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The price discovery in California almond market: new linkages to almond trading with China and India

Pei Xu
Department of Agribusiness, California State University Fresno, Fresno, California, USA, and
Srini Konduru and Todd Lone
California State University Fresno, Fresno, California, USA

Abstract

Purpose – To help farmers better understand market price impacts and international supply-demand situations and to improve their price forecast for the next growing season, this study utilizes monthly trade prices between 2015 and 2022 to China, India and the world marketplace (published by the United State of Department of Agriculture, Global Agricultural Trade System) to analyze the price linkage.

Design/methodology/approach – This study applies both the vector auto-regression (VAR) model and the vector error-correction model to examine the correlation between local California wholesale prices and the export prices to China, India and the world market prices in the same time periods.

Findings – The short-run VAR model results suggest that the local California wholesale price is a major price influencer that determines the following month's trade price. If a price shock happens in the local market, international prices with major trader players of China and India will adjust in the same direction and to a great magnitude. This study also concludes that China has a unidirectional negative impact on the local California wholesale price. In the longer term of more than one year, when the export price to China goes up, the local wholesale almond price will go down. This affirms the existence of a strong market linkage between China and California's almond wholesale market, and the speed of price convergence is relatively rapid.

Originality/value – This study is an original work. It affirms the existence of a strong market linkage between China and California's almond wholesale market, and the speed of price convergence is relatively rapid.

Keywords Almond international trade, Almond wholesale, Almond export to China, Almond export to India, VAR model, VEC model

Paper type Research paper

1. Introduction

California's Central Valley is the largest supplier of almonds in the world, producing 80% of the total output (USDA-FAS, 2022). In recent years, fluctuations in almond prices globally, particularly in the Asian market, have drawn the attention of local growers, international marketers and agricultural policymakers. These stakeholders in the almond industry are eager to understand the global supply and demand dynamics and how this connection influences local wholesale prices, subsequently affecting farm-level economic welfare. Specifically, they want to know if synchronized changes occur in almond prices in overseas markets and how to navigate the challenges and opportunities created locally to maintain profitability (Xu *et al.*, 2022).

The ability to remain profitable in the global marketplace is essential for the success of California almond growers, as they increasingly face price risks and shrinking profit margins

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in the domestic market (Sumner *et al.*, 2015; Fulton *et al.*, 2019). Additionally, almond production has gained notoriety for being a heavy water user, and with rising water costs, these growers are continually seeking local and international market opportunities to implement efficient entry and expansion strategies that enhance or maintain profitability (Krieger, 2015; Belmecheri *et al.*, 2016; Fulton *et al.*, 2019). The COVID-19 pandemic also spurred an additional incentive to explore international opportunities, as health organizations recommended increased consumption of tree nuts to boost immune response and prevent infection. Therefore, rapidly capitalizing on this new international consumption trend, identifying suitable market pricing and developing effective expansion strategies are crucial for the marketing success of California's almonds.

The general interest in analyzing agricultural commodity prices arises from significant economic benefits and policy implications. Theoretically, agricultural studies have highlighted the interconnection between international market prices and regional as well as local prices (Mafimisebi, 2001, 2012; Krieger, 2015; Reisman, 2019, 2020; Xu *et al.*, 2022). In the case of almond trading, if price cointegration exists, both growers and international marketers may react to external price shocks from the global market to take advantage of profitable opportunities or to avoid potential economic losses. Additionally, a simultaneous price increase from multiple major trading partners may put pressure on costs, as it could lead to higher demand and increased production resource costs. Therefore, when examining price integration relationships, it is essential to include more than one trading partner to understand the differences between markets and response strategies. This study compares results drawn from the markets of China, India and the overall world.

Although theoretical models exist and their application to agricultural issues has been extensively explored, research gaps remain in this field, and little has been done to help tree nut producers understand price integration. This study uses a vector auto-regression to examine short-term price linkages, while a vector error correction (VEC) model analyzes long-term price movements. A previous study revealed significant automatic adjustments of local almond wholesale prices in response to increases in USA export prices in the global market (Xu *et al.*, 2022). However, no academic research has investigated price linkages between California and its key trading partners, China and India. It is crucial for California almond stakeholders to determine whether such a price relationship exists and to comprehend the duration of cointegration, particularly whether it indicates short-term linkages or long-term co-movement. With this knowledge, growers can not only take advantage of global market opportunities driven by rising demand for California almonds but also formulate more accurate market price expectations to enhance their resource allocation decisions.

This article uses monthly data from March 2015 to July 2022 to examine the correlation between selected international markets and local wholesale almond prices in California. To isolate the cross-price effect resulting from the price sensitivity of substitute products, the relationship between almond and local walnut prices is also analyzed. Additionally, to investigate the time-varying direction of the impact among China, India and the local wholesale market, a Granger causality test and a Johansen cointegration test are performed. These tests indicate whether a unidirectional causal impact from the global marketplace exists and, if so, the duration of the price integration.

