AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

The Economics of Plant-Based Milk

Sharon Raszap Skorbiansky, USDA Economic Research Service

sharon.raszap@usda.gov

Monica Saavoss, USDA Animal and Plant Health Inspection Service

monica.saavoss@usda.gov

Kevin M. Camp, Sacramento City College

campk@scc.losrios.edu

Selected Paper prepared for presentation at the 2022 Agricultural & Applied Economics Association Annual Meeting, Anaheim, CA; July 31-August 2

Disclaimer: The findings and conclusions in this article are those of the authors and should not be construed to represent any official USDA or US Government determination or policy.

Introduction

Demand for plant-based beverages in the United States is rising. According to the Plant Based Foods Association, U.S. plant-based milk retail sales reached $2.5 billion in 2020 (PBFA, 2021). While overall retail sales increased, the literature for plant-based beverages remains in its infancy. The objective of this research is to understand the structure and trends of the conventional and organic plant-based milk markets, which are evolving quickly and becoming less concentrated. We use Information Resources, Inc. (IRI) InfoScan scanner price data along with data from USDA-NASS and USDA-FAS to analyze the structure of the plant-based milk market and how input markets affect plant-based milk prices.

Commonly available plant-based beverages include almond milk, soy milk, and coconut milk.[1] Plant-based beverages have quite distinct input markets, and as such are likely subject to some independent supply- and demand-side innovations. For example, almonds are a water-intensive crop grown in California whereas coconuts are grown in tropical climates and imported to the United States. At the same time, substitution between the plant-based beverages and cow's milk is known to occur. Given the lack of knowledge about pricing determination and the interrelationships among these markets, further inspection can help clarify the determinants of prices and the degree to which these markets move together.

We explore the overall price trends for almond, soy, and coconut milks from 2014 to 2020. The premiums for plant-based milks relative to cow's milk have been cited as an impediment to consumers purchasing the products. A better understanding of pricing and the

[1] Oat milk is another recently popular type of plant-based milk, but data in for oat milk is scarce in our sample.

relationships—among these milks, and to the input costs—will provide us with enhanced information on how these markets may scale up, and where economies of scale could decrease premiums in the future. For this purpose, we estimate a seemingly unrelated model, taking the inputs of each plant-based milk into account. Relationships among the plant-based milks and their inputs may vary. Almond milk, for example, may be more influenced by the price for the commodity input than soy milk since nut prices are higher than prices for legumes.

We supplement the analysis with information on each plant-based milk market.

The plant-based beverage literature has mostly explored own- and cross-price elasticities between select beverages and cow's milk.[2] Broadly, this literature has found that the own-price elasticities of cow's, soy, and almond milk are negative and inelastic, meaning that quantities demanded are largely unresponsive to changes in corresponding prices. Meanwhile, the cross-price elasticities for cow–soy and cow–almond are almost zero. In other words, the plant-based markets have limited effects on the cow's milk market. Stewart et al. (2020) modeled the relationship between household purchases of plant-based and cow's milks and found that plant-based milks were not the primary driver of the decline in cow's milk consumption. Using time series data and cointegration analysis, Raszap Skorbiansky, Saavoss, and Stewart (2022) found that prices for soy and almond milk reacted to shocks in cow's milk prices, but cow's milk prices remained unresponsive to shocks prices for plant-based milks. Goldenberg and Frost (2022) summarized market conditions in the plant-based and cow's milk industries, highlighting raw materials, packaging, production, and research and development,

[2] See Raszap Skorbiansky, Saavoss, and Stewart (2022) for a detailed review of the own- and cross-price elasticity literature for cow's and plant-based milks.

overhead, marketing, logistics, and profit as the major cost elements for milk production (plant-based or cow's). The authors concluded that the price differential primarily results from higher blending costs, more expensive packaging, and less streamlined bottling for plant-based milks. Yet there are few other articles documenting plant-based milk price trends or investigating the determinants of plant-based milk prices.

