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Price Transmission and Asymmetry in the Colorado Potato Supply Chain

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Abstract

We conduct a time-series analysis of Colorado, Idaho, and national potato markets to examine price transmission and asymmetry (relative likelihood and magnitude of upward versus downward price shocks). Prices are typically driven by supply-side shocks. Colorado potato producers' prices are influenced by Idaho and experience unfavorable asymmetry relative to downstream parties. We apply findings to the COVID-19 lockdown period as a case study to explore market behavior during that time. Identifying and noting potentially harmful price dynamics in commodity markets could help producers effectively respond to similar shocks in the future.

Keywords: commodity markets, Granger causality, local food, price asymmetry, price transmission, Russet potatoes, agri-supply chain, COVID-19

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Introduction

During March 2020, the global COVID-19 pandemic stymied economic activity in some sectors in the United States as state and local governments adopted shelter-in-place and stay-at-home orders in an attempt to slow the spread of the virus. As the American public faced the lockdown due to COVID-19 in March and April 2020, food retailers, such as Walmart, Target, and Kroger, saw major sales gains as consumers stocked up to prepare for extended stays at home and shifted their food expenditures toward food at home as opposed to food away from home (Redman, 2020a; Redman, 2020b; Redman, 2020c; U.S. Census Bureau, 2020). Specifically, grocery sales increased 28.5% from $56.5 billion in March 2019 to $72.6 billion in March 2020 (U.S. Census Bureau, 2020).

As consumers shopped for groceries with the goal of staying at home for long periods of time, they purchased food staples, cleaning supplies, and other household essentials (Parker-Pope, 2020). Potatoes were the highest-volume crop moved in refrigerated trucks during the March 1–May 31 COVID-19 lockdown period (USDA AMS, 2020b). Potatoes were a popular item in uncertain market conditions because they are seen as a shelf-stable pantry staple. A recent analysis of U.S. produce markets has shown that the volume of potatoes purchased by consumers in March 2020 was 41% higher than it was in March 2019 (Pieterse, 2020). Fresh potato sales increased 19.2% in dollars and 15% in volume in the third quarter of the marketing year 2020 (Potatoes USA, 2020b; Potatoes USA, 2020c).

With the retail sector performing so strongly, one might expect that sales and price gains might transmit back to the farmers that sell some of their product through these high-performing retail markets. However, historically, farmers have not reaped the full benefits of strong food demand. To explore that price transmission dynamic, we present a historical time-series analysis of farm gate, terminal market, and retail prices in potato commodity markets. Moreover, to explore whether Colorado farms were able to capture a share of the strong demand experienced in 2020, we compare potato price patterns during the pandemic to our historical analysis.

Our research questions are: What factors drive Colorado farmgate prices? What is the nature of price transmission and asymmetry experienced by Colorado potato farmers, particularly relative to Idaho? And, when demand for potatoes is strong at the retail level, as during the COVID-19 lockdown period, do farmers capture a proportional price gain? We explore the price transmission question by identifying Granger causality relationships at several key points in the potato supply chain using time-series datasets. When we refer to price asymmetry, we mean the speed with which prices return to "normal" pre-disruption levels if they are shocked by the market.

Background and Literature Review

We provide an overview of the study sector and region, Colorado potato production in a national context, supply chain margins, and market power before introducing our research methods.

Study Sector and Location

At the same time fresh potato markets saw increased activity during the COVID-19 lockdown period, markets focused on processed potatoes saw decreased sales as institutional purchasing (such as that by restaurants and schools) dropped drastically. The U.S. National Restaurant Association documented a 40% decrease in sales during the spring of 2020, compared to the same time period in 2019 (Jennings, 2020). Eighty-five percent of frozen potato sales typically go to the food service sector, and the remaining 15% to retail (Potatoes USA, 2020a). In comparison, 48% of fresh potato sales go to food service, and 52% go to retail. In 2020 some potatoes grown for processing were diverted to the fresh market. Increased demand and an influx of processing potatoes were competing pressures on fresh market potato prices. We chose to focus our analysis on the fresh potato market because it experienced consistently higher sales than the processed potato market and even absorbed some of the processed potato market for a short time.

Our focus on the fresh market sector led to our choice of study area. Colorado is second only to Idaho in terms of fresh table stock production (J. Ehrlich, personal communication). An active producer industry group in Colorado encouraged our examination of market power and price dynamics. Lessons learned about the relationship between Colorado and the fresh potato market's highest-volume contributor likely are generalizable to other states who have lower production volumes. If the market is structured such that when supply chain shocks like COVID-19 happen, some parties are more likely to experience better or worse outcomes on a consistent basis, that is important information. It could be used to inform policy mechanisms that would make food supply chains more resilient to shocks.

The San Luis Valley, a six-county region in southern Colorado, is a rural area whose economy is heavily reliant on agriculture. Crop production, chiefly potatoes, and adjacent activities are primary occupations (San Luis Valley Development Resources Group, 2008). Even before the COVID-19 pandemic, potato farmers in San Luis Valley provided anecdotal evidence of the prices they receive for their potatoes being influenced by price shocks emanating from Idaho potato markets, so we set out to investigate whether the econometric evidence aligns with their claim. In the late stages of our historical time series research, the COVID-19 pandemic started, providing an opportunity to see how the price dynamics we had detected econometrically played out during the early stages of the pandemic.