2. Literature review

Although about 50% of California's almonds are consumed domestically, exports have grown significantly and become more valuable to the almond industry in recent years (Sumner *et al.*, 2015). The top five export destinations are China/Hong Kong, Spain, India, Germany and the United Arab Emirates, which together account for about half of all California almond exports (Sumner *et al.*, 2015). The trade tensions that escalated in 2018 between the USA and China severely impacted California almond exports after China raised tariffs on USA almonds to 50%, leading to an approximately one-third decrease in exports to mainland China

(Maldonado, 2019). Almond exports to China continued to decline in 2019, with shipments to both Hong Kong and mainland China falling to 19,000 metric tons, a 25% reduction (Produce Report, 2019). The decrease in exports results from increased tariffs on USA in-shell almonds and kernels – where tariff rates rose from 50 to 60% for both products – and from international competition from Australia, a major USA rival. Australia is geographically closer to China, and its exports to China surged by 36,309 metric tons in 2019, 13 times the previous year's volume, due to the Chinese Government's implementation of a zero tariff (Produce Report, 2019).

Despite China's temporary reduction of food imports due to hiking tariffs, some agricultural marketing experts still believe China provides a remarkable market opportunity for California almonds. The Almond Board of California (ABC) reports pointed out that rapid urbanization and increased purchasing power in China's newly emerging city areas have spurred new demand for high-quality and nutritious foods such as almonds. Thus, the ABC has invested in developing the Chinese market for over 15 years with an average expenditure of $6m yearly. To avoid China's high tariff, the board-initiated transshipments via Vietnam and exploration of alternative Asian markets such as Australia (California Almond Facts: China, 2017).

From the consumer perspective, California almonds have always been Chinese consumers' primary choice, as indicated by market research results and reflected by ABC's efforts to educate the market about the nutritional benefits of California almonds. For example, in 2019, ABC worked with key opinion leaders and China's largest E-commerce platform, T-mall, to promote California almonds to female consumers and to help them understand the nutritional benefits of California almonds (ABC Industry News, 2019). However, little academic research has looked at Chinese consumers' price acceptance of California almonds. One study examined consumers' willingness to pay a price premium for the selected almond attributes of country of origin, brand name, organic production, freshness and taste of the nuts. The study found that Chinese consumer's attitudes towards California almonds differ across regions, with wealthier cities of Guangzhou and Wuhan having the strongest demand for imported USA nuts. In addition, the study demonstrated that all surveyed consumers would consider the country of origin when purchasing almonds as a healthy snack and these consumers showed a positive willingness to pay of $33.35 per pound for California almonds (Xu *et al.*, 2019). Another study demonstrated that China's new-generation consumers, those with greater disposable income, are willing to pay a small price premium for California-grown tree nuts (Xu and Wang, 2014). Specifically, these consumers were in favor of imported California pistachios when the price was set reasonably comparable to that of domestic Chinese alternatives.

India imports most of its almonds from California and was California's largest export market in the 2020/2021 crop year with a total of 362.1 million pounds (Almond Board of California, 2019). To take advantage of lower tariff rates, 95–99% of all almonds are shipped in shell. Before 2019, India charged $0.42/kg (using the January 2023 exchange rate) for California in-shell almonds; however, after 2019, the import duty was $0.49/kg, i.e. a 17% increase. This was the result of the Indian Government removing California almonds from its list of Generalized Scheme of Preferences (GSP) in 2019 due to the USA implementing additional tariffs on Indian steel and aluminum in 2018 and removing India from its list of GSP (Almond Board of California, 2019). In response to this change in USA policy, India purchased more almonds from Australia and charged a lower tariff for Australian almonds (GSP rate of $0.49/kg). Despite the hiked tariffs and competition from Australia, India was still California's largest Asian importer in 2022, with 2,373 total annual shipments (Volza Grow Global, 2022) and a total volume of 500.7 million pounds (USDA Foreign Agricultural Service, 2022).

The ABC has maintained a sustainable marketing program in India for several years. The board believed that consumers' perceptions of the health benefits of eating almonds were driving the middle class to purchase California almonds, and data showed a 9% increase in consumption in 2021 compared to 2020. Additionally, due to the rise of e-commerce and the proliferation of online shopping platforms during the COVID-19 lockdowns, there was a growing number of middle-income consumers from southern and eastern India who switched from cashews to almonds, believing that almonds help build a better immune system (Nut Grower.org, 2020). Furthermore, in 2022, the ABC budgeted $8m to further expand the Indian market, which led to a 16% increase in the number of shipments and enhanced almond consumption among both children and adults (Almond Board of California, 2019).