Our preliminary results provide some additional context to how plant-based milk prices trend together and are affected by changes in prices for cow's milk and inputs such as the primary ingredient price (e.g., almonds for almond milk). Our main results show that changes in quantity demanded for the three plant-based milks can be explained by shocks to their own prices, as well as shocks to prices for the other plant-based milks. Given apparent substitutability among the plant-based milks, it is neither surprising for prices to move together, nor for retailers to index the prices to some extent. Additionally, even after accounting for the cross-price effects between plant-based milks, the price for cow's milk remains an important component of pricing for plant-based milks.

Data and Model

Plant-based milks can be considered substitutes for each other. As a result, a change in the price for one is likely to affect that of another. Copeland (2016) estimated the cross-price elasticity between almond and soy milk, finding a negative elasticity between the two in 2011. The mechanism by which substitutability creates these cross-price impacts is simple: as the price for one milk advances, the demand for the (newly relatively cheaper) substitute rises in response, increasing its price as well. Additionally, retailers may index the price for one milk against one another to shield against high price volatility (Raszap Skorbiansky et al., 2022). For those reasons, we are interested in understanding the interrelationships among the different types of plant-based milks, and the effects of key variables on their prices.

We draw weekly almond milk, coconut milk, soy milk, and cow's milk retail prices from the Neilsen/Information Resources Inc. FoodAps grocery store scanner data from 2014 to 2019. These data survey grocery stores, convenience stores, dollar stores, drug stores, and mass-merchandiser/club stores across the county, covering prices for goods sold. In 2012, the data represented 46 percent of all Census grocery stores in the United States (Muth et. al, 2016). Prices for plant-based milks in the survey are the store-level average reported values for 64-ounce containers. The data exclude all other sizes, as 64-ounce containers are the most common size.

To bolster our model, we include the following exogenous variables:

- Primary ingredients of each plant-based milk—we use soybeans for soy milk, coconut for coconut milk, and almonds for almond milk, to account for the effects of raw material costs. Monthly soybean prices come from the USDA National Agricultural Statistics Service Information. Almonds used for almond milk production are for the most part grown domestically in California. However, domestic almond and almond prices are unavailable, so we use the export price for fresh shelled almonds (computed as the share of value over volume). Because coconuts are not domestically grown, we use the monthly import price for fresh coconut in the shell as our proxy for coconut prices. See Figure A1 for commodity prices from 2014 to 2019.

- Weekly gasoline prices—we incorporate all grades and formulations from the Energy Information Administration to account for shipping and manufacturing costs.
- Measure of inflation—we include the Personal Consumption Expenditures Price Index (PCEPI). The index accounts for economy-wide changes in the costs of goods and services that impact both input and general retail prices. The PCEPI is a measure produced by the U.S. Bureau of Economic Analysis. Specifically, it measures the price that individuals living in the United States—or those buying on their behalf—pay for goods and services.

At the weekly level, all plant-based series are stationary, indicated in results from the Augmented Dickey-Fuller and modified Dickey-Fuller t tests. However, aggregating the series with a monthly periodicity introduces unit roots. Byrne et al. (2009) examined aggregation and unit roots, showing that inflation series can be characterized by a unit root process when aggregated, despite that the disaggregated series are stationary. Stationarity has implications for the way we model these series. Therefore, for this paper we choose to keep our endogenous variables at the weekly level, and instead disaggregate our monthly variables (input prices and the PCECPI). We test two methods of disaggregating the monthly series: (1) use the monthly average as the midpoint of each month and use inter- and extrapolation methods to obtain the rest of the weekly series; (2) repeat the monthly series for all 4 weeks of the month. Regardless of the method, results are robust.