Potatoes: U.S. and Colorado Context

In the 2018 marketing year, the United States produced 45 billion pounds of potatoes at a total value of $3.75 billion on 1 million acres of cropland (National Potato Council, 2019; USDA NASS, 2019). In terms of U.S. production, Colorado ranked sixth for overall potato production and second for fresh or table stock production (see Table 1) (J. Ehrlich, personal communication) (National Potato Council 2019; USDA-NASS, 2019). Ninety-five percent of Colorado potatoes are shipped fresh (Ehrlich, Sullins, and Jablonski, 2020), and Colorado producers' focus on the fresh market makes them more attentive to perishability, fresh product demand and movements, and active distribution through a variety of market channels. Colorado sold 1.4 billion pounds of potatoes as fresh table stock during the 2018 marketing year, which amounted to 13.5% of all table stock in the United States (USDA NASS, 2019; Colorado Potato Administrative Committee, 2020) .

A previous study found that while the U.S. potato market tends to behave efficiently in terms of price transmission overall, there is some room for improvement (Durborow et al., 2020). The Colorado Potato Administrative Committee (CPAC) is an industry group based in San Luis Valley, Colorado. Their annual report for the 2019 marketing year states, "Prices received by growers of potatoes are influenced by a competitive relationship with other growing areas, and to some extent, by U.S. economic trends. Current and potential supply levels, quality of supplies, time of harvest, consumer demand, and shipments of processed potatoes influence the price for fresh potatoes" (Colorado Potato Administrative Committee, 2020).

Table 1. Top 10 Potato Producing States

State	Total Production (100,000 lbs.)	% of Total Market Share	Price per 100 lbs. ($)	Value of Crop ($1,000)
Idaho	141,750	31.5%	6.85	960,199
Washington	100,800	22.4%	6.52	688,512
Wisconsin	27,135	6.0%	12.00	340,800
Oregon	27,000	6.0%	7.49	210,169
North Dakota	23,725	5.3%	9.70	226,592
Colorado	21,722	4.8%	9.69	210,486
Minnesota	18,705	4.2%	9.27	173,395
Michigan	18,240	4.1%	10.00	182,400
California	15,457	3.4%	14.50	224,497
Maine	15,035	3.3%	10.20	156,519

Note: Production volumes and prices are from the 2018 marketing year (National Potato Council, 2019; U.S. Department of Agriculture, Economic Research Service, 2019).

Idaho was the largest potato-producing state by volume in the 2018 crop year (see Table 1). Together, Idaho and Washington comprised more than 50% of the national market share by volume, much of which went to processed potato products. These states typically receive lower average prices for their potatoes, likely due to price differen ces between fresh table stock potatoes and potatoes destined for processing (National Potato Council, 2019). Idaho alone represented almost a third of the total U.S. potato market share by volume, while by comparison, Colorado's market share was 4.8%. Due to Idaho's large market share relative to other potato-producing states, of which Colorado is one example, we hypothesize that Idaho may have some influence over lower production volume states' fresh potato prices. Lessons learned about the relationship between Idaho's and Colorado's relative market and price dynamics can inform marketing strategy for other lower production volume states. We examined price data econometrically to identify evidence of price transmission patterns (one indicator of potential concentrated market structure) from other growing areas, particularly Idaho, due to its status as the industry leader in potato production.

In 2017, 69% of the potato acreage planted in the United States went into Russets, 21% into other white varieties, 7% into red and blue varieties, and 3% into yellow varieties (National Potato

Council, 2019). In Colorado, an even higher 80% of the acreage was planted in Russets, 10% in yellow varieties, 7% in red varieties, and 3% in other white varieties. Russets also constitute the largest category in terms of volume (66%) of all potatoes sold (Karst, 2018). As Russets are the dominant variety in terms of acres planted and volume sold, we focus our analysis on that variety to capture market dynamics at play in this predominant product category. A general survey of supply chain literature provides helpful context before we revisit our sector and region of interest.

Farmer Share of the Food Dollar

As supply chain efficiency and delivery of more differentiated products to consumers have increased, the distribution of revenues along longer, more complex agri-supply chains has changed (Van der Spiegel, 2004; Van der Vorst, 2005). Every dollar spent by consumers at the retail level must be divided amongst all the parties that contributed to the production, processing, distribution, and retailing of the final product (Cucagna and Goldsmith, 2018). As a result, in 2018, only 7.7% of every dollar spent by consumers on food made its way back along the supply chain to the farmer who grew the raw product, down from 21% in 2000 and 40% in 1952 (Coltrain, Barton, and Boland, 2000; USDA ERS, 2020).

The various supply chain parties who capture food revenues generally include agricultural producers, storage facilities, processors, shippers or distributors, retailers, restaurants, and consumers, all of whom may or may not have aligned values, missions, and governance with one another (Cucagna and Goldsmith, 2018). Some businesses achieve economies of scale and cost savings through vertical integration, which combines several supply chain links into a single enterprise (Sexton, 2000; Saitone and Sexton, 2017). Happe et al. (2008) and LeRoux et al. (2010) found that many possible strategies to improve producer outcomes, specifically revenues, must address how to change the roles, transparency, and competitive market behaviors along the supply chain. Therefore, it is imperative to consider the entire supply chain, even when the outcome of interest is concentrated in one stage (e.g., producers). Price transmission, asymmetry, market power, and other factors that reflect dynamics amongst actors at various stages of the supply chain are important determinants for farmer outcomes, and more broadly, for rural economic development (Rogers and Sexton, 1994; Happe et al., 2008; LeRoux et al., 2010; Saitone and Sexton, 2017; Willingham and Green, 2019; Sexton 2000).