Both China and India are crucial international markets that require California growers to establish effective export volume and pricing strategies. Increasing tariffs may compel growers to reduce production costs (such as equipment or fertilizer expenses) in order to potentially absorb more of the international shipping costs to remain competitive in trade negotiations. Additionally, the published international market prices serve as vital indicators for local California growers to adjust their resource allocations and develop effective production plans. One published study explored the uncertainty of California wholesale prices caused by ripple effects from the international markets of East Asia, Europe, North America and the global market (Xu *et al.*, 2022). The study demonstrated that the local California wholesale market benefits from world trade prices and Asian market prices. It also indicated that a modest increase in export prices to China can significantly enhance local wholesale prices in the short term, but not in the long run. However, current academic research has not investigated the price relationships among China, India and local California wholesale prices. To assist farmers in understanding market price impacts and international supply-demand dynamics, as well as to refine their price forecasts for the upcoming growing season, this study uses monthly trade prices to China, India and the global market [published by the United State of Department of Agriculture, Global Agricultural Trade System (USDA GATS)] to analyze price connections and proposes policy implications.

3. Research methods

Following Xu *et al.* (2022), this study applies both the VAR model and the vector error-correction (VEC) model to examine the correlation between local California wholesale prices and the export prices to China, India and the world market prices in the same time periods. To take into consideration the wholesale-level substitution impact, the wholesale price of California walnuts was included. Several agricultural economists have applied the VAR and VEC models to analyze price interactions between commodity prices (McKenzie *et al.*, 2002; Zheng *et al.*, 2012; Mafimisebi, 2012; Xu *et al.*, 2022). The models are identified as effective econometric tools to evaluate the magnitude and timing of external price shocks on agricultural prices (Orden and Fackler, 1989).

To conduct the econometric procedure, price series were gathered from the USDA GATS system and local wholesale tree nuts websites. The price series were then log transformed to (1) normalize the bell curve to obtain valid results, (2) correct any skewness in the distribution of prices that arises from the non-negative market prices and (3) interpret differences of the natural logs as econometric returns and thus make the results meaningful to be understood. The vector of prices in logarithmic form is constructed using the format of $P_t = (P_{1t,}P_{2t\ldots}P_{pt})$ and the vector is generated by a k_{th}-order VAR model (Motamed *et al.*, 2008; Xu *et al.*, 2022):

$$P_t = \beta_1 P_{t-1} + \ldots + \beta_k P_{t-k} + \mu + \epsilon_t \tag{1}$$

where:

The vector P_t is the log-transformed local California wholesale prices, export prices to China and India during the selected time horizon, world almond trade prices, and local prices of the alternative nuts (walnuts), μ is a vector of constants and ε_t are the error terms.

First, the Augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1979) is conducted to find out if the first-order difference $((\upharpoonleft_t - \upharpoonleft_{t+1})$ is stationary or not. If the first-order difference of the log-transformed time series are stationary, the conclusion is that the time series are integrated of order one *I(1)*, and the ADF test is then used to find out the degree to which a null hypothesis can be rejected at *I(1)*. If the ADF test shows the time series are non-stationary, then further transformation of the data is needed to turn the data into stationary. For the price data, if the time series deviate without bound and perform a random walk, the conclusion is no long-term market equilibrium exists between the local prices and the trade prices.

The DF test (Dickey and Fuller, 1979) is further assessed to determine the change in price trend over time. If the DF test shows that the price series are (1) nonstationary, (2) first difference is stationary and (3) the price series are integrated of order 1 *I(1)*, then a Johansen test is conducted (Johansen, 1995). If the Johansen results show there is a cointegration relationship between price series, then a VAR model and a VEC model are both applied to further the analysis. Otherwise, only a VAR model is applied.

In this study, the Johansen test revealed cointegration price relationships. Thus, the VAR and VEC models were utilized in the following format (Lubik and Matthes, 2015):

VAR model:

$$lnlocali_t = \sigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{i=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{j=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{m=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \mu_{1t} \quad (2)$$

$$lnworldi_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{i=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \mu_{2t} \quad (3)$$

$$lnChinai_t = \varrho + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \mu_{3t} \quad (4)$$

$$lnIndiai_t = \varsigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_{mi} \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \mu_{4t} \quad (5)$$

$$lnwalnutsi_t = \varsigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_{mi} \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \mu_{5t} \quad (6)$$

VEC model:

$$\Delta lnlocali_t = \sigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{i=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{j=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{m=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + +\lambda_1 ECT_{t-1} + \mu_{1t} \quad (7)$$

$$\Delta lnworldi_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{i=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \lambda_2 ECT_{t-1} + \mu_{2t} \quad (8)$$

$$\Delta lnChinai_t = \varrho + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_m \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \lambda_3 ECT_{t-1} + \mu_{3t} \quad (9)$$

$$\Delta lnIndiai_t = \varsigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_{mi} \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \lambda_4 ECT_{t-1} + \mu_{4t} \quad (10)$$

$$\Delta lnwalnutsi_t = \varsigma + \sum_{i=1}^{k} \beta_i \Delta lnlocali_{t-i} + \sum_{j=1}^{k} \phi_j \Delta lnworldi_{t-j} + \sum_{m=1}^{k} \varphi_{mi} \Delta lnChinai_{t-m} + \sum_{n=1}^{k} \xi_n \Delta lnIndiai_{t-q} + \sum_{m=1}^{k} \rho_h \Delta lnwalnutsi_{t-f} + \lambda_{54} ECT_{t-1} + \mu_{5t} \quad (11)$$