Prices for almond, soy, coconut, and cow's milk all fall between \$3 and \$4 per gallon (table 1). Out of the three plant-based milks, coconut milk has historically had the highest prices and the largest standard deviation. In comparison, the price for cow's milk is substantially cheaper. While prices across the milk types have remained mostly stable, the price for almond milk has a clear downward trend (figure 1). The price for the first week of January 2018 was over 10 percent lower than the price for the first week of January 2014. This decrease could relate to the decline in almond prices in recent years, following record crops in California. Almond milk prices aggregated at the yearly level are highly positively correlated with annual almond prices from NASS (ρ=0.9509***).[3] In contrast, the correlation between soy milk and soybean cash prices was negative but not significant. Soybeans are relatively cheap and may not make up a significant amount of the cost structure of soy milk; instead, more of the cost was likely driven by packaging and processing.

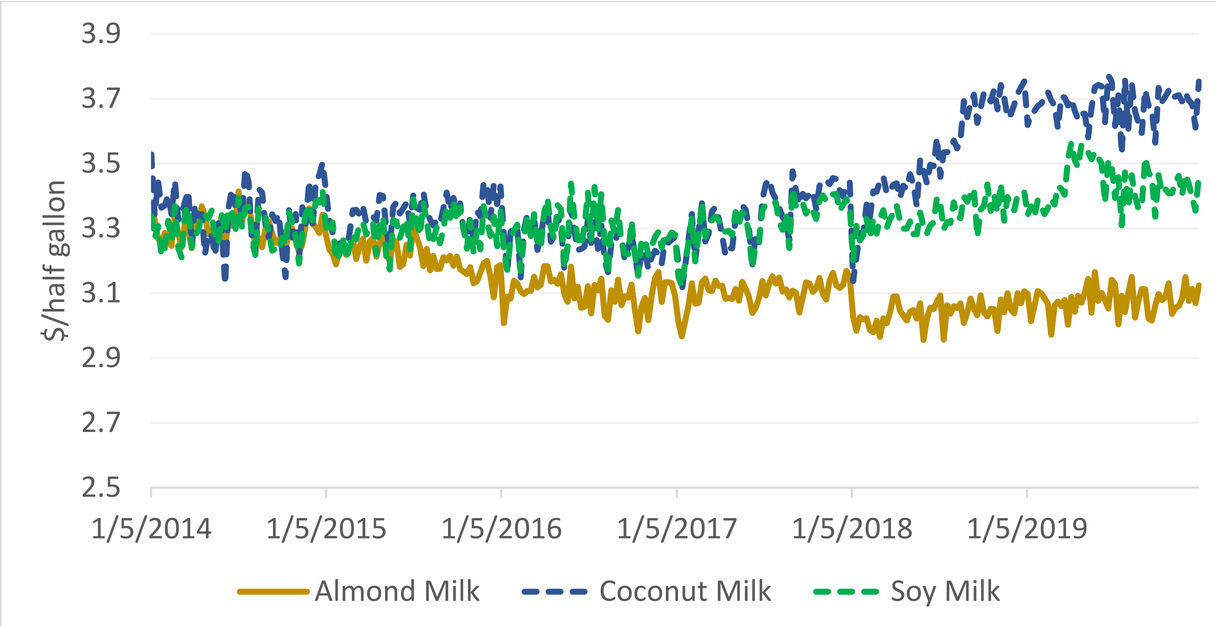
Table 1. Descriptive Statistics

Variable	Average	Standard Deviation	Unit
Prices			
Cow's milk	$1.97	$0.08	Half gallon
Almond milk	$3.12	$0.08	Half gallon
Soy milk	$3.33	$0.07	Half gallon
Coconut milk	$3.42	$0.17	Half gallon
Gasoline	$2.60	$0.35	Gallons
Soybean	$9.35	$0.88	Bushels
Almonds, fresh or dried, in shell	$5.05	$0.68	Metric Ton
Coconut fresh in shell	$810.26	$101.75	Metric Ton
PCEPI	106.02	2.64	Inflation index

Sources: Neilsen/Information Resources Inc. FoodAps; USDA FAS GATS, USDA NASS, Bureau of Labor Statistics; Bureau of Economic Analysis.

