorter et al., 1992; Fogarty, 2010; French and Nuckton, 1991; Green et al., 1991; Henneberry et al., 1999; Huang, 1996; Lave, 1963; Nuckton et al., 1988; Okrent and Alston, 2012; Weatherspoon et al., 1999; You et al., 1998; You et al., 1996). Values used here are on the low end of the ranges found in the literature, given our focus on short-run responses. Domestic demands are inelastic (−0.45 for raisins and −0.19 for table grapes). Supply is assumed not to respond to current prices and is held constant given our short-run focus. Trade elasticities are about one-half, in absolute value, for this representation of short-run export demands and import supplies that implicitly reflect the limited scope for foreign producers and consumers to respond to changing prices.

The U.S. table grape and raisin market is an interesting case to study (Table 1). With respect to trade, both goods are exported, and imports of table grapes are also important. There is an intuitive appeal to the processed product, which tends more to look akin to a stereotypical homogeneous good with a mostly one-way trade flow, exports in this case, while the fresh product is both exported and imported. Fresh produce trade is often motivated in part by seasonal factors. Domestic demand for both goods is important, but more so for table grapes than for raisins. The size of ending stocks suggests that there is little scope for stock adjustments to mitigate the price impacts of a shock. Fresh grapes can substitute at the margin between these two uses; the two final goods are linked through competition for the same agricultural commodity input.

Table 1. U.S. Table Grape and Raisin Market Quantities

Commodity	**Attribute**	**2017/2018**	**2018/2019**
		(metric tons)	
Grapes, Fresh Table	Production	934,682	996,906
	Imports	618,334	570,662
	Total Supply	1,553,016	1,567,568
	Exports	335,806	368,511
	Fresh Domestic Consumption	1,217,210	1,199,057
	Total Distribution	1,553,016	1,567,568
Raisins	Beginning Stocks	103,139	68,564
	Production	241,402	263,000
	Imports	36,480	30,000
	Total Supply	381,021	361,564
	Exports	107,457	110,000
	Domestic Consumption	205,000	205,564
	Ending Stocks	68,564	46,000
	Total Distribution	381,021	361,564

Source: USDA, FAS, Production, Supply and Distribution, 2020

There are *limits* to this combination of two different models. We see a few as being of particular relevance here. First, the time frames of the two models are not perfectly matched. The supply chain model with defined options is designed to support decision making at greater frequency than the partial equilibrium model. However, our focus on short-run impacts alleviates the issue of mismatched time frames. Our focus on an annual model is partly tied to the availability of market data at this time, but the impacts we discuss could in reality be compressed to a shorter period of time. For example, events subsequent to our quantitative analysis suggest that labor disruptions might be intense for a span of months, not a full year. Model assumptions that disallow grape production changes, commodity or product stocks responses, or radical supply

chain reconfiguration seem consistent with shorter time periods. Given these facts as well as our use of directions of effects (signs) and relative impacts among scenarios to draw conclusions, the potential mismatch might not call subsequent text into question.

Second, one set of links between the two models consists of the relationships between prices and margins at the market level, and the supply chain cost per unit. The market model uses this relationship to signal indicative prices that should approximate how consumer prices change. The supply chain model generates average per-unit cost for an array of similar retail goods that are assumed to be strong substitutes for consumers in the context of the aggregate market. A possible extension to this representation might be to identify more individual goods or otherwise differentiate by output types in some other way.

Third, we assume that the links between farm and product markets are not completely severed, at least not for a substantial amount of time. This risk might seem remote if not for the stories of severe labor disruptions in meat processing in Spring 2020 that led to the destruction and disposal of some animals without their carcasses being used to manufacture any product. This suggests a rupture such that retail prices and farm commodity prices might no longer have been related through the processing sector, with the marginal value of farm commodities unsupported by any final-use value and consequently dropping to zero. While the effect appeared temporary and might not be appropriate for representing the annual market outcomes, there could very well be important implications for producer revenues and food security concerns—implications that undoubtedly were considered by policy makers.

Labor disruption representation scenarios

The scale of the labor shock resulting from the pandemic to the supply chain is difficult to quantify. We test a few cases here. An important distinction is between a shock to the cost of labor and a shock that limits the quantity of labor.

Labor-related costs could include additional pay to workers, higher allowances for paid sick leave, and complementary spending necessary during a pandemic, such as personal protection equipment (PPE), hand sanitizer and washing stations, physical separators and other barriers between work stations, and delay of tasks due to time spent carrying out safety procedures and queueing. We present scenarios where labor costs rise sharply to represent short-term expenses on workers and complementary inputs, although the exact increase in labor costs is unknown at this time.

The labor constraint is imposed on the supply chain as a newly binding constraint. Even in the short run, we normally expect no constraint on changes in labor use, at least for marginal changes. Firms can presumably expand or contract their labor force during the span of a year as market conditions warrant, at least within a certain range and barring atypical conditions. The pandemic, however, is an atypical condition. Thus, we test the implications for the grape supply chain with a constraint that is less than the labor used in the base case. Optimizing the supply chain with this constraint effectively reducing the quantity of labor used will lead to new configuration decisions in the chain from farm to consumer.

These shock representations are difficult to tie directly to the current event, let alone to the actual data. At present, there is inadequate information about how extensively the pandemic has disrupted labor based on which we can reliably quantify shocks. Anecdotes, worst-case stories, and tales of unique outcomes in special cases can be a poor guide for the design of modeling scenarios. The results could be more or less extreme than presented here and could operate over a different time frame than the annual data we use; we do not claim to have a precise understanding of current events or that our simulations constitute predictions. However, the directional impacts and their scale warrant consideration, for reasons discussed below.

Market disruption scenarios

We collect data representing the U.S. table grape and raisin markets early in the pandemic. Our focus for market disruptions is on the shocks to domestic demand and international trade. The season for U.S. farm grape production was not underway at the onset of the pandemic, so there were few observed data about how seriously the pandemic could affect commodity production. Our shocks to the market are guided by data early in the pandemic and developed to generate a plausible case. We use changes in prices and quantities relative to the previous year, account for the impact of price based on model elasticities, and attribute the remaining shift to the pandemic.