$lnlocali_t = log\ transformed\ almond\ local\ wholesale\ monthly\ price\ series\ 2015-2022;$

$lnworld = log\ transformed\ world\ monthly\ export\ price\ series\ 2015-2022;$

$lnChina = log\ transformed\ monthly\ export\ price\ China\ series\ 2015-2022;$

$lnIndia = log\ transformed\ monthly\ export\ price\ India\ series\ 2015-2022;$

$lnwalnuts = log\ transformed\ walnuts\ local\ wholesale\ monthly\ price\ series\ 2015-2022;$

k = the lag length;

$\beta_i, \phi_j, \varphi_m, \xi_n, \rho_h = short-run\ coefficients\ for\ the\ vector;$

$\mu_{it} = residuals/stochastic\ error\ terms$

The lower triangular matrix on the main diagonal and we define the element of the matrix in row i and column j as λ_t^{ij}:

$\lambda_t^{ij} = speed\ of\ adjustment\ parameter\ with\ a\ negative\ sign;$

To understand the causal relationship between selected price series, a Granger causality test is conducted. If the probability value is smaller than the χ^2 value, we can conclude that there exists a causality relationship between price series.

4. Data

This study uses monthly price data from March 2015 to July 2022 for a total of 89 price points. Local wholesale price data for almonds and walnuts were obtained from an agribusiness management company and local tree nut wholesalers. International trading prices were gathered from the Global Agricultural Trade System (GATS) data set for unit values of exports from the United States of America to China and India as well as to the overall world market. Unit price was calculated by converting unit value in metric tons to price per pound in US dollars for all selected time series. Focusing on the price series after 2015 occurred for three reasons: first, almond trading to China only emerged after 2005, when their gross domestic product started to pick up; second, trading with India only exhibited a quick increase after 2012 (USA Export Data, 2021), and third, local wholesale monthly price data were only available to the researchers after 2015. Thus, monthly data after 2015 provided complete and consistent data for China, India and local wholesale prices. Initial observation of the data for trends revealed no significant fluctuations in price movement, meaning the results are not exaggerated and can be used to draw meaningful conclusions.

Figure 1 depicts price trends for all selected time series. First, there exists a clear correlation between local almond and walnut prices during most of the tested months, except from 2019 to 2020, when local wholesale almond prices show an increase to about \$3.00 per pound, but walnut prices dropped to below \$0.50 per pound. Second, the figure indicates that almond wholesale prices precede the price change of walnuts such that when almond prices dropped from \$3.00 per pound to a little bit above \$2.00 in the first half of 2020, walnut prices followed and fell from about \$1.00 to less than \$0.50 per pound later in 2020 and most of the 2021–2022 production cycle. When almond wholesale prices increased to above \$2.50 in the middle of the 2021–2022 cycle, walnut prices started to rise later in 2021. Third, local wholesale almond

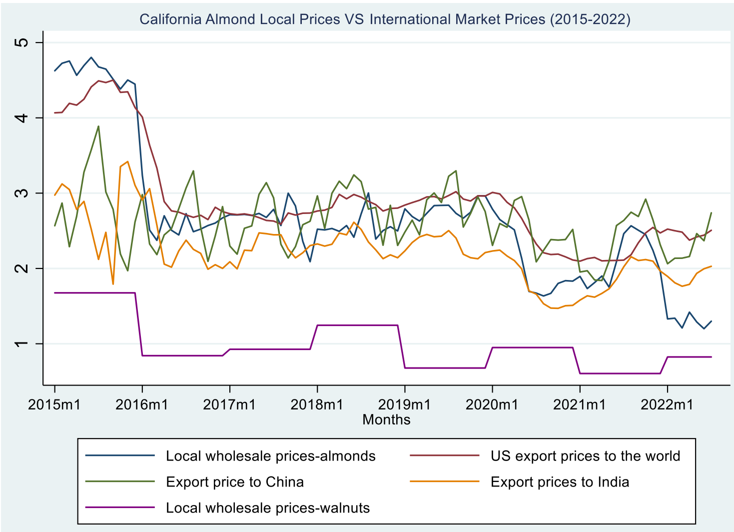

Figure 1. California almond, walnuts wholesale prices vs international market trade prices, 2015–2022 (dollar per pound). Source: Authors' own work

prices present a similar trend as USA export prices to the world for most of the tested months, except in 2022 when USA overall export prices were stable and relatively high at about $2.50 per pound and local wholesale prices dropped to less than $1.50 per pound. Forth, local wholesale almond prices show a similar trend with export prices to China and India. However, the export prices to China were above the prices to India most of the time, making unit profit higher for growers to sell to China except during the production cycle of late 2015–2016. In that year, export prices to India were high to about $3.50 per pound, while those to China were below $2.00 per pound. Finally, after 2016, export prices to China and India show similar movements, but unit prices were higher when selling to China versus India, noting that GATS data reveal a higher volume was shipped to India.