[3] NASS only reports almond prices on an annual basis.

Figure 1. Plant-Based Milks Prices



Source: Neilsen/Information Resources Inc. FoodAps

Since the series are stationary, we model their relationship using a vector autoregressive model (VAR), as follows:

$$\boldsymbol{Y}_{i,t} = \boldsymbol{\alpha}_i + \boldsymbol{\beta}_{i,1} \sum_1^p \boldsymbol{Y}_{t-1} + \boldsymbol{\beta}_{ij,1} \sum_1^p \boldsymbol{Y}_{t-1} + \boldsymbol{\beta}_{i,2}\, \boldsymbol{X}_t + \boldsymbol{u}_t$$

$\boldsymbol{Y}_{i,t}$ is the matrix of the logged endogenous variables, the plant-based milk types, *i* = almond milk, soy milk, or coconut milk. The $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$s are coefficients, $\boldsymbol{X}$ is a matrix of logged exogenous variables, and $\boldsymbol{u}$ is the white noise error. The optimal lag chosen for the model is based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Preliminary Results

Information criteria determined optimal lag length of three when modeling the three types of plant-based milks together. We include two lags for cow's milk. Additionally, model selection prefers long-term (6 month) lags for the exogenous variables. Postestimation tests show that our model is stable; all eigenvalues lie inside of the unit circle, satisfying stability conditions, and autocorrelation is rejected.

Note that our results from the vector autoregression model are preliminary (table 2). All variables are correlated with at least one of their past values, meaning past prices can explain current pricing behavior to an extent for each of the three milk types. Furthermore, prices are positively correlated with previous price trends. The 1-period own lag significantly and positively influences almond and coconut milk prices; a 1-percent increase in the lag increases current prices by 0.34 and 0.47 percent, respectively. For soy, the trend appears to be slower. A 1-percent increase in the price for soy milk three weeks ago increases soy milk prices this week by 0.24 percent.

With respect to cross-milk effects, each milk price is influenced by at least one other type of plant-based milk. Almond milk follows the movement of coconut milk. A 1-percent increase in the 1-period lag of coconut is related to a 0.18-percent increase in almond milk's current price. Similarly, soy milk moves with the 1-period lag of coconut milk (a 0.16 percent increase after a 1-percent increase). Interestingly, a 1-period lag of soy milk price appears to correlate negatively with the price for coconut milk; a 1-percent increase in the price for soy milk the previous week leads to a 0.28-percent decrease in the price for coconut milk. When interpreting soy milk results, it bears mentioning that, unlike the almond and coconut milk equations with R-squared values in the range of 0.80–0.90 (meaning that a large portion of their variance is explained by our included regressors), the soy milk model R-squared falls close to 0.50. We address this further in our discussion section.