These data suggest that the domestic consumption of the two goods have moved in opposite directions, with greater demand for table grapes (+5%) and less for raisins (−7%). This finding, based on the data available at the time, supports the view that U.S. food demand is fairly inelastic. The shock of the pandemic to behavior and income has affected how people eat and what they eat, but the overall food purchased might not change much. This general statement certainly overlooks the many cases of increased food insecurity in the United States during the pandemic, but most U.S. consumers are expected to respond to tightening budgets and social constraints by shifting what food they buy or where they buy food, rather than reducing the overall consumption of food. For example, the fact that U.S. consumers buy less food at restaurants during the pandemic does not mean that total food consumption falls by this amount, but instead that U.S. consumers eat more food at home. Thus, the case at hand might mirror broader food consumption patterns, with negative shifts in some domestic demands and positive shifts in others.

The trade data for the early months of the pandemic relative to the same period of the previous year suggest mostly negative shocks. Table grape export demand is somewhat lowered (−1%), as is import supply (−2%). Raisin trade is mixed, with the already small quantity of imports reduced further (−36%) and export demand increased (+2%). Like the underlying equations, these shocks reflect a host of explanatory factors. Foreign demand and production shocks affect the U.S. trade. For example, if the pandemic was at its worst during the harvest season of a Southern hemisphere grape producer, such as Chile or Peru, then the U.S. export demand might shift out and the import supply might shift back. On the other hand, negative income shocks in any trading countries where food demand is less inelastic than in the United States could cause the opposite impacts on export demand and import supply. Disruptions to the trade system—including inspection slowdowns, port closures, or vessel delays—would seem to have

unambiguously negative impacts on export demand and import supply, but that is not necessarily the case. For example, if a country close to the United States normally ships a large portion of its fresh fruit production to more distant markets other than the United States, then disruptions that hinder or stop long-distance trade of perishable products could lead to a shift in trade patterns that increases the U.S. import supply. Rather than guessing the exact causes or how these various factors could evolve and combine into market shocks, however, we rely on the data available early in the pandemic to drive our scenarios.

There are limitations to this approach. First, we attribute to the pandemic all quantity changes in Spring 2020 not explained by price effects. In reality, there are other factors that shift demands and trade. Second, the overall effects of the pandemic will differ from the experiences at that time in terms of scale and duration. One could scale up or down the effects if the pandemic affected the severity, but not the pattern, of effects. At the least, one could assign the impacts to a somewhat shorter time scale. A more fundamental change, however, could take place if the direction of the pandemic's impacts on domestic demands or trade change. Third, we set aside here the risks to domestic supply. There is the possibility that, even with adequate time for preparation, domestic supply could suffer due to the pandemic. While these risks should be recognized, they should also be understood in the context of economic science that offers lessons about the consequences of a supply shock.

Results

The results of the labor disruptions and market shocks are presented in sequence to show the cumulative impact (Table 2). From left to right, the experiments represented here are as follows:

- Labor cost increase only, with two different rates of increase;
- Constraint on labor quantity without a change in per-unit labor cost, either wages or complementary costs relating to worker safety during the pandemic;
- Domestic demand shocks, with consumers buying more table grapes and fewer raisins at any given price;
- Trade shocks;
- Cumulative shock with all market shocks (demands and trade) and a labor cost increase; and
- Cumulative shock with all market shocks (demands and trade) and a labor quantity limit.

Labor cost shocks to the supply chain largely follow expectations based on the economic literature on marketing margins and farm-to-retail processes, as summarized earlier, but the complicating factors are the presence of two retail goods and trade.

Evidence about table grapes and raisins suggests that labor plays a much larger role in table grape processing than for raisins, although the available information is dated (American Forest and Paper Association, 2003). The increases in labor prices cause a larger increase in table grape margins, whether for domestic use or export. The price of table grapes for either use rises to cover all the costs of labor, the agricultural commodity, and all other inputs. At the higher price, quantities are reduced, although inelastic demands are evident in the smaller proportional change

in these quantities as compared to the price changes. The higher prices draw in more table grape imports.

Table 2. Impacts of labor and market disruptions.

	Supply chain labor			Market shocks		Labor and market	
	Labor cost shocks		Constrain	Domestic	Exports and	with labor	with labor
	+40%	+60%	quantity	demand	imports	cost +60%	quantity limit
Supply chain margins							
Domestic table	10.0%	15.1%	-12.9%	0.0%	0.0%	15.1%	-12.9%
Domestic raisin	2.2%	3.1%	12.1%	1.5%	2.9%	6.8%	4.8%
Export table	10.5%	15.9%	-25.9%	0.0%	0.0%	15.9%	-25.9%
Export raisin	1.9%	2.5%	13.2%	1.6%	3.2%	6.6%	13.8%
Raisin market							
Domestic use	0.2%	0.3%	-2.4%	-7.2%	-0.8%	-7.7%	-10.3%
Exports	0.8%	1.3%	-7.4%	-1.2%	-0.3%	-0.2%	-8.6%
Imports	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Domestic price	-0.4%	-0.7%	5.4%	0.9%	1.8%	1.9%	7.8%
Export price	-1.5%	-2.5%	14.7%	2.4%	5.1%	4.7%	21.5%
Table grape market							
Domestic use	-0.1%	-0.2%	0.1%	5.4%	-0.1%	5.1%	5.4%
Exports	-0.6%	-1.0%	1.9%	-0.1%	-1.3%	-2.5%	0.1%
Imports	0.3%	0.5%	-0.4%	0.1%	-2.3%	-1.7%	-2.5%
Domestic price	0.7%	1.0%	-0.8%	0.1%	0.3%	1.6%	0.0%
Export price	1.6%	2.4%	-4.7%	0.4%	0.8%	3.7%	-2.8%
Farm grapes							
Quantity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Price	-5.0%	-7.6%	8.1%	2.0%	4.6%	-0.5%	18.9%
Other indicators							
Domestic cons. cost	0.4%	0.6%	0.0%	3.2%	0.4%	4.3%	3.7%
Total farm receipts	-5.0%	-7.6%	8.1%	2.0%	4.6%	-0.5%	18.9%
Export receipt	0.4%	0.6%	-0.1%	0.5%	1.1%	2.2%	1.6%
Import expenditure	1.0%	1.5%	-0.9%	0.2%	-1.8%	-0.1%	-2.0%

The higher labor cost also increases the margins needed to cover the raisin supply chain costs, but the quantity of raisins still increases. The relative impact of labor is smaller, and more grapes

are used for raisin production than table grapes. Indeed, the price of raisins for domestic or export use falls as the quantity of raisins supplied rises.