Market Power and Price Setting at the Farm Gate

Consolidation of supply chains over the past several decades has contributed to increased efficiency in the distribution of agricultural goods around the country (Rogers and Sexton, 1994; Azzam and Schroeter, Jr., 1995; Morrison Paul, 2001; Hausman and Leibtag, 2007; Saitone and Sexton, 2017; Willingham and Green, 2019). Commonly, that focus on efficiency unintentionally resulted in the concentration of buying power into fewer agribusinesses. Some have argued consolidation had negative impacts on family farms or independent farms without sufficient negotiating leverage to challenge the requirements of corporate buyers, manufacturers, processors, and distributors (Rogers and Sexton, 1994; Willingham and Green, 2019, Sexton, 2000; Sexton, 2013). Saitone, Sexton, and Sumner (2015) and Saitone and Sexton (2017) found that concentrated market power among agricultural buyers was associated with a decrease in farmer market access and opportunities to fully realize any gains from investments in quality improvement measures or increased consumer demand. Instead, downstream supply chain actors captured a disproportionate share of gains from these changes. Moreover, McBride and Key (2003) point out that costs to farmers associated with participating in more efficient, high-volume supply chain pathways may outweigh potential gains due to costly contracting requirements and other transaction costs. As one example, the United States Department of Agriculture Economic Research Service (USDA ERS) reported concerns on the part of fresh produce shippers that retailers had used their consolidated market power to demand more than their fair share of the retail dollar in the form of fees and special services (Calvin et al., 2001). The literature suggests that increased efficiency and commoditization of agricultural supply chains, frequently accompanied by oligopsony relationships, may be associated with less bargaining power for producers in the marketing of their products.

Data and Empirical Methods

We explored key dynamics among supply chain stage (shipping point price, terminal market price, and retail price) and geographic markets by performing Granger causality and dynamic Houck price asymmetry tests. In this section, we introduce the data used in our analysis, report exploratory and fundamental analytical approaches, and finish by outlining the Granger causality and dynamic Houck hypothesis tests.

We tested non-organic Russet potatoes in 50-lb. cartons (size 70) and 10 5-lb. bags (film bag, mesh film bag, mesh bag, and sacks). Analyzing price transmission and price asymmetry patterns required a compilation of time-series price data for several points along the supply chain, and in our case, multiple states, since we were interested in potential price transmission from Idaho products to Colorado products. We used publicly accessible U.S. Department of Agriculture Agricultural Marketing Service (USDA AMS) data on three price points along the supply chain: shipping point price (a proxy for farm gate price), terminal market price (a proxy for wholesale price), and retail price (see Figure 1) (USDA AMS, 2019). We examined the supply chain dynamics for Colorado and Idaho potatoes—Idaho being Colorado's primary fresh market competitor—in order to draw inferences about potential price transmission and source of price shocks.

Figure 1. Simplified Potato Supply Chain Identifying Available Data Points

Shipping point and terminal market data were available from January 1998 to May 2019, and retail data were available from October 2007 to May 2019. USDA AMS collects data weekly, and to minimize the potential bias from missing data points, we aggregated the data to a monthly average of the available weekly prices. The final aggregated data had no more than four missing monthly observations out of the 257 expected observations per variable (see Table 2). We adjusted prices for inflation using the Consumer Price Index (CPI) and converted nominal prices to real prices on a per pound basis. We confirmed the accuracy of post-conversion AMS prices by comparing them to National Agricultural Statistics Service data. Summary statistics for the final set of variables are available below (see Table 2).

Table 2. Summary Statistics of Price Variables ($/lb.)

Variable	Observations	Mean	St. Dev.	Min.	Max.
Colorado shipping point price for 50-lb. cartons	253	$0.118	$0.038	$0.048	$0.257
Colorado shipping point price for 5-lb. bags	253	$0.080	$0.022	$0.044	$0.160
Terminal market price for 50-lb. cartons	257	$0.358	$0.087	$0.197	$0.697
Terminal market price for 5-lb. bags	255	$0.281	$0.052	$0.184	$0.470
National retail price	140	$0.524	$0.056	$0.413	$0.696
South central retail price	140	$0.448	$0.073	$0.307	$0.705
Idaho shipping point price for 50-lb. cartons	257	$0.128	$0.045	$0.051	$0.272
Idaho shipping point price for 5-lb. bags	257	$0.072	$0.021	$0.040	$0.161

Note: All price data are compiled using the USDA-AMS Custom Price Report Function (U.S. Department of Agriculture, Agricultural Marketing Service, 2019).

Mean Price Comparison

We performed preliminary *t*-tests on select pairs of shipping point prices of interest to see if they were significantly different, and additional analyses were warranted: Colorado and Idaho prices for 50-lb. cartons, Colorado and Idaho prices for 5-lb. bags, and Colorado prices for 50-lb. cartons and 5-lb. bags. In each case, the null hypothesis was that the means of the two price series being compared were equal. Statistically significant differences between Idaho and Colorado shipping point prices justified additional time-series analysis on prices to better understand dynamics across markets. We compared prices for different package sizes from Colorado, as well as Idaho and Colorado prices for different package sizes. *T*-test results are summarized below in Table 3. Colorado shipping point prices for 50-lb. and 5-lb. bags were statistically significantly different at the 1% level. Colorado and Idaho prices for both 50-lb. bags and 5-lb. bags were also significantly different at the 1% level.

Table 3. *T*-Test Results for Different Package Sizes and for Idaho Versus Colorado Shipping Point Prices

Variables	*T*-statistic	*P*-value	Mean Difference
Colorado shipping point price for 50-lb. cartons > Colorado shipping point price for 5-lb. bags	13.50	< 0.01	0.04
Colorado shipping point price for 50-lb. cartons < Idaho shipping point price for 50-lb. cartons	-2.70	0.01	-0.01
Colorado shipping point price for 5-lb. bags > Idaho shipping point price for 5-lb. bags	4.09	< 0.01	0.01

Note: All price data are compiled using the USDA-AMS Custom Price Report function (U.S. Department of Agriculture, Agricultural Marketing Service, 2019).