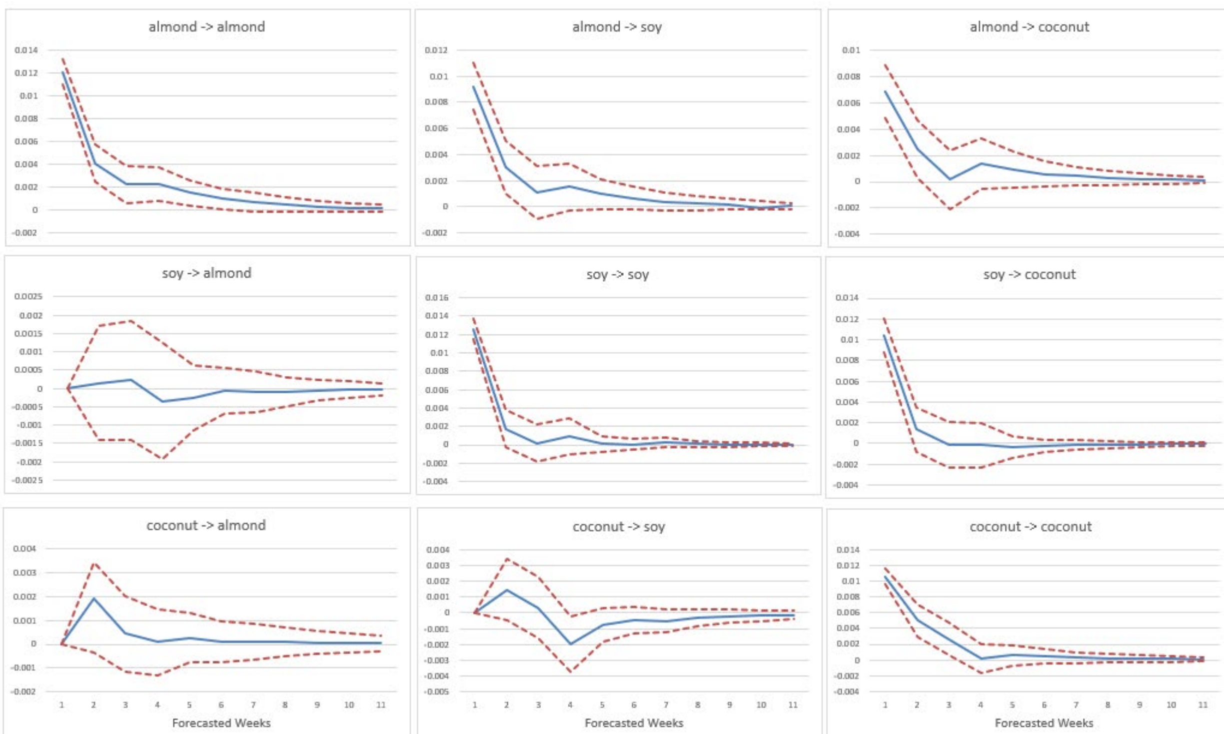
Table 2. Results from Vector Autoregression Model

	Almond Milk	Soy Milk	Coconut Milk
$Almond\ Milk_1$	**0.34******	0.13	0.15
	(0.079)	(0.102)	(0.107)
$Almond\ Milk_2$	0.52	-0.06	-0.05
	(0.084)	(0.084)	(0.091)
$Almond\ Milk_3$	**0.14***	-0.05	-0.04
	(0.076)	(0.082)	(0.089)
$Soy\ Milk_1$	-0.16*	0.12	**-0.28******
	(0.087)	(0.092)	(0.116)
$Soy\ Milk_2$	0.08	0.05	-0.12
	(0.080)	(0.101)	(0.109)
$Soy\ Milk_3$	0.015	**0.24****	0.12
	(0.075)	(0.108)	(0.103)
$Coconut\ Milk_1$	**0.18****	**0.16***	**0.47******
	(0.073)	(0.092)	(0.099)
$Coconut\ Milk_2$	-0.11	0.03	0.16
	(0.073)	(0.092)	(0.100)
$Coconut\ Milk_3$	-0.032	**-0.20****	-0.04
	(0.067)	(0.093)	(0.091)
$Cow's\ Milk_1$	**0.21******	**0.33******	**0.37******
	(0.086)	(0.111)	(0.117)
$Cow's\ Milk_2$	-0.06	-0.11	-0.09
	(0.102)	(0.056)	(0.178)
$Gasoline_{26}$	0.01	0.00	0.01
	(0.013)	(0.023)	(0.025)
$PCEPI_{26}$	-0.47	**1.68******	**3.12******
	(0.294)	(0.471)	(0.495)
$Soybeans_{26}$	-0.01	-0.01	-0.01
	(0.023)	(0.027)	(0.029)
$Coconut_{26}$	0.02	0.01	**-0.03******
	(0.012)	(0.015)	(0.012)
$Almond_{26}$	-0.01	**0.04******	**0.06***
	(0.012)	(0.016)	(0.017)
$year$	**-0.01******	**-0.01****	**-0.16******
	(0.003)	**(0004)**	**(0.017)**
Constant	**19.98******	**10.30******	**18.51****
	(6.004)	**(7.749)**	(8.148)