The higher margins for a given quantity of output in the short run cause the farm price to decrease, as expected. Farm receipts decrease with the falling price, but domestic consumer expenditures rise in total, with higher expenditures on table grapes more than offsetting the raisin market impacts. The gross value of trade also increases.

These results show what labor substitution can look like in practice. The mix of products changes with rising labor price, as a larger share of the farm commodity is shifted to the retail good that uses less labor. Labor is thus substituted out of the supply chain as a consequence of the changing composition of final goods made from the given domestic supplies. Of all the prices, the farm price is affected most by the higher labor cost given the fixed short-run supply, but the effect is less pronounced given automatic reallocation of product to the less labor-intensive alternative. The trade response automatically moderates product price effects to domestic labor cost shocks.

Labor quantity constraint that outright limits the use of labor in the supply chain. While the shadow price or marginal value of labor also rises in this case, this is a separate scenario from the previous one, and the price per unit of labor is assumed not to change. The supply chain optimization causes not only a reallocation of the farm good and productive resources to the path that uses less labor, as in the case of a higher wage, but also shifts in production processes that reduce the labor input as much as needed. As labor and other inputs are often complementary and because supply chain options are expected to include alternatives that deliver sets of retail goods that are substitutes, the consequence is a smaller supply chain margin due to the new configuration used to get table grapes to market.

A key aspect of the model is the underlying view that there are related retail goods that can be generated and sold at different price levels, with different supply chain inputs and cost profiles, but are substitutes for consumers. Here, the decision maker in the table grape supply chain opts to deliver this good to consumers in forms that take less labor. For example, if table grapes in combination with other cut fruits in ready-to-eat packages constitute a more labor-intensive product but yet are a strong substitute for consumers for bunches of fresh grapes that require less labor, then a labor constraint would imply that more bunches of grapes and fewer table grapes in ready-to-eat fruit combinations would be sold.

The result is a sharply lower margin for table grapes, as the supply chain margin saves on labor costs. It follows in part from the assumption that less labor-intensive options exist to deliver products (or bundles of products) that consumers are willing to buy. For raisins, there appear to be fewer such options, and the margin rises. The consequences for market quantities follow directly. Because one would normally expect that supply chain labor disruptions reduce demand for the farm commodity, the possibility of a higher farm price is counter-intuitive. Lower supply chain cost from rationing labor and consumer substitution combined lead to this outcome.

By way of analogy to the wider food and agriculture sector, consider the potential impact of a shock that constrained labor use in the supply chain and had no other effect. While by no means does our experiment capture the full extent of the current pandemic's profound impacts, the thought exercise asks what to expect if the only effect was to force the supply chain to deliver food while using less labor. Data suggest that the pandemic has resulted in a large shift away from restaurant and hotel spending and toward grocery store purchases (Chetty et al., 2020). Labor costs are a substantial share of the marketing margin in the United States, particularly in food service establishments and other businesses where food is consumed away from home (USDA, ERS, 2011). If labor constraints caused a vast reduction in food consumption away from home and associated food service expenses, before considering other impacts of the pandemic, then the aggregate marketing bill could fall. The transition might add costs, and consumers would lose the added value provided by food services and the utility of away-from-home consumption. However, given the inelastic aggregate food demand and the willingness of consumers to switch to an alternative means of acquiring food, the consequence could be a lower marketing bill in the presence of a labor constraint.

Food loss in the supply chain increases in this case, representing another key outcome. The constraint on labor causes changes in supply chain operations that lead to greater loss of the farm commodity relative to the case without a constraint. Farm commodity loss during processing amounts to a shock to the balance: the commodity quantity on the market shrinks. Given the inelastic short-run responses, this shock causes the farm price of the commodity to rise.

The two cases of labor disruption presented here suggest two directions of theoretically possible outcomes. The labor cost increase can be understood in light of the established literature, although complicated by the commodity supply chain and market conditions. The labor constraints have the possibility of unexpected outcomes – if viewed in isolation – by reducing the aggregate supply chain cost and increasing food loss. One might presume that a combination of cost and constraint effects can take place in the context of a pandemic.

The market shocks are first presented in parts to decompose their impacts. The *domestic demand shock* is an increase in table grape demand and a reduction in raisin demand. Greater domestic demand for table grapes more than offsets weaker domestic raisin demand, leading to higher grape and grape product prices. The higher prices lead to reduced exports of table grapes and raisins, while table grape imports rise. The net effect is greater consumer expenditures on grapes, higher farm receipts, and larger trade values. A larger negative shock on raisin demand or a weaker positive shock to table grape demand could presumably reverse the directions of the impacts on the farm price and consumer expenditures.

The exact sizes of shocks affect the size and even the direction of some key results, but there is a broader intuitive appeal behind the domestic demand scenario. The apparent shift in demand from one product to another reflects consumption patterns of these goods and might reflect broader food demand conditions. The inelasticity of U.S. food demand in total limits the aggregate agricultural sector impacts. Even radically different food consumer behavior and macroeconomic or policy shocks associated with the outbreak of the pandemic are more likely to

change what foods people buy or where they buy food rather than to reduce food consumption overall. The net effect could be negative if income falls, but the interpretation of this effect is complicated by the new patterns of consumption as a result of quarantines and public policy responses that have increased subsidies to unusually high levels. The end result of the demand shocks for the price of farm grapes in the case presented here is a positive change. But the broader and more important point is that the demand shifts alone might not cause negative impacts as large as, for example, the labor cost increases in the supply chain shown earlier that raised the margin between food demand and supplies on the market in the short run.