5. Results

To analyze the correlation and directionality of the log-transformed variables on local wholesale almond prices, linear regression analysis was performed. Results demonstrate that local almond prices are positively affected by world export prices (alpha<0.001) and the export price to China (alpha<0.10) and India (alpha<0.10) (see Table 1). The trend in prices for the selected months shows that when export prices to the world market, China and India went up, the local wholesale almond price tended to be higher. The results also confirm the economic principle about substitutable products: the price of local walnuts has a negative impact on almond prices even though the result was not statistically significant. The model's goodness-of-fit was statistically significant with a Prob > *F*-value close to zero.

The ADF test was used to test the unit root of the selected price time series to understand if the series was stationary or not. The results in Table 2 show all five selected price series appear to be nonstationary, such that the statistical mean of these five selected price series is time

Table 1. Regression on transformed variables

Variables	Coefficient	Standard errors	$p>\|t\|$	95% confident intervals	
World prices	1.061	0.188	0.000***	0.686	1.434
China prices	0.230	0.133	0.089*	−0.036	0.495
India prices	0.319	0.164	0.055*	−0.006	0.645
Local walnut prices	−0.003	0.086	0.968	−0.175	0.168

Note(s): Asterisk (***) denotes variables significant at 1% level and (*) denotes variables significant at 10% level
Source(s): Authors' own work

Table 2. Augmented Dickey–Fuller (ADF) test

Prices, lags(4) $n = 79$	$Z(t)$ test Statistics	Mackinnon *p*-values	Interpolated DF 5% critical value	First degree differenced Statistics	Mackinnon *p*-values	Interpolated DF 5% critical value
Local prices	−1.660	0.452	−2.899	−6.542***	0.001	−2.906
World prices	−1.987	0.292	−2.899	−3.505**	0.007	−2.906
China prices	−4.796	0.001	−2.899	−8.115***	0.000	−2.906
India prices	−2.669	0.079		−6.655***		
Local walnuts prices	−2.429	0.134	−2.899	−6.561***	0.000	−2.906

Note(s): Asterisk (***) denotes variables significant at 1% level and (**) denotes variables significant at 5% level
Source(s): Authors' own work

dependent. Thus, a first-order transformation of the log of the series is needed to induce stationarity and differences using a random walk process (Xu *et al.*, 2022). Results in Table 2 reveal the first-order differenced series are stationary, which confirms the time series variables are first integrated of order one I(1). The results affirm that almond market prices tend to be non-stationary, even after log transformation, but converge to be stationary after first-order differentiation (Xu *et al.*, 2022). This result is consistent with other previous findings on food commodity prices in general, where in the short run, local wholesale prices and export prices to different regions of the European and Asian markets tend to be affected by export prices to selected world markets (Alexander and Wyeth, 1994; Ogundare, 1999; Franco, 1999; Chirwa, 2001; Mafimisebi, 2001, 2012; Okoh and Egbon, 2003; Oladapo, 2004). In the longer run, the impact fades due to price inflation, seasonality and other market realities.

The VAR model requires identification of a lag order, and four tests were used to select the appropriate lag order including the prediction error test (final prediction error), Akaike's Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBIC) and the Hannan and Quinn Information Criterion (HQIC). These tests achieve the goals of reducing the mean-square-forecast errors of the VAR model and eliminating the autocorrelated errors of the fitted time series (Lutkepohl, 1993). The results in Table 3 show that a lag of one is optimal because the HQIC and SBIC are the best criteria with lower absolute values than the AIC score, moving the fitted model closer to the true impulse response function than other selected models (Keating, 1995).

Given the selected time series presents an integration of order one *I(1)*, conducting a cointegration test is required to understand the long-run relationship, and Table 4 presents the results of Johansen's cointegration test with maximum eigenvalues and trace statistics. In this test, the null hypothesis (H_0) states there is no cointegration relationship between the price series, and the alternative hypothesis (H_1) states the opposite. The Johansen test was performed using the log-transformed raw variables, and the results are based on the trace statistics using a

Table 3. Selection order criteria results

Lags	LL	LR	d.f	*p*	FPE	AIC	HQIC	SBIC
0	175.951				0	−3.930	−3.873	−3.788
1*	488.608	625.310	25	0.000	0	−10.543	−10.20*	−9.692*
2	518.574	59.933	25	0.000	0	−10.657	−10.029	−9.098
3	539.484	41.820	25	0.019	0	−10.563	−9.650	−8.295
4	571.898	64.826*	25	0.000	0*	−10.733	−9.535	−7.757