Fundamental Analysis

Once data were cleaned and adjusted for inflation, we conducted fundamental time-series analyses on each price series to test for stationarity and appropriate lag length. The empirical tests we performed relied on the principle of stationarity in the data, meaning the mean and variance of the data were constant over time (Gujarati and Porter, 2009). In other words, we performed tests to assure the data did not exhibit any trends over time that made behavior of prices fundamentally different at different points in time. We used an Augmented Dickey-Fuller Test with trend and intercept terms to test for stationarity in all eight price series (Gujarati and Porter, 2009). The null hypothesis of the Augmented Dickey-Fuller Test was that a unit root was present in a time series, meaning the data were not stationary.

We chose to address potential lag specification issues by determining appropriate lag length using the ad hoc sequential estimation or “testing up” method described by Gujarati and Porter (2009). Determining appropriate lag length was important because in the distributed lag model that we employed, omitting a lag that had a statistically significant effect would subject the model to omitted variable bias, invalidating the results of hypothesis testing (Gujarati and Porter, 2009). Once we included the appropriate number of lags, identified as two lags for all price series, we could reject the null hypothesis of the Augmented Dickey-Fuller test, indicating stationarity for all price series of interest.

Our process to assure the stationarity requirement within our empirical methods of choice allowed us to deflate prices using the CPI. Without adjusting the price series for inflation, the mean price would likely change over time. There is some debate in the literature about the best approach because deflating prices can change the properties of a time series relative to its nominal counterpart (Peterson and Tomek, 2000). However, some previous studies that used a Granger causality framework deflated the commodity prices used in their analyses (Bradshaw and Orden, 1990; Myint and Bauer, 2010). We felt that the benefits of performing our analysis on a stable series of prices over time outweighed the potential complications of deflation.

Granger Causality

The next step was to perform a Granger causality test among all links of the supply chain (Equations 1-2). The Granger causality test consisted of two "opposite" regressions, F-tests on the variables of interest in each regression, and a subsequent comparison of the resulting *p*-values. For example, if we wanted to examine the relationship between two prices series, price series X and price series Y, we would run the following regressions if the appropriate lag number were 2:

$$y_t = \alpha + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \beta_3 y_{t-1} + \beta_4 y_{t-2} + e \tag{1}$$

$$x_t = \gamma + \delta_1 y_{t-1} + \delta_2 y_{t-2} + \delta_3 x_{t-1} + \delta_4 x_{t-2} + e \tag{2}$$

Note that the contemporaneous independent variable of interest was excluded. The three possible outcomes of the Granger causality test were unidirectional causality, bidirectional causality, or independence. If the *p*-value of one F-test was statistically significant and the other one was not, we concluded unidirectional causality, meaning one variable Granger-caused the other at the 5% significance level. If the *p*-values of both F-tests were statistically significant, we concluded bidirectional causality, meaning both variables Granger-caused each other at the 5% significance level. If the *p*-values of neither F-test were significant, we concluded independence, meaning that statistical tests did not detect a significant Granger-causal relationship at the 5% level.

Price Asymmetry

We used the dynamic Houck Method as presented by Capps Jr. and Sherwell (2005) to examine the data for price asymmetry (Equation 3). We tested several pairs of variables for price "stickiness," or rigidity, using the directionality established by the Granger causality test, with a particular focus on whether that rigidity varied for positive and negative shocks: Colorado shipping point and terminal market prices, Colorado terminal market and national retail prices, Colorado shipping point and national retail prices, and Idaho shipping point and Colorado shipping point prices. All relationships were tested for both 50-lb. cartons and 5-lb. bags.

$$\Delta P_{rt} = \alpha_0 + \textstyle\sum_{i=0}^{M_1} \alpha_{1i} \Delta P^{+}_{ft-i} + \sum_{i=0}^{M_2} \alpha_{2i} \Delta P^{-}_{ft-i} + v_t \text{, where:} \tag{3}$$

ΔP_{rt}=First-differenced retail prices

$\sum_{i=0}^{M_1} \alpha_{1i} \Delta P^{+}_{ft-i}$= Sum of positive lagged first-differenced farmgate price variables

$\sum_{i=0}^{M_2} \alpha_{2i} \Delta P^{-}_{ft-i}$ =Sum of negative lagged first-differenced farmgate price variables

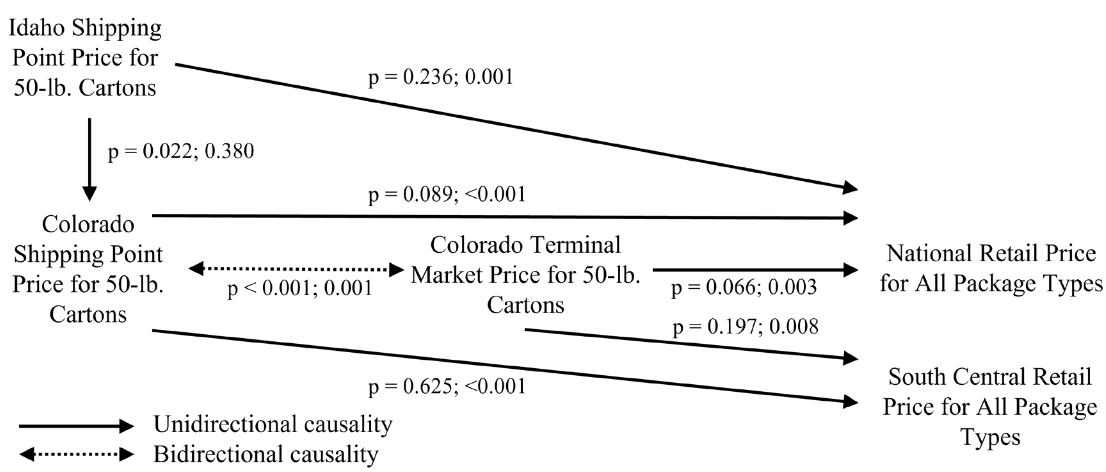
$$H_0: \sum_{i=0}^{M_1} \alpha_{1i} \Delta P^{+}_{ft-i} = \sum_{i=0}^{M_2} \alpha_{2i} \Delta P^{-}_{ft-i}$$

The price asymmetry test informed us about the speed with which prices returned to "normal" pre-shock levels after they are shocked by the market. If certain parts of the supply chain took longer to return to "normalcy," those prices were considered "sticky" or asymmetric.