Changes in trade alleviate the stress of the domestic market shock. The trade response automatically helps meet the changing domestic needs. Domestic demand for table grapes rises, thereby increasing their price and leading to more imports and fewer exports. Because the overall increase in demand causes the price of raisins to rise, despite lower domestic demand for raisins, exports of raisins fall. This reduction in raisin exports allows more of the farm commodity to be shifted into domestic markets. These trade responses help moderate the extent of the domestic price increases and consumer expenditure impacts of the domestic demand shocks.

The *trade shocks* decrease table grape export demand and table grape import supply, and increase raisin export demand. (Raisin imports account for less than 10% of domestic use and are held constant in this exercise.) The market outcomes with these three shocks suggest a dominant effect of the change in large table grape imports that draws down supplies and, along with greater raisin export demand, causes the prices of farm grapes and grape products (table grapes and raisins) to be bid higher. The net effect is stronger farm sales of grapes and higher consumer costs due to fewer imports and more exports.

The scenario featuring a *labor cost increase and market shocks* shows that labor price increases can play as large a role as the market shocks considered here. The greater margins caused by higher labor prices continue to explain the widening gap between the prices paid by buyers and the producer price. Shifts in inelastic domestic demand seem to dominate the trade shocks. The rising prices associated with wider supply chain margins tend to reduce the market quantity effects relative to market shocks alone—with the exception of table grapes, whose negative impacts are moderated by increases in domestic demand and price. The end result includes rising consumer expenditures as producer receipts fall, higher export sales, and lower import expenditures.

The scenario featuring a *labor quantity constraint and market shocks* preserves the earlier result that a labor constraint can in principle narrow the aggregate margins. Given the generally positive effects of the market shocks on producer returns in this case plus a narrowing of the margin, producer prices and receipts rise. Consumer expenditures also rise. All quantity changes in this case are at least as large as the results in any other scenario, in absolute terms. Indeed, the labor constraint, quantity reallocation, and price changes suggest large adjustments that could take time and money to achieve, although we do not focus on the adjustment process itself.

Again, the result in which a labor constraint leads to narrower aggregate margins is based on the premise of a short-run reallocation of farm commodities to less labor-intensive retail products to which consumers are willing to substitute. For the products at hand, this potential is greater for table grapes than for raisins; thus, the cost of producing table grapes from farm grapes is constrained to a lower value in order to contain labor use, and domestic consumers buy about as much of similar goods at lower prices. Domestic raisin use is reduced by the demand shock and by the inability to reallocate supply chains to less labor-intensive options. And, as noted before, an analogy can be made to the broader market impacts of a supply constraint. At least in the short run with the existing options, a supply constraint can lead to the production of foods with lower labor costs and consequently lower production costs overall. This outcome presumes that consumers will switch readily among retail goods, even though the form in which they come might be quite different. Moreover, as discussed earlier, if less labor input causes greater food loss, then there is upward pressure on commodity prices that might or might not offset other factors.

The labor disruption scenarios in these last two columns reflect two effects, cost increases and quantity limits, but we do not argue that one is necessarily more plausible than the other. We note that the nature of results can depend on how the labor market disruption affects the supply chain; what alternatives are available in terms of their labor and cost profiles; and whether consumer demand for the good or goods is inelastic overall and also unresponsive to the exact form of the food. The short-run effects within a marketing year might not reflect long-run results once firms and consumers fully adapt. Indeed, the idea of a labor constraint on long-run results would defy the fundamental view that long-run analysis is characterized by the flexibility to choose firm scale and make other adjustments.

Hypothetical trade policy response

Policy makers might choose to respond to domestic food security needs or labor disruptions by attempting to engineer offsetting shocks to trade. Here, we add to the scenarios with labor disruption and market shocks an additional negative shock to trade to represent a hypothetical policy response. We assume an effort to reduce exports in order to shift more of the farm commodity and resulting products to domestic users and to focus labor on domestic needs, while being subject to constraints. We are agnostic about the hypothetical mechanism: one could imagine an export tax, intermittent bans on exports of perishable products, or other measures. The goal is not to speak to any actual policy, but instead to help broaden the understanding from beyond the specific case to others, including country-commodity pairs where trade measures already exist or might be employed. In no case do we recommend any policy response; this exercise is to demonstrate the consequences of a choice, not to make any argument about what policies, if any, should be undertaken.

The hypothetical policy causes a reduction in table grape exports by shifting that demand further beyond the reduction that the pandemic seems to have caused already. There are two reasons to target table grape exports in this case. First, the year-to-date data suggest that the pandemic has shifted demand from raisins towards table grapes, so a policy that intends to support food security might be based on the idea that exporting fewer grapes will free up supplies to meet

rising domestic demand. Second, table grapes use more labor in this representation, so a policy focused on restricting exports would conserve supply chain labor.

The results show that this policy can lead to greater domestic use relative to the effects without the policy to reduce table grape exports, but the results spill over dramatically in this scenario (Table 3). The targeted exports are reduced, and the domestic price effect of the pandemic plus trade policy is limited or even becomes a price reduction. However, the domestic table grape demand is price-inelastic, so the increase in targeted use is proportionately quite small. Instead, the main effects are greater imports of the table grapes, a decrease in the price of farm grapes, and a reallocation of farm grapes toward the raisin market, where domestic demand is more sensitive to price changes and exports constitute a larger share of the market. In the case of labor disruptions that constrain the quantity of labor used, without affecting the price, the export reduction is sufficient to alleviate this constraint while allowing existing product forms or patterns to persist. This means that high-labor varieties of the retail goods might be maintained in the output mix with exports of the fresh product constrained by policy. The demand and trade shocks, including the export policy, drive most of the results for markets and supply chains in this case.