Note(s): Asterisk (*) denotes variables significant at 10% level. LL: log likelihood and LR: log likelihood with j lags
Source(s): Authors' own work

Table 4. Johansen cointegration test results

Maximum Rank	Parms	LL	Eigenvalue	Trace Statistic	5% Critical value
0	30.000	466.468		81.217	68.520
1	39.000	482.300	0.297	49.553	47.210
2	46.000	494.242	0.233	25.669*	29.680
3	51.000	502.210	0.162	9.733	15.410
4	54.000	505.815	0.077	2.522	3.760
5	55.000	507.077	0.028		

Note(s): Asterisk (*) denotes variables significant at 10% level
Source(s): Authors' own work

lag of one. At Rank 0, the trace statistics are greater than the 5% critical value. Thus, the null hypothesis of no cointegration is strongly rejected, meaning there is at least one cointegration. At Rank 2, the trace statistics further confirm there are two cointegration relationships, i.e. in the long run, the external shocks to the international market can have a ripple effect on local wholesale almond prices. The Johansen cointegration test confirms there are long-run price relationships among selected price series such that if there are price shocks in the short run, these shocks may affect price movement in the long run, and the price series will converge over time. Assuming there exist both the short-run and long-run price relationships between the selected price series, it is necessary to estimate both the VAR and VEC models with an optimal lag of one to identify the magnitudes of the cointegration.

The monthly data from 2015 to 2022 was used to fit the VAR model, and the results appear in Table 5. Root mean squared error statistics measure the spread of the standard deviation of the residuals from the predicted best fit line, and the results show the spread for each equation is small across the equations such that changes in the independent variables can explain California wholesale prices for up to one month. The small $p > \chi^2$ values indicate the estimated equation is statistically significant at the 1% confidence level. The R-sq value shows that a change in the export price to the world market and to China and India has a strong impact on the local market and can explain 91.7% of the price variation in the local market. The results also suggest there is a smaller external impact on export prices to China, such that only 53.0% of the price variation to China is explained by the change from the world market, California and India. Thus, export prices to China are more likely to be determined by non-market factors such as policy intervention and government tariff rates.

The estimated coefficients for the VAR model for Equations (2) through (6) are shown in Table 6, and the Granger causality results are presented in Table 7. Given the VAR model reports the short-run price interactions, these two tables present the directional impact of the price movement to reveal the causality of price changes. First, California's local wholesale price is statistically and positively affected by last month's local wholesale price such that when a wholesaler determines the price, they will take into consideration last month's wholesale prices of surrounding sellers (alpha = 1%). This result reveals an automatic price adjustment in the local market such that if last month's price is low, the price will adjust to adhere to a similar trend in the following month. It is worth noting the price impact only comes from the previous one month, i.e. there exists a price correlation for a short time of up to one month. Second, last month's price of a substitutable product was also a deterministic factor

Table 5. VAR model percentage results

Equation	Parameters	RMSE	R-sq	χ^2	$p > \chi^2$
Local prices	11	0.097	0.917	978.989	0.000***
World prices	11	0.027	0.983	5202.536	0.000***
China prices	11	0.112	0.530	100.159	0.000***
India prices	11	0.092	0.767	292.610	0.000***
Local walnuts prices	11	0.122	0.857	533.882	0.000***

Sample	03/2015–07/2022	Observations	89
Log likelihood	527.722	AIC	−10.622
FPE	0.000	HQIC	−10.003
Det (Sigma_ml)	0.000	SBIC	−9.058

Note(s): Asterisk (***) denotes variables significant at 1% level. RMSE = Root Mean Square Errors
Source(s): Authors' own work

Table 6. VAR model coefficients estimates

Variables	Period	Estimated coefficients Local almond	World	China	India	Local walnuts
Local almond	1	1.059***	0.489	−0.030	0.122	0.143*
World	1	0.084***	1.296***	−0.004	0.048	0.029
China	1	0.286**	0.349	0.604***	0.121	0.104
India	1	0.091	0.548	0.062	0.599***	−0.078
Local walnuts	1	−0.048	0.463	0.000	0.042	0.876***

Note(s): Asterisk (***) denotes variables significant at 1% level, (**) denotes variables significant at 5% level and (*) denotes variables significant at 10% level
Source(s): Authors' own work

Table 7. The Granger causality results

Equation	Excluded	χ^2	Degree of freedom	Prob > χ^2
Local	World	1.981	2	0.371
	China	0.297	2	0.862
	India	1.742	2	0.419
	Walnuts	2.998	2	0.223
	ALL	8.578	8	0.379
World	Local***	12.201	2	0.002
	China	0.361	2	0.835
	India	3.187	2	0.203
	Walnuts	1.804	2	0.406
	ALL**	19.248	8	0.014
China	Local***	6.318	2	0.042
	World	1.274	2	0.529
	India**	8.502	2	0.014
	Walnuts	1.200	2	0.549
	ALL***	21.134	8	0.007
India	Local	2.220	2	0.33
	World	2.650	2	0.266
	China	2.498	2	0.287
	Walnuts	0.997	2	0.607
	ALL*	14.720	8	0.065
Walnuts	Local	0.894	2	0.64
	World	2.721	2	0.257
	China	3.603	2	0.165
	India	0.991	2	0.609
	ALL	7.869	8	0.446