Price asymmetry is an important characteristic, and we can consider two situations when price stickiness would be detrimental to Colorado producers. First, if prices are asymmetric between Idaho and Colorado producers, and if the market experiences a downturn and prices are low, the Colorado producers' prices may be depressed for longer than would be the case under more sensitive markets. Second, if the market experiences higher-than-average prices driven by a demand shift, lack of price transmission due to price asymmetry means that producers may not be able to capture gains from strong markets as quickly (or at all) as other parts of the supply chain. In short, the market dynamics of the supply chain could hinder the financial performance and viability of producers. It is the second situation that COVID-19 potato markets gave us the opportunity to examine.

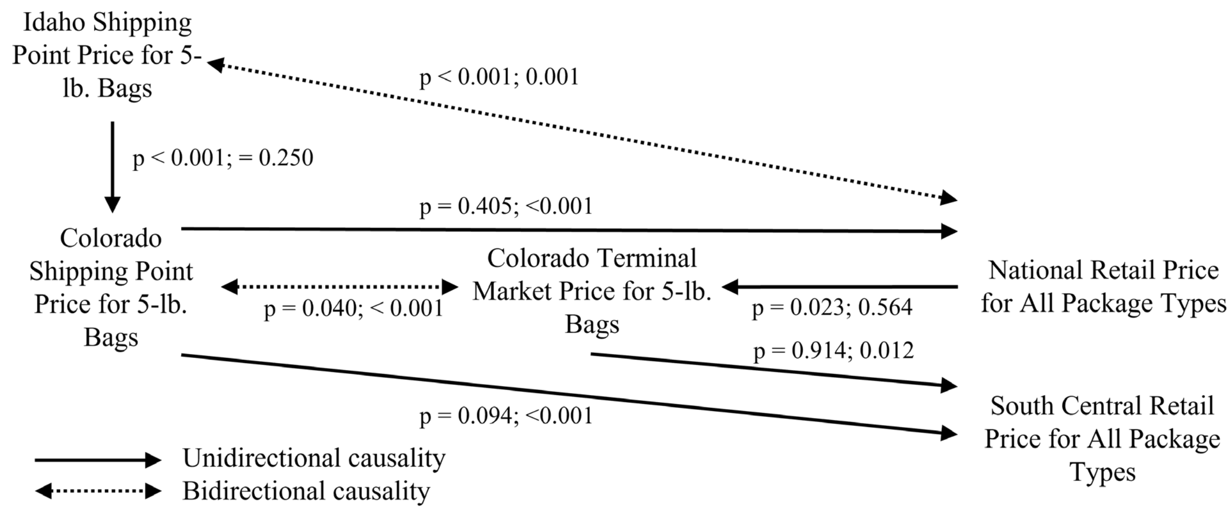
Results

We present the results of the Granger causality test for the 50-lb. carton and 5-lb. bag prices through a visualization of relationships (see Figures 2-3). Note that, in general, the direction of price causality flowed "downstream" from points of production in the supply chain to points closer to final consumption. A key result was that, for both package sizes, Idaho farmgate prices Granger-caused Colorado farmgate prices, as well as national retail prices. In the case of 5-lb. bags, the Idaho-national retail Granger causality result was bi-directional (see Figure 3). Econometric results support anecdotal evidence from Colorado potato farmers that Idaho may have catalyzed price shocks (which may have allowed them to exert some market influence) for fresh potatoes, perhaps because that state produced such a high volume and production share of U.S. potatoes.



Note: *P*-values are provided for F-tests performed on each pair of prices. *P*-values are listed for the F-test on the regression with the "upstream" contemporaneous price variable first as the dependent variable and then as the explanatory variable. Shipping point prices are "upstream" of terminal market prices, which are "upstream" of retail prices. In the case of Idaho versus Colorado prices, *p*-values are listed for the F-test on the regression with the contemporaneous Colorado price variable first as the dependent variable and then as the explanatory variable.