Table 3. Impacts without and with a hypothetical export reduction policy

	Labor and market shocks		With table grape export reduction	
	with labor cost +60%	with labor quantity limit	with labor cost +60%	with labor quantity limit
Supply chain margins				
Domestic table	15.1%	-12.9%	15.1%	0.0%
Domestic raisin	6.8%	4.8%	2.6%	-0.2%
Export table	15.9%	-25.9%	15.9%	0.0%
Export raisin	6.6%	13.8%	2.0%	-0.3%
Raisin market				
Domestic use	-7.7%	-10.3%	-6.3%	-6.6%
Exports	-0.2%	-8.6%	3.9%	2.7%
Imports	0.0%	0.0%	0.0%	0.0%
Domestic price	1.9%	7.8%	-1.0%	-0.3%
Export price	4.7%	21.5%	-3.5%	-0.9%
Table grape market				
Domestic use	5.1%	5.4%	5.2%	5.4%
Exports	-2.5%	0.1%	-11.9%	-10.9%
Imports	-1.7%	-2.5%	-2.0%	-2.5%
Domestic price	1.6%	0.0%	1.0%	-0.1%
Export price	3.7%	-2.8%	2.2%	-0.2%
Farm grapes				
Quantity	0.0%	0.0%	0.0%	0.0%
Price	-0.5%	18.9%	-8.5%	-1.3%
Other indicators				
Domestic consumer cost	4.3%	3.7%	3.6%	2.9%
Total farm receipts	-0.5%	18.9%	-8.5%	-1.3%
Export receipt	2.2%	1.6%	-6.8%	-7.2%
Import expenditure	-0.1%	-2.0%	-1.1%	-2.5%

Applicability to other cases

Grapes represent an important share of income among fruit, vegetable, melon, and nut growers, especially when grape-based products other than raisins, such as wine and juice, are considered (Table 4). Given that wine is a unique product with its own data challenges and modeling issues, our model does not span that good. Thus, the grape income share given here overstates the

degree to which our results represent directly the possible impacts on the income of fruit, vegetable, melon, and nut growers, but the results presented here might indirectly relate to other cases and be more relevant for farm income than if wine is included. With proper adaptation, our models could be applied to other specialty crops, but doing so goes beyond the scope of the present exercise. As such, we focus on table grapes and raisins as a case for which suitable supply chain and market models can be prepared. Results can be extrapolated to the extent that other specialty crops have similar market and supply chain structure.

Table 4. U.S. farm income of selected fruit, nuts, vegetables, and melons, 2015-18 averages, USD millions

Fruits and nuts		30,003
	Grapes	6,231
	Apples	3,272
	Strawberries	2,774
	Oranges	1,984
	Cherries	843
	Almonds	5876
	Other fruits and nuts	9,023
Vegetables and melons		19,577
	Potatoes	3,188
	Lettuce	3,130
	Tomatoes	2,148
	Onions	970
	Corn, Sweet	933
	Other vegetables and melons	9,209

Source: USDA, ERS, Farm Income and Wealth Statistics, 2020.

We see several broad similarities to other specialty crop markets. Fresh and processed markets are present for many specialty crops, not just grapes. For example, fruit and vegetables are sold either as fresh product or in a processed form as the result of drying, cutting, chopping, juicing, freezing, pickling, or some other technique. Additionally, both fresh or processed fruit and vegetables are used as ingredients in a wide variety of processed food products. The elasticities that inform this study are based on what we found in the literature for fruit in general, although focusing on those few studies that give elasticities of fruit demand. From our reading, we have the impression that the demand for fresh fruit is more inelastic than the demand for processed fruit. Possible reasons include the potential to store processed products longer or to change input mixes in ways that reduce the need for a specific specialty crop if its price rises.

Trade plays an important role in the U.S. grape market. Fresh grapes account for 9% of U.S. fruit imports and 6% of U.S. fruit exports (Table 5). Compared to the trade shares for other fruit and

vegetables, the trade shares for grapes seem unexceptional, suggesting that the values involved are comparable. The presence of both imports and exports of a product is something of a complication, and this shows up in results when exports and imports of table grapes adjust to changing circumstances. This difference might be bridged by considering the difference to be equivalent to net exports or net imports, subject to the caveats that trade partners are different and that the elasticities and pandemic-related shocks of specific fruit and vegetables presumably differ as well.

To assess the importance of trade, one could set the trade numbers to a different scale. If export value is expressed as a ratio of farm income, then some idea of scale might be obtained. In this light, the export-to-income ratio for fresh grapes is similar to the ratios for lettuce and strawberries, greater than the ratios for potatoes and tomatoes, and less than the ratios for apples and oranges. By this measure, exports are much less important for grapes than they are for almonds or cherries. While not universally representative, the export-to-income shares suggest that the case of grapes is somewhat near average.

Table 5. U.S. exports and imports, 2015-18 averages.

Import values and shares			**Export values and shares**		
Vegetables	USD million	Share	Vegetables	USD million	Share
Tomatoes, Fresh	2,190	23%	Lettuce, Fresh	392	10%
Peppers, Fresh	1,377	14%	Edible Brassicas	302	8%
Cucumbers, Gherkins	689	7%	Potatoes, Fresh	211	5%
Vegetables, Frozen	610	6%	Onions And Shallots	194	5%
Asparagus, Fresh	629	7%	Kidney Beans, Dried	200	5%
			Sweet Potatoes	175	5%
Fruits and nuts			Fruits and nuts		
Avocados	2,134	13%	Almonds, No Shell	3,463	26%
Bananas, Fresh or Dried	2,130	13%	Pistachios, In Shell	1,256	9%
Grapes, Fresh	1,487	9%	Almonds, In Shell	1,026	8%
Cashew Nuts	1,344	8%	Apples, Fresh	975	7%
Cranberries	914	6%	Walnuts, No Shell	848	6%
Raspberry, Blackberry	917	6%	Grapes, Fresh	766	6%

Source: USDA, FAS, Global Agricultural Trade System, 2020.

Winners and losers

A reasonable starting point for our analysis that we expressed at the beginning of this paper is that the pandemic is not likely to have benefited anyone in table grape and raisin supply chain.

Our results largely concur, but there are a few potential exceptions. If the combined effect of the lockdowns and income shocks, taking subsidies into account, causes consumers to switch to a good, then the producers of that good could benefit. Of course, the shift towards one food product is almost certainly a turn away from another given fairly constant total food demand, so producers of the other good would lose in this case.