Notes: ***, **, *, denote significance at the 1%, 5% and 10% level, respectively. The vector autoregression model includes lags for the last 3 periods for each plant-based milk, two lags for cow's milk, a 6-month lag of the exogenous variables (gasoline, PCEPI, soybeans, coconut, and almond) and a year dummy.

To better examine the dynamics between the types of plant-based milks, we look at the orthogonalized impulse-response functions (IRFs) after a price shock (figure 2). An IRF traces the response to a single shock in period zero over a specified time horizon, useful because we can observe not only the immediate impact and magnitude of a shock, but also the return to equilibrium of each series. As previously mentioned, a 1-percent increase in the 1-period lagged price for almond milk causes the price for almond milk to jump up. However, the price for almond milk begins to fall immediately, and by 6 weeks the series is fully back to equilibrium. The IRFs also provide additional context to the interaction between soy and coconut milk. For example, initially a rise in the soy milk price increases the price for coconut milk, but causes a longer-term small decrease in the price for coconut milk.

Figure 2. Weekly Orthogonalized Impulse Response Functions



Notes: Weekly orthogonalized impulse response function results. The solid line in each panel represents the impulse response from a positive 1-standard-deviation shock to the price for the first named commodity. For example, “soy -> coconut” depicts the effect that a positive price shock to soy milk has on the price for coconut milk. Depicted in dashed red lines are the 95-percent confidence intervals.

We are particularly interested in the effect of changes in cow's milk prices on those for plant-based milks. Raszap Skorbiansky et al. (2022) found that a 1-percent increase in the weekly price for cow's milk led to 0.2-percent and 0.15-percent increases in the prices for almond milk and soy milk, respectively, but included neither price dynamics between plant-based milks themselves, nor exogenous regressors. Our results are in line with those previously found. We find that a 1-percent increase in cow's milk in the previous month leads to 0.21-percent and 0.15-percent increases in the prices for almond and soy milk, respectively. Even after accounting for cross-price effects and exogenous variables, the price for cow's milk is an important component of pricing in plant-based milks.

Next, we turn to the effects of gasoline, the PCEPI, and input prices. We find that the price for gasoline does not significantly affect the prices for almond, soy, or coconut milk. However, a different specification of the model (using the repeated monthly series as opposed to the interpolated series) found a small—about 0.07 percent—but significant relationship between the price for gasoline and plant-based milk prices.

A 1-percent increase in the PCEPI half a year prior increases the prices for soy and coconut milk by 1.7 percent and 3.1 percent, respectively. This result is an indication that soy and coconut milk prices are sensitive to inflation, increasing at a faster rate. That is true notwithstanding our inclusion of the PCEPI as a control for other coefficients. Finally, we see very little response from our input prices. An increase in the price for fresh shelled almonds has a small positive impact on soy and coconut milk prices (a 1-percent increase in the price 6 months ago results in increases of 0.04 and 0.06, respectively). A 1-percent increase in the price for coconuts 6 months ago is related to a 0.03 decrease in the current price for coconut milk.

Discussion

We used a vector autoregressive model to detail the relationship between three types of plant-based milks. We incorporated covariates to determine the effect of prices for cow's milk, gasoline, and inputs, as well as general inflation, on the retail prices for these three milks. Our results largely concord with a priori expectations. First, we find that lagged prices for each milk are significantly and positively correlated with future prices. More specifically, shocks to each price are persistent, but quickly decline back to equilibrium as shown by the orthogonalized impulse response functions. Additionally, we find that cow's milk prices are an important component in the plant-based milk equation, even after accounting for other factors. A 1-period lag in cow's milk prices significantly and positively impacts prices for all three types of milks.