Note(s): Asterisk (***) denotes variables significant at 1% level, (**) denotes variables significant at 5% level and (*) denotes variables significant at 10% level
Source(s): Authors' own work

such that when the wholesale price of walnuts goes up, the local almond wholesale price tends to increase (alpha = 10%). This finding confirms the economic principle that substitute products create a rivalry, and the pricing of substitute products exhibits a positive impact. Also, the VAR model further confirms this relationship holds for up to a month in the case of wholesale almond pricing when walnuts are the substitute product. Interestingly, last month's wholesale almond price does not have a statistically significant impact on the pricing of local walnuts, making the direction of the impact one-way. This may be explained by the fact that almonds have about twice the per-unit value as walnuts, and thus, the demand is more elastic than its rival product. Third, the world market export price the following month is statistically and positively affected by the previous month's California wholesale prices. Thus, the previous month's price movement in California's local wholesale market leads to price changes in world almond trading. This result is reasonable given California is the world's largest almond producer, producing 10 times the output of its close rival of Spain. The Granger causality test further confirms these results and shows that when one lag is used, the hypothesis that the world price does not have a causal relationship with the California local price cannot be rejected at the 1% confidence level. Lastly, importers of China and India have little power in terms of affecting the world export price, but the California local wholesale price has a statistically significant impact on the export price to China such that if last month's wholesale price in California was high, the export price to China in the following month will adjust to be higher. Again, this result is further affirmed by the Granger test. Interestingly, the Granger test also reveals the export price to India has a positive impact on the export price to China. This seems to prove that when the export price to India in the previous month is high, the export price to China will adjust to become higher. Thus, if international marketers successfully negotiate a higher price to sell to India, it may result in a better price when selling to China in the following month.

Table 7 presents the results of the Granger causality test to further identify the causal direction of price change in California's local almond market. When one lag is used, the hypothesis that California's local wholesale price does not impact the export price to the world market is rejected at the 1% confidence level. Also, the hypothesis that California's local wholesale price does not affect the export price to China is also rejected at the 1% level. Thus, there exists a unidirectional causality impact of California's local wholesale market price on the export prices to China and the overall world marketplace. However, this local price does not show a causality relationship with export prices to India.

Table 8 displays the long-term price impacts derived from both the VEC results and the Johansen normalization results with restrictions applied. It is important to emphasize that because the variables in Table 8 are dependent, the signs must be reversed in interpretation. Consequently, in the long run, the export price to China negatively affects California's local wholesale price, with this result being statistically significant at the 1% level. Additionally, the export price to India positively impacts California's local wholesale market prices (alpha <1%). While the coefficients should not be interpreted as a measure of magnitude, they do indicate that over a longer period, beyond one year, an increase in export prices to China leads to a decrease in local wholesale prices. Conversely, when export prices to India rise, local wholesale prices also increase. This suggests that when trade prices to China are higher, the price margin is not passed down to local California wholesalers, potentially being retained by international marketers to cover trade costs or enhance profits. The findings differ in the case of sales to India, where California's local wholesalers receive a share of the price margin.

Table 9 shows the results of the estimated speed of adjustment parameters and the statistical significance of the cointegration equation. First, the overall model goodness-of-fit indicates

Table 8. Long-term VEC model – price impacts of export markets on California's local wholesale market

	Coefficients	*Z*	$p>\|z\|$	95%	Conf
World	−0.179	−0.120	0.905	−3.119	2.761
China	5.775	5.410	0.000***	3.681	7.868
India	−3.913	−3.000	0.003***	−6.473	−1.353
Walnuts	−0.462	−0.670	0.503	−1.813	0.889

Note(s): Asterisk (***) denotes variables significant at 1% level
Source(s): Authors' own work

Table 9. Long-term VEC model – estimated speed of adjustment parameters

	Coefficients	*Z*	*p*>|*z*|	95%	Conf
Local	−0.001	−0.060	0.951	−0.017	0.016
World	0.002	0.950	0.341	−0.002	0.007
China	−0.059	−6.190	0.000***	−0.078	−0.041
India	0.001	0.130	0.899	−0.016	0.018
Walnuts	0.016	1.510	0.132	−0.005	0.038
χ^2	50.076		$p > \chi^2$		0

Note(s): Asterisk (***) denotes variables significant at 1% level
Source(s): Authors' own work

that the selected time series are statistically significant in explaining the changes in the independent variables ($p > \chi^2 = 0$). Second, in the long run, the export price to China exhibits an adjustment term such that the previous year's (12 months) deviation from long-run equilibrium was corrected within the 12-month period, with a speed of convergence of 5.9%. Third, none of the other speed adjustment coefficients were found to be statistically significant, indicating that the previous year's errors in those selected price series showed a smaller speed of adjustment over the past 12 months. Thus, combining the results from Tables 8 and 9 reveals that export prices to China moved in the opposite direction of local wholesale prices during the 12-month period. However, the price divergence occurred at a relatively high speed of 5.9% until it reached the international market equilibrium level.