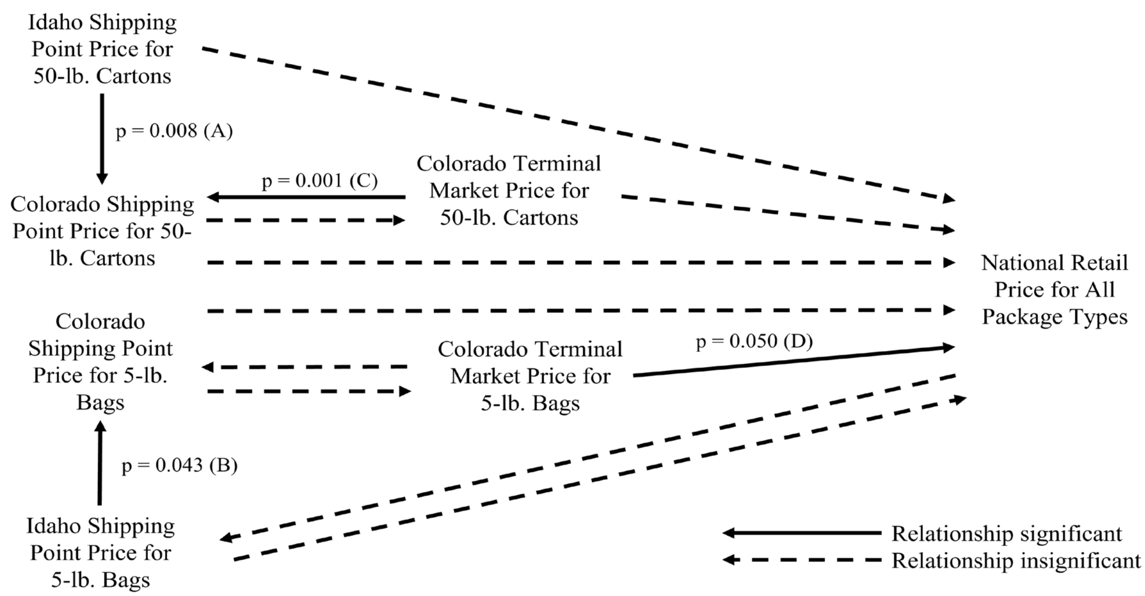
Figure 2. Granger Causality Results for 50-lb. Cartons



Note*:* *P*-values are provided for F-tests performed on each pair of prices. *P*-values are listed for the F-test on the regression with the "upstream" contemporaneous price variable first as the dependent variable and then as the explanatory variable. Shipping point prices are "upstream" of terminal market prices, which are "upstream" of retail prices. In the case of Idaho versus Colorado prices, *p*-values are listed for the F-test on the regression with the contemporaneous Colorado price variable first as the dependent variable and then as the explanatory variable.

Figure 3. Granger Causality Results for 5-lb. Bags

The results of the price asymmetry test indicated that there was price asymmetry between Idaho and Colorado farmgate prices at the 5% level for 5-lb. bags and at the 1% level for 50-lb. cartons (see Figure 4). There was also asymmetry at the 1% level between the Colorado shipping and terminal markets for 50-lb. cartons and asymmetry at the 5% level between Colorado terminal markets for 5-lb. bags and national retail prices. In short, there is evidence to suggest that high-volume production actors (Idaho) and "downstream" supply chain actors (proxied by terminal and retail markets) may be the source of price shocks and affect the speed of price transmissions, motivating a closer look at these dynamics.



Notes: Statistically significant (5% level) asymmetric price relationships are represented by solid lines and labeled with capital letters, and *p*-values are provided. Statistically insignificant asymmetric price relationships are represented by dotted lines. Full regression results for statistically significant asymmetric price relationships are available in Table 4.

Figure 4. Summary of Results of Price Asymmetry Tests

Table 4. Price Asymmetry Regression Results for Colorado Shipping Point Prices (50-lb. Cartons)

Independent Variable	Coefficient (Std. Err.)	T-statistic	*P*-value
Positive Once-lagged First-differenced Idaho Shipping Point Price for 50-lb. Cartons	0.194 (0.010)	1.94	0.053
Positive Twice-lagged First-differenced Idaho Shipping Point Price for 50-lb. Cartons	-0.267 (0.112)	-2.39	0.018
Negative Once-lagged First-differenced Idaho Shipping Point Price for 50-lb. Cartons	0.343 (0.079)	4.35	< 0.001
Negative Twice-lagged First-differenced Idaho Shipping Point Price for 50-lb. Cartons	0.069 (0.078)	0.89	0.374
Constant	0.005 (0.002)	2.31	0.021

Note: Regressed on Idaho Shipping Point Prices for 50-lb. Cartons (relationship (A) from Figure 3). F-statistic = 4.13, *P*-value = 0.043.

Table 5. Price Asymmetry Regression Results for Colorado Shipping Point Prices (5-lb. Bags)

	Coefficient (Std. Err.)	**T-statistic**	***p*-value**
Positive once-lagged first-differenced Idaho Shipping point price for 5-lb. bags	0.394 (0.076)	5.18	< 0.001
Positive twice-lagged first-differenced Idaho Shipping point price for 5-lb. Bags	-0.448 (0.080)	-5.64	< 0.001
Negative once-lagged first-differenced Idaho Shipping point price for 5-lb. bags	0.165 (0.083)	2.00	0.047
Negative twice-lagged first-differenced Idaho Shipping point price for 5-lb. bags	0.075 (0.077)	0.97	0.331
Constant	0.001 (0.001)	1.64	0.101

Note: Regressed on Idaho Shipping Point Prices for 5-lb. Bags (relationship (B) from Figure 3). F-statistic = 7.11, *P*-value = 0.008.

Table 6. Price Asymmetry Results for Colorado Shipping Point Prices (50-lb. Cartons)

Independent Variable	**Coefficient (Std. Err.)**	**T-statistic**	***P*-value**
Positive once-lagged first-differenced Colorado Terminal market price for 50-lb. cartons	<0.001 (0.056)	0.01	0.996
Positive twice-lagged first-differenced Colorado terminal market price for 50-lb. cartons	-0.179 (0.065)	-2.75	0.006
Negative once-lagged first-differenced Colorado terminal market price for 50-lb. cartons	0.154 (0.050)	3.08	0.002
Negative twice-lagged first-differenced Colorado terminal market price for 50-lb. Cartons	0.004 (0.050)	0.08	0.933
Constant	0.005 (0.002)	2.62	0.009

Note: Regressed on Colorado Terminal Market Prices for 50-lb. Cartons (relationship (C) from Figure 3). F-statistic = 11.16, *P*-value = 0.001.