The current analysis provides food for thought on the input prices that should be used for studying plant-based milk markets. First, while raw materials can represent a large share of the cost function for plant-based milk production, raw material costs remain lower than those for cow's milk. Relative to cow's milk producers, plant-based counterparts spend a larger portion of their cost on packaging, production, bottling, and research and development, overhead, marketing, and logistics (Goldenberg and Frost, 2021). Bearing in mind that, on average, 85–90 percent of plant-based milk is water by composition, we did not expect raw material being the most significant driver of plant-based milk price movements. Our current analysis uses the NASS soybean price to proxy for the soy milk input, despite that a large percentage of soy milk tends to be organic (our plant-based series do not separate organic from conventional). While organic food-grade soy prices tend to be incredibly thin, our future analysis will include an organic feed soybean price as proxy.

Looking at data from the AMS National Organic Program Organic Integrity Database for organic certified plant-based milk processors, we find that organic soy milk factories were more concentrated on the West Coast, with 35 percent of the facilities based in California. While the United States is a major soybean producer, organic soybeans are mainly imported; the most widely used port for organic soybeans is in San Francisco (Raszap Skorbiansky et al., 2021). For organic almond milk, only 14 percent of processors operated in California—in other words, California almonds are moved to other parts of the country for processing. This would explain the small but positive effect from gasoline prices. Future analysis will incorporate other covariates as well, such as energy costs (as electricity use constitutes a large share of dairy production cost), crude oil prices to proxy for gasoline prices, and desiccated coconut prices to proxy for coconut prices. Finally, we plan to integrate data through 2020, allowing for analysis on whether the COVID-19 pandemic affected the prices and interrelationships.

References

Byrne, Joseph P., Alexandros Kontonikasa, and Alberto Montagnolib. "Unit roots in inflation and aggregation bias." University of Glasgow Discussion Paper 2007-07 (2007).

Copeland, A.M. 2016. Consumer demand for conventional fluid milk and selected dairy alternative beverages in the United States. [Unpublished Master's Thesis]. Texas A&M University.

Goldenberg, Marcle, Simone Frost, "Are plant-based products sold at (un)-justified premiums?" Mintec, Mintec Insight Series, Series 1 The Milk Comparison, 2021.

Muth, Mary K, Megan Sweitzer, Derick Brown, et al. "Understanding IRI Household-Based and Store-Based Scanner Data," Economic Research Service, Technical Bulletin 1942, April 2016.

Plant Based Foods Association (PBFA). 2021. Retail Sales Data. https://www.plantbasedfoods.org/retail-sales-data/ Accessed 9/14/2021.

Raszap Skorbiansky, Sharon, Hayden Stewart, and Monica Saavoss. 2022. "Cow's Milk Still Leads in the United States: The Case of Cow's, Almond, and Soy Milk." *Agricultural Economics*. Forthcoming.