6. Conclusions and implications

This study addresses the requests of local California almond growers and marketers to understand the impact of export marketing on producer-level profitability. Almond growers are increasingly concerned about the volatility of food and agricultural commodity prices in recent years and how fluctuations in local and international markets influence farm-level economic returns. With their growing knowledge of international marketing, many growers believe that global supply and demand forces affect the prices they receive locally, meaning a slight increase in trade costs could lead to reduced profit margins at the farm level. This study tested short-run price cointegration and long-term price convergence between the international and local almond markets using VAR and VEC models.

This study is the first to confirm the price linkage between selected export destinations, namely China, India and the global marketplace, as well as their relationship with local California markets. The short-run VAR model results indicate that price movements in the local California wholesale market from the previous month precede price changes in global almond trading. Consequently, the local California wholesale price has become a significant influencer of export pricing, as international marketers referenced last month's California wholesale prices when setting the trade price for the upcoming month. If a price shock occurs in the local market, such as from rising water prices, international prices among major trading players are likely to adjust in the same direction and to a considerable extent. Since California is the world's largest almond supplier, this sensitive price response from the global market aligns with our expectations.

Second, the VAR model suggests that rather than relying heavily on the world market price to determine farm-level wholesale prices, local California wholesalers typically consider their previous month's wholesale prices and those of nearby sellers to set the price paid to growers. These wholesalers focus primarily on the previous month's price instead of using long-term historical prices. Additionally, the price of walnuts influences local almond wholesalers in setting the price paid to growers, such that when walnut prices increase, local almond wholesalers tend to offer more to almond growers. This trend explains why wholesale almond prices are generally twice as high as walnut prices, and consumers are more sensitive to changes in almond prices, often switching to walnuts when almond prices rise.

Third, this study concludes that export prices to China and India have minimal impact on local California wholesale prices in the short run. Instead, there is a unidirectional relationship where local California wholesale prices influence export prices to China and India; if last month's wholesale price in California was high, the export prices to China and India will be higher the following month. Additionally, India's prices positively affect export prices to China, indicating that when the previous month's export price to India is high, the export price to China will also increase the following month. In summary, the California wholesale price serves as the primary influence on prices in the global almond trade, followed by the export price to India, while China appears to have a limited short-run effect on almond prices.

Finally, to analyze high price volatility in the long run, this study initiated a VEC model and found that China has a unidirectional negative impact on the local California wholesale price. In the long term, exceeding one year, when the export price to China increases, the local wholesale almond price decreases. Therefore, when using last year's export price to China to forecast this year's local wholesale price, wholesalers may need to consider implementing a lower price. This outcome can be explained by the fact that if last year's export price to China was high, more almond wholesalers tend to sell to China, resulting in heightened competition and subsequently depressing the price. These export price asymmetries to China differ from the price impact observed when selling to the overall East Asian market, as identified by a previous study (Xu *et al.*, 2022), which did not establish a long-term price integration between California and the East Asian market. The current study identifies a long-term relationship with a negative directional impact and confirms the existence of a strong market linkage over the long run, with the speed of price convergence occurring rapidly within a year. This may relate to the greater bargaining power that China holds in almond trading. It has been documented that China is a significant member of the Regional Comprehensive Economic Partnership Agreement of 2017, which enabled China to import more almonds from its geographically closer trading partner, Australia, thereby increasing its bargaining power when purchasing from California. Consequently, in the long term of one year, China may negotiate a better trade deal and switch to alternative suppliers if the export price from California is not advantageous for them.

This study confirmed a price cointegration between California and two of its largest trading partners, China and India. These price relationships do not just occur occasionally but demonstrate a clear trend over the past seven years. Future research is needed to understand why California almond prices tend to be more responsive to long-term price shocks from the international market while being less sensitive to short-term signals from overseas trading partners. Trading in the agricultural sector typically responds more to short-term shocks from the international market due to seasonality and a short production cycle. However, the almond price linkage is distinct due to its long-term co-movement. Future research may reveal the reasons behind this price movement.

Almond producers, price analysts, international marketers, local investors and policymakers can gain valuable insights from this study. It not only provides details about price movements to help the industry set better price expectations but also assists almond shareholders in developing more effective production and marketing strategies. The increasing integration of commodity markets, especially in the food industry, will continue to foster dependency between countries. Therefore, it is becoming increasingly imperative for food producers, including almond growers, to understand international pricing trends and the factors influencing price movements to stay competitive in the global market.

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Corresponding author
Pei Xu can be contacted at: pxu@mail.fresnostate.edu