Producers of farm commodities could see increased sales due to a labor disruption in theory, as results here show, but the conditions might not be right for such an outcome in many cases. If labor constraints cause the supply chain to shift towards less labor-intensive foods with lower margins, if consumers substitute readily to food products with lower labor intensities, and if a portion of this difference in supply chain costs flows back to producers in the form of higher bids for their outputs, then there could be an increase in farm receipts. However, the producer impacts of these conditions might be reversed, such as if there is a modest cost in the transition from one supply chain output to another. Greater on-farm costs or disruptions that cause a negative shock could reduce the possibility of increased farm sales revenue. Moreover, if labor costs rise, then there is unambiguously negative pressure on farm output prices and receipts.

Supply chain workers, i.e. those work in production, processing, packaging and transportation, are worse off in all these cases relative to the pre-pandemic situation. The pandemic makes it less safe to work in general, and a labor constraint implies fewer hours worked and perhaps some jobs lost in their entirety. The higher labor cost scenario should not be seen narrowly as if it reflects a case of rising wages to workers. While that could be the case, these increases are presumably premiums that offset safety concerns, such as giving bonuses to retain workers during a pandemic or expanding paid sick leave. Moreover, labor costs in our usage here include complementary inputs to labor during the pandemic, such as PPE, workspace changes, and similar costs that do not form part of the wage. It is difficult to imagine how any of the scenarios examined in this paper can be seen as anything but a loss for these workers.

Consumer demand for table grapes and raisins may have increased due to the pandemic, but not by very much overall. One can only eat so many table grapes and raisins. Our expectation is that aggregate food demand has changed very little and perhaps fallen with declines in household income and increases in food prices. Any observed reduction in aggregate consumer expenditures on food thus would reflect a real decline in total food consumption. We assume that consumers will substitute to less labor-intensive foods if foods with greater labor requirements become more limited, but that does not mean consumers get no value from the extra services. For example, the reduced ability to eat at restaurants might be caused in part by constraints to the use of labor in that part of the supply chain, and consumers will choose to buy a similar quantity of food for at-home consumption. But these consumers will have to assign more of their own time to food preparation and clean-up than before, with consequences for consumer well-being.

Trade also implies winners and losers, as the shocks generated by the pandemic extend into broader markets. Higher labor costs in the U.S. supply chain can encourage imports of goods, even if labor markets in supplying countries are seriously affected. A more subtle complication is the cross-product impacts, as shown in the case presented here. Higher labor costs affect the

fresh product market more than the processed product market in the case of table grapes and raisins, with such severe impacts that the reduction in the farm price can overwhelm the labor cost impact on the processed product. In other words, labor costs can cause lower prices for the more processed product, if this product tends to use less labor than the fresh product, and it is very likely that the more processed products are less perishable and easier to transport internationally without damage or loss. In sum, higher labor prices for the fresh produce supply chain could increase trade in processed products.

Trade policies to constrain exports and increase domestic supplies have additional welfare implications. Foreign buyers are clearly among the losers of a policy that reduces their ability to acquire U.S. agricultural products, implying that foreign consumers pay more to get less. Because of inelastic U.S. demand of the target commodity, the quantity impact here is small, yet the price reduction is nevertheless a benefit to U.S. consumers. The main quantity effects spill over to the more processed use of the commodity (e.g., raisins), with both domestic and foreign buyers enjoying lower prices. The reason for these price reductions is reduced demand overall with the export constraint, and that is apparent in the lower producer price, as U.S. producers clearly lose from an export constraint.

We do not make any proposal for policy or business priorities. Each option to intervene in the market rebalances the outcome among those who benefit and those who don't without making everyone better off, and these decisions consequently involve trade-offs that go beyond the scope of this paper. With respect to worker safety during a pandemic, one can speculate about some actions with widespread benefits. Innovations that enhance worker safety in the face of the pandemic could reduce the potential for labor disruptions, thereby raising producer receipts and decreasing consumer costs. Indeed, higher labor costs would seem to provide businesses with a strong incentive to innovate, going beyond the currently available set of options at each stage of the process. Policy makers might likewise identify higher labor-related costs as a target for some form of intervention. Policies that subsidize safety measures would shift costs from the sector's workers, firms, commodity producers, and final consumers onto taxpayers. New innovations that avoid higher labor costs by circumventing labor requirements overall would reduce labor demand in the sector.

Discussion

The food chain and market disruptions of the COVID-19 pandemic have been astounding. The fresh produce sector is no exception; indeed, the potentially high-cost, time-sensitive, and labor-intensive steps needed to get fresh produce from farm to consumer either directly or in the form of a processed product might make this sector more vulnerable to the effects of the pandemic. However, the short-run nature and intensity of the shock might test the ability of existing economic tools to analyze the means by which agricultural commodities are combined with other inputs to make food. Labor disruptions and market shocks in the United States have the potential to spill over into other countries via international trade. These relationships are complicated by interactions in the supply chains of goods set for different uses, and because of market interactions among users and products, all are tied to a single farm commodity.

In this paper, we examine farm grapes, table grapes, and raisins as a case for analysis. We apply two existing tools to address these new shocks to the supply chain and markets. The supply chain model focuses on existing options at each stage of the chosen case. This representation replaces the more stylized approach seen in some foundational studies in this area. The supply chain model acts as a sort of representative firm that optimizes over the choices of modes and inputs at each stage in order to move grapes from farm product to retail products. Labor is among the inputs. We can examine the impacts of higher labor costs, whether owing to wage increases to address safety concerns or the complementary inputs now necessary for worker safety, as well as the effect of an outright limit on labor use to represent the risk that lockdowns and safety constraints force workforce reductions given the available facilities.