Table 7. Price Asymmetry Regression Results for National Retail Prices

Independent Variable	Coefficient (Std. Err.)	T-statistic	*P*-value
Positive once-lagged first-differenced Colorado Terminal market price for 5-lb. bags	-0.070 (0.173)	-0.41	0.685
Positive twice-lagged first-differenced Colorado terminal market price for 5-lb. bags	-0.310 (0.175)	-1.77	0.079
Negative once-lagged first-differenced Colorado terminal market price for 5-lb. bags	0.183 (0.178)	1.03	0.305
Negative twice-lagged first-differenced Colorado terminal market price for 5-lb. Bags	0.085 (0.173)	0.49	0.623
Constant	0.005 (0.004)	1.32	0.188

Note: Regressed on Colorado terminal market prices for 5-lb. bags (relationship (D) from Figure 3). F-statistic = 3.92, *P*-value = 0.050.

The price asymmetry tests allowed us to understand the nature of price shocks by comparing the magnitude, speed (comparing different lag lengths), and direction of positive and negative price changes at various points in the supply chain (see Tables 4-7). Past work by Capps Jr. and Sherwell (2005) used such results to explore the "balance" between positive and negative adjustments and infer what that meant for the behavior of various supply chain actors, but focusing more on the cumulative effect (see Figure 3) tells a more complete story than any one of the coefficients for a particular market pair-lag length response.

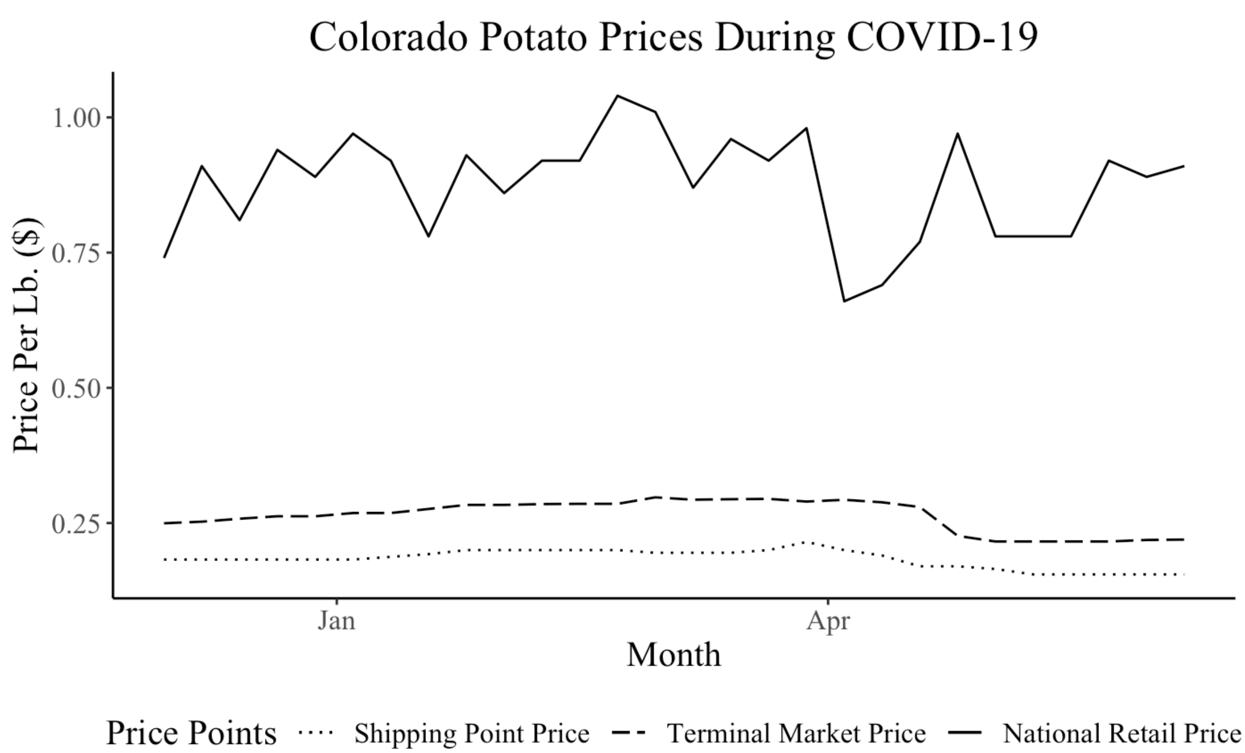
We observed that positive price changes in Idaho shipping point prices were associated with positive effects on Colorado shipping point prices at one lag and negative effects on Colorado shipping point prices at two lags, suggesting a potential correction to an overresponse as time goes on (see Tables 4-7). Negative price changes for 50-lb. cartons at the Idaho shipping point had a highly statistically significant effect on Colorado shipping point prices (see Table 5), so in that part of the commodity potato market, negative price changes at the shipping point in Idaho had a rapid and cumulatively stronger effect on the Colorado shipping point prices.

In addition to geographic effects, we also noted asymmetric transmission across different stages of the supply chain. Notably, we observed that prices transmitted between Colorado shipping point and terminal market prices indicated different speed in price response, as the negative terminal market price shifts had a statistically significant effect when lagged one period, while positive terminal market price shocks took two periods to transmit to shipping points (see Table 6). We interpreted this to mean that negative price changes traveled more quickly than positive price changes from "downstream" terminal market supply chain points back up the supply chain to producers.

Potato Prices during COVID-19

Turning our attention to recent events, the Colorado potato market amidst COVID-19 food supply chain market dynamics is a timely case to explore some of the implications of the price dynamics faced by farmers. If we take a closer look at the COVID-19 lockdown event period of March–May 2020, we see a more nuanced story than is reflected in the strong annual retail gains. We chose to examine nominal prices during this relatively short event period and relied on the assumption that inflationary pressures would not affect the key takeaways in a 7-month snapshot as much as they would over a 20-year period.