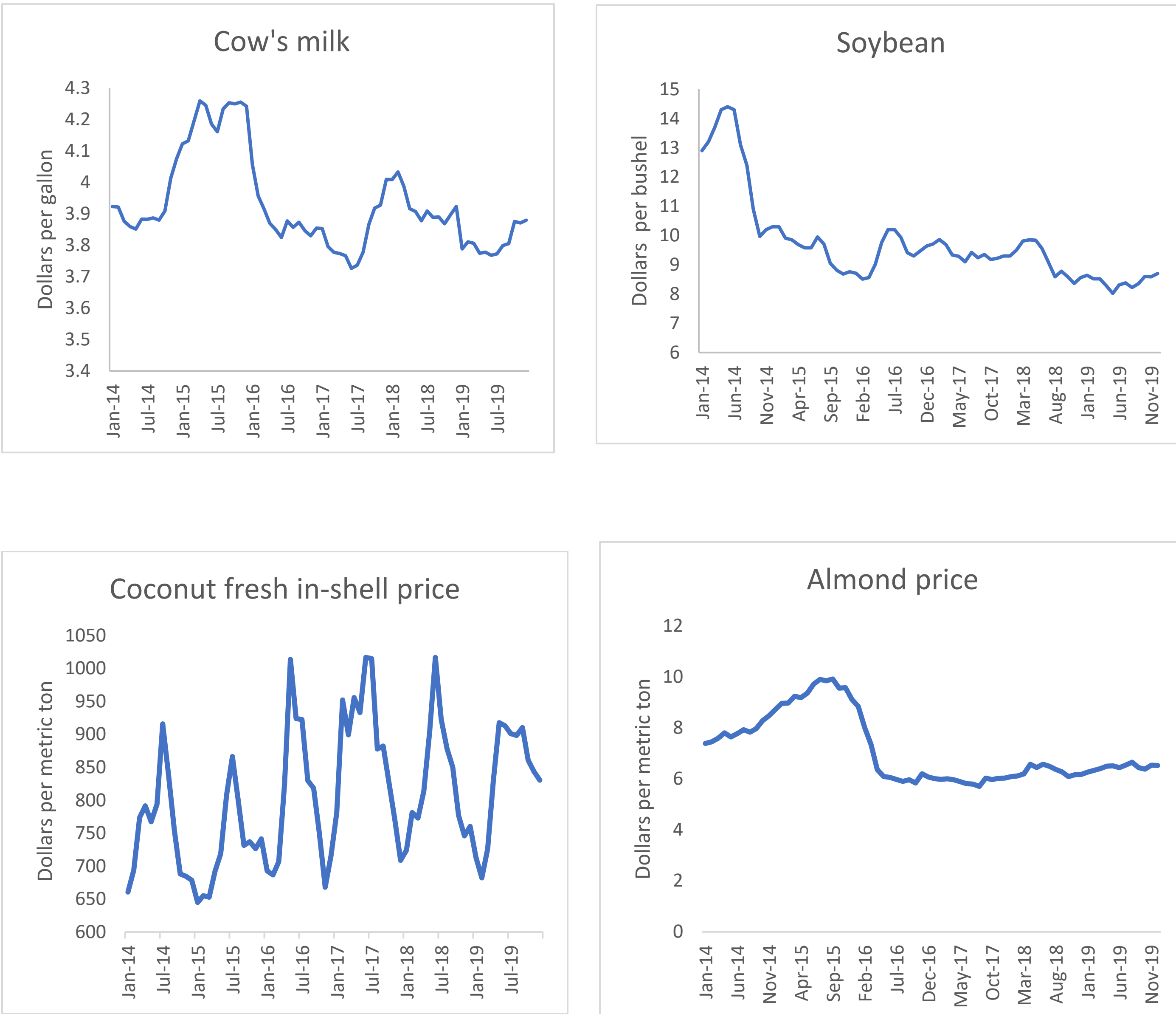
Raszap Skorbiansky, Sharon, Sebastian Molinares, Gustavo Ferreira, and Michael McConell. 2021. U.S. Organic Corn and Soybean Markets. Feed Outlook, FDS-21h. USDA Economic Research Service.

Raszap Skorbiansky, Sharon, and Michael K. Adjemian. "Not All Thin Markets Are Alike: The Case of Organic and Non-genetically Engineered Corn and Soybeans." Journal of Agricultural Economics 72.1 (2021): 117-133.

Stewart, Hayden., Kuchler, Fred, Cessna, Jerry, and Hahn, William. 2020. "Are Plant-Based Analogues Replacing Cow's Milk in the American Diet*? Journal of Agricultural and Applied Economics*, 52(4), 562-579.

Appendix

Figure A1. Cow's milk and Commodity Prices



Sources: Neilsen/Information Resources Inc. FoodAps; USDA FAS GATS, USDA NASS.