The market model represents demands, domestic and foreign, and import supply of the consumer products and links these markets to the farm commodity market through the margins implied by the supply chain model. For the U.S. case, a literature review leads us to assume inelastic demands. Year-to-date data lead us to represent the impacts of the pandemic as an array of shocks. Interestingly, the domestic demand shocks appear to have gone in opposite directions, with greater demand for the fresh product, table grapes, and less demand for the processed product, raisins. Trade shocks are also mixed. We leave production unchanged to reflect the short run impacts when the pandemic first hit. We do not speculate about the extent to which labor concerns are a factor during the growing season. Moreover, whereas our approach to supply chain impacts and their interactions with markets is novel, we feel that farm commodity supply shocks are better understood.

Our approach has limitations. We focus on the initial impacts of the pandemic, only, and the size of those shocks remains uncertain even now. We do not account for the scope for farm commodity supply shocks. Risks to the specialty crop supply are certainly real but speculative in this case because the harvest was still well in the future at the onset of the pandemic and perhaps better understood than the supply chain impacts seen during the first half of 2020. Our new method of combining approaches relies on an assessment of short-run options that seem appropriate for the current event but might not capture the scope for adaptation over time. The demand results depend in part on the willingness of consumers to substitute among retail goods with dissimilar forms, although we emphasize in our description the negative impact on consumers that can come with lower expenditures if associated with less value added from labor. A key assumption is that supply chain disruptions do not sever vertical links for an extended period of time. The supply chain connects farm commodity supply and food demand over the course of the year. Stories relating to the livestock and meat sector, as well as poultry and milk, demonstrate that supply chain disruptions can sever the connections between farm and retail at least temporarily and locally.

In our representation of the supply chain, labor accounts for a larger share of table grape supply chain costs from farm to consumer than is the case for raisins, yet there is also more scope to choose methods that reduce labor inputs for the fresh product and deliver retail goods with varying value added than for raisins. The supply chain model generates sharp increases in margins for the labor-intensive fresh product in the face of higher labor costs, even to the point that the farm price is reduced with weaker fresh demand. The net effect of a lower commodity

price and a higher margin can be downward pressure on the processed product's price; the farm product is reallocated from the high-margin fresh product to the processing product. A labor force reduction in this case, where consumers buy fresh products with high labor input share, narrows the aggregate margin for this commodity sufficiently that the producer price remains strong. This possibility likely evaporates if there is little scope to deliver similar retail goods with less labor or if the product with high labor cost share accounts for a small share of the farm commodity market.

The outright labor constraints unaccompanied by greater labor costs require the use of less labor without raising the costs of labor, including both wages and worker protection. The supply chain configuration reflects the possibility that some options of delivering the product basically become infeasible as a result of labor constraints. In this representation, the impact can be that the constraints disallow options that have relatively large labor requirements and high margins, causing a reduction in the aggregate marketing margin and less impact on prices of remaining options or even unexpected ones if labor is reallocated into these processes. If consumers readily substitute the products with low-labor options for those with high-labor options temporarily not being offered, as seems possible given inelastic demands, then the reduction in marketing margin could in principle lead to some upward pressure on the farm price.

The U.S. away-from-home food consumption tends to have higher margins and labor costs than at-home food consumption (USDA, ERS, 2011), so by way of broad analogy, one might imagine the impacts on marketing margins if the only shock was a forced shift to at-home consumption without affecting the overall food consumption. The willingness of consumers to substitute without reducing food consumption overall is not perfect but might be very strong if we expect that the overall food use is fairly constant. The share of agricultural commodities' value in food expenditures could increase in this case.

This analogy sidesteps at least three cases or complications that bear attention. First, the meat sector might be a case where there is no low-cost option, and effective constraints on labor use have removed all possible options for some time and in some locations, severing the links between retail and farm. Second, the apparent stability of total U.S. food demand includes many households for which food consumption quantities are uncertain and which could be negatively affected. Third, while of lesser priority, the fact that consumers spend less on food does not mean that they are better off. Consumers who chose to buy higher priced food products that embody more labor can no longer do so, possibly implying a large decrease in their welfare as they are left to assign their own time to in-home food preparation and clean-up, as well as depend on only their own capabilities for the quality of food served in their household.

We present labor cost increases and quantity constraints as alternative extremes. In reality, it might be more likely that a combination of higher labor costs and at least localized constraints on labor quantity take place. Moreover, the limited data currently available offer little guidance about how much weight to place on either sort of shock. These experiments raise a key point relating to innovation and prioritization that is likely reinforced by market incentives, specifically the importance of alternative strategies to get products from farm to consumer that use less labor. The pressure to identify less labor-intensive alternatives that can constrain cost

effects or even circumvent the worst outcomes seems a priority, particularly for those goods that do not have any processed alternative. Speculating, such a list might include meat and other livestock products at some stages of the supply chain and, among specialty crops, perhaps a few vegetables like lettuce, some nuts and melons, and other cases where fresh uses with high supply chain labor costs might dominate.

The impact on individual buyers, including foreign buyers, is sensitive to the combined impacts of labor costs in the supply chain to get them their goods and the downward pressure from the farm price; in the case examined in this paper, buyers of the processed product pay a lower price. The result might suggest that the severe disruptions in meat processing could reflect a lack of less labor-intensive alternatives available as short-run options. In our work, we do not address the risk of a complete severing of the links between the farm commodity and retail goods.

The impacts on the domestic demands for the fresh product (table grapes) and the processed product (raisins) appear to move in opposite directions in this case. Opposite demand shocks might have a broader analogy in that the total U.S. food demand might tend not to change very much even for a large shock. The reallocation in this case has a small net positive impact on farm income, but it might be reasonable to assume that most of the demand disruption shocks end with a reduced farm price, even before considering the potential that labor costs rise and drive these prices lower.

The pandemic is bad for pretty much everyone involved: workers likely lose in all these cases, consumers can sometimes win at the expense of others, and only in unusual conditions could producers win. The higher labor cost constraint reflects pay increases to offset safety risks or complementary inputs, neither of which is a win for workers in all likelihood, given the current public health crisis. In some cases, relative price changes can be positive for some domestic or foreign buyers, but usually someone else seems to pay more. Even the case where the disruption is so severe that high-cost supply chain options are forsaken and marketing margins appear to fall, the underlying implication is that consumers cannot buy some products that they chose to buy before. Consumer expenditures might fall if consumers no longer buy ready-to-eat goods or reduce their food spending away from home, but that does not mean that they are better off. The shocks to demands and supply chains can raise producer prices and, setting aside farm commodity supply risks, cause an increase in short-run receipts. But these effects might erode quickly if labor costs rise or demand shocks become more negative because the outlook for farm income, even with subsidies taken into account, becomes more pessimistic.