Retail prices for potatoes dropped drastically in late March 2020, and subsequently recovered throughout the month of April (see Figure 4). During that same time period, prices at the farmgate briefly and mildly improved and then steadily decreased with no price recovery in line with retail prices (USDA AMS, 2020a). The lag in price transmission and slow regression back to "normal" price levels at the farmgate, once other links of the supply chain had returned to "normal" price levels, was a recent example of price asymmetry. It is difficult to tell to what extent fresh market prices were driven by an oversupply due to diversion from processed potato markets versus structural dynamics of the fresh market itself. And contracts with buyers may have locked in prices for a period of a few months and created rigidity in pricing during an otherwise dynamic period of price fluctuation. But the story of uneven price gains along the supply chain aligns with the historical Granger causality and price asymmetry analyses presented above. The spring 2020 situation of strong demand and prices at the retail level failing to transmit back along the supply chain to the farmer is neither unique nor surprising. Price dynamics were likely due, in part, to the smaller scale and negotiating power of Colorado farms compared to Idaho growers and distributors.



Note*:* Data were compiled using the U.. Department of Agriculture's Custom Price Report tool (U.S. Department of Agriculture, Agricultural Marketing Service 2020a).

Figure 5. Farmgate, Terminal Market, and Retail Prices for Potatoes December 2019–June 2020

The fact that farmers do not appear to capture more revenues when prices strengthen "downstream" in the supply chain indicates that there may be imperfect information flows or competitive conditions in the potato supply chain that make it challenging for producers to capture a higher price in conjunction with their retailer counterparts, particularly if they are not in the industry's highest-volume growing region. It seems that in commodity supply chains, the gains farmers receive when prices are higher than usual are disproportionate to the losses they suffer when prices are unexpectedly low, indicating that they pay for taking the risks inherent in production agriculture but less frequently see the benefits. In short, market or policy interventions may be justified in cases of price asymmetry, and events related to COVID-19 draw attention to where supply chains exhibit such shortcomings.

Conclusions

The goal of this analysis was to examine the dynamics of market price transmission, differential influence among supply chain actors, and price response asymmetry patterns across Colorado and national potato supply chains. Through Granger causality and dynamic Houck price asymmetry tests, we found evidence that commodity potato supply chains in Colorado experience imperfect price transmission and price asymmetry, which may represent higher downside price risk for producers and thwart opportunities for them to capture favorable price movements that occur "downstream" in the supply chain. Our analysis contributes evidence of a specific mechanism (i.e., price transmission along supply chains) that policy makers can target to improve economic outcomes in agriculturally focused communities, as higher or more stable prices would likely improve the resilience of those foodsheds. While many studies have focused on the concentration of market power becoming more prevalent among buyers of agricultural products, our contribution indicates there may also be evidence of concentrated market power across crop production actors within the supply chain, especially when one growing region dominates others in terms of volume produced. Vertical integration between buyers and those larger regions may also play a role here, but such exploration is left to future research.

Potential policy interventions to improve price transmission include expanded contracts with retailers to reduce downside price risk, increased participation in local markets and shortened supply chains, and government-funded efforts to strengthen communication between producers and institutional buyers who want to build marketing relationships in Colorado, such as public schools and buying agents in public buying entities. Potato producers in lower production volume states other than Colorado and producers of other crops located outside the highest-volume production region may also consider implementing these strategies.

The trends during COVID-19 align with findings from historical data analysis and demonstrate the potential role of alternative marketing channels, such as local food markets, as a market intervention to capture the benefits of strong consumer markets. Such marketing opportunities can move a limited volume of products, but they represent an opportunity to rebalance or partially address power dynamics if they are identified in commodity market pricing behavior. Shortening supply chains may also improve producers' chances of capturing higher prices for investments in quality, such as breeding improvements, equipment upgrades, and production practices. Expanded contracts with retailers may be able to provide some price stability as producers experiment with other marketing channels.

Efforts to increase institutional buying are underway not only with potato producers, but with farmers in other key Colorado commodity sectors, such as peaches, wheat, and beef (Jablonski et al., 2019). The Denver Food Vision, adopted by the City of Denver in October 2017, includes a 2030 “Winnable Goal” that 25% of all food purchased by public institutions in Denver will come from Colorado (Hancock, 2017). Local and state policies, such as the Denver Food Vision, that prioritize shortened and localized supply chains in institutional food procurement policies may allow producers to capture more of the proportion of the food dollar that they added value to by investing in quality improvements. Scaling up to the national level, the Good Food Purchasing Program (GFPP) is a nationwide certification program that aims to reorient agri-supply chains toward local and regional purchasing behavior (Center for Good Food Purchasing, 2020). It aims to harness collective purchasing power and leverage it to make food and agriculture practices along the supply chain more ethical, including fairer prices for producers in the local markets (Center for Good Food Purchasing, 2020).

After the supply chain disruptions of COVID-19, many states and food sectors are considering policies to support a more resilient food system, with both an eye toward securing a food supply for their region and to support the economic viability of their producers and food enterprises. Without downplaying the benefits of staying connected to national and global markets, state and local policy leaders and economic development stakeholders are exploring innovative ways to connect agricultural producers, value-added food enterprises, and household and institutional buyers, including new procurement programs such as the GFPP.

Oregon farmer Cory Carman summarized the benefits of local food supply chains during the pandemic, saying, “Everything that made us a little less efficient, a little less competitive before is making us more resilient, more secure, and more responsive now.” (Curry, 2020). In other words, there are notable tradeoffs between highly efficient commodity agri-supply chains and shorter supply chains that support farmer viability, a more favorable risk exposure, and connections to broader local economic development goals in agriculturally dependent regions.

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