Trade policies to offset these effects might seem like a blunt instrument–subject to the elasticities and interactions of the market in question. An export policy to support domestic consumption has impacts, but these spill over quickly to other markets. A reduction in exports of the fresh product that might be intended to offset rising demand or constrained labor can cause more imports and more exports of the processed product. Both responses partly offset this policy if measured in terms of its impact on domestic use. In addition, the policy of reducing exports will tend to reduce the farm commodity's price and increase consumer prices outside of the country.

In the face of the COVID-19 pandemic, humility is in order for a great many things, including our ability to estimate the economic consequences of the pandemic. The model employed in this paper is a combined representation of the supply chain and product markets that is newly built from existing methods. This approach allows for fresh analysis, but models are representations, of course, and do not include all possibilities. We sidestep some key factors, such as the potential of a supply shock due to labor or other disruptions. We also do not estimate the scope for innovations that create new options in the supply chain that can deliver consumer goods with high value yet do so with reduced labor share. Indeed, we outline a case where the incentives for such innovations, private or public, could be very high; yet we do not explore any specific steps. Labor disruption mitigation seems a way to reduce the negative impacts of the pandemic without creating side effects that reduce the effectiveness of the mitigation or even reduce people's well-being– excepting, of course, workers themselves in the event that the mitigation increases the risks to worker safety or if labor is replaced with other inputs. We also must be humble about the nature of the shocks. Given that we have only several months of observed data to see how the pandemic has affected supply chains and markets, our assumptions will undoubtedly prove either too optimistic or too pessimistic. For these reasons, we try to draw conclusions that are dependent not on the exact shocks that we choose, but rather on the relationships and patterns overall as sketched by our model of the table grape and raisin supply chain and, to the extent possible, as a reflection of the markets for other specialty crops and agricultural and food products.

Conclusions

The global COVID-19 pandemic and policy responses stressed agricultural and food supply chains and altered what foods people buy and where they get those foods. Initial disruptions to the supply chain were often tied to labor: essential worker safety measures could lead to additional costs, and non-essential workers were at times banned from the workplace. Food demand overall might not have changed very much, but the mix of goods purchased changed suddenly, as the spending on food consumed away from home fell and was replaced with food purchased for at-home use, with repercussions as consumers sought different goods presented to them in different ways and made from a different array of ingredients.

We develop a novel approach that integrates a supply chain optimization model and a market equilibrium model to study how labor disruptions and market shocks play out in terms of their impacts on buyers and sellers, domestic or foreign. The application to the case of U.S. farm grapes, raisins, and table grapes reflects many complications observed in food markets more generally. Evidence collected early in the pandemic indicated shifts in demand and trade during this period, including a reallocation of food demand. The labor market disruptions took place in a common context for food and agriculture, with raw farm products delivered in a fresh form with a greater labor cost share and a processed form with a smaller labor cost share, and with trade playing a more important role in the processed good market. This setting might reflect some other produce markets, as well as livestock product markets to some degree.

We find that labor cost increases owing to such factors as higher wages, more paid sick leave, or complementary inputs to protect worker safety tend to be passed back to producers in the form of

lower prices at least in the short run. As a sudden shock allows too little time for producers to respond and domestic users are not sensitive to price changes, the largest quantity changes due to the labor cost increase are in traded volumes and prices. Labor disruption that curtails outright the use of labor in the supply chain can have more dramatic short-run consequences. Without time to alter supply chain options more radically, the only means to constrain labor use in this case is to shift towards retail goods that embody less labor and to allow food loss to rise. The observed marketing margins might be squeezed as labor expenses fall, and food loss during processing can lead to higher prices as domestic and foreign buyers compete for a smaller quantity.

The demand shocks appear to be neutral in the sense that food demand seems to shift in this case (and more broadly) among forms of the agricultural commodity rather than to fall overall. However, these demand shifts occur in the context of different supply chain labor input requirements for the foods and different trade shares in each food market. The domestic demand shifts can affect margins as supply chains adjust to handle the changes in throughput. Moreover, the domestic demand shocks tend to have large spillover trade effects. A hypothetical trade policy that attempts to alleviate the price increase associated with greater domestic demand for one food might also have spillover effects in the form of offsetting trade and consumption impacts in the food market that is not targeted by the trade policy. This experiment suggests that a complete assessment of the effects of a trade policy targeting one food type would need to take into account the consumption and trade of competing uses of the agricultural commodity.

The results of the analysis tend towards pessimism. The pandemic and associated policy responses, in the short run, appear to cause labor disruptions and market shocks that tend to have negative impacts on domestic consumer expenditures, import bills of foreign buyers, and workers. In this case, there is the potential that labor market disruptions that curtail labor use in the supply chain could lead to such an increase in food loss that food prices are bid higher. If so, it might be possible that producer receipts are bid higher as well. Higher labor costs, as opposed to outright labor constraints, are likely to increase margins and depress farm commodity producer prices and receipts. In the case of workers, the higher labor cost tested here should not be assumed to be higher wages given that these costs might be for greater sick leave among workers or for complementary inputs to preserve worker health. The worker benefits of policies or innovations that alleviate labor market disruption would presumably be judged at least in part on the basis of worker health. Consumers, domestic or foreign, tend to experience higher prices in all cases explored here as supply chain labor disruptions and market shocks combine to drive up the prices they pay.

Our work opens the door of a plethora of research opportunities. The integrated supply chain optimization and market equilibrium framework can be adapted to study other specialty crops and livestock products with the corresponding supply chain and market data. While only the short-term impact of labor shocks is addressed in the current study, it will be interesting to extend modeling framework to study the long-term supply chain and market dynamics.

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