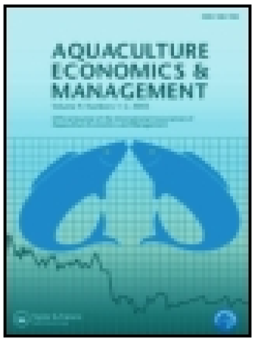

Aquaculture Economics & Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uaqm20

Asymmetric price transmission in a changing food supply chain

Dejene Gizaw , Øystein Myrland & Jinghua Xie

To cite this article: Dejene Gizaw , Øystein Myrland & Jinghua Xie (2020): Asymmetric price transmission in a changing food supply chain, Aquaculture Economics & Management, DOI: 10.1080/13657305.2020.1810172

To link to this article: https://doi.org/10.1080/13657305.2020.1810172

Published online: 26 Aug 2020.

AQUACULTURE ECONOMICS & MANAGEMENT
https://doi.org/10.1080/13657305.2020.1810172

Taylor & Francis
Taylor & Francis Group

Asymmetric price transmission in a changing food supply chain

Dejene Gizaw, Øystein Myrland, and Jinghua Xie

School of Business and Economics, The Arctic University of Norway, Tromso, Norway

ABSTRACT

The farmed salmon supply chain in Europe is changing. There is a growing concentration at intermediary levels in the supply chain and more product differentiation in the market. This means that different price determination processes could apply in various product sub-markets. In this study, price transmission relationships in the salmon value chain were investigated at two different product levels. Specifically, a relatively unprocessed salmon product (fresh salmon) and a more processed product (smoked salmon) were investigated since processing costs might have a significant impact on a vertical price linkage. A threshold cointegration model was applied to estimate the price transmission between the Norwegian export market and the retail markets of France and Spain. The results indicated a price transmission relationship along the fresh salmon chain in both markets; but not along the smoked salmon chains in either market. Furthermore, for the fresh salmon value chain, asymmetric adjustment was observed in both markets.

KEYWORDS
Asymmetry; farmed salmon food chain; price transmission; threshold

Introduction

Due to the recent increased levels of firm concentration at intermediary levels in the supply chain (i.e., wholesalers and retailers); both researchers and the industry have raised concerns about the potential market power of intermediaries in the supply chain of seafood (Fernández-Polanco & Llorente, 2019; Guillen & Franquesa, 2015; Simioni et al., 2013). Intermediaries with market power are likely to employ pricing strategies that result in a relatively complete and rapid pass-through when farm price increases and an incomplete and slow pass-through when farm price decreases. At the same time, due to the increasing development of new product forms and transaction methods, the seafood value chain has become more sophisticated in recent years (Asche et al., 2014; Asche &

CONTACT Dejene Gizaw dejene.g.kidane@uit.no School of Business and Economics, The Arctic University of Norway, Tromso 9037, Norway.

Smith, 2018), and often these innovations require economies of scale or coordination (Anderson et al., 2018; Bergesen & Tveterås, 2019; Kvaløy & Tveteras, 2008).

In the study of price transmission, asymmetric price transmission is of particular interest for the understanding of seafood markets. It is expected that firms' marketing strategies for each product form are different. For instance, in the case of salmon, for more processed products such as smoked salmon, retailers would probably like to be engaged in a long-term contract (usually for six months or longer) to fix the price of raw fish. However, for a less processed product such as fresh salmon, retailers would prefer shorter contracts and more flexible pricing to avoid price risks (Asche et al., 2014; Larsen & Asche, 2011). The diversity of firms' marketing behaviors applied to different product forms might influence the price transmission of the same species along its value chain.[1]

Earlier asymmetric price transmission studies on seafood focused on different species (e.g., salmon, cod) but in an aggregated product form. To the best of our knowledge, there are only two studies in the literature of salmon asymmetric price transmission, Simioni et al. (2013) and Ankamah-Yeboah and Bronnmann (2017), both focusing on aggregate salmon products. However, understanding the different price transmission mechanisms among different salmon products in a disaggregated product level is important. Asche et al. (2014) and Landazuri-Tveteraas et al. (2018) investigated price transmission for a broader set of salmon products in the UK and French retail markets; they showed that the degree of price transmission varied with product forms, and was higher for relatively unprocessed product forms. This indicates that it is important to also consider product form when investigating asymmetric price transmission.

The main objective of this study was to examine the asymmetric price transmission in the value chain of whole fresh salmon and smoked salmon from the export market of Norway to the retail markets of France and Spain. Fresh whole salmon and smoked salmon were selected because fresh whole salmon is an unprocessed salmon product while smoked salmon is one of the most processed salmon products being exported. The reasons for selecting the French and Spanish markets are twofold: France and Spain are the main export markets for Norwegian salmon, and earlier studies on asymmetric price transmission have not covered these two markets. The main method used in this study is the threshold cointegration model with both zero and non-zero threshold. We use the threshold cointegration model because it allows us to investigate the presence of any price asymmetry in the value chain.

The rest of this paper is organized as follows. The next section contains background and a literature review. The theoretical framework of price transmission is presented in the third section. The fourth and fifth sections present the methodology and data used in the study, followed by the empirical results in the sixth section and the concluding remarks in the last section.

Background and literature review

The relationship between commodity prices is an important research area of agricultural product markets. In general, there are two common forms of price transmission, vertical and horizontal price transmission (von Cramon-Taubadel & Meyer, 2004). Studies in vertical price transmission look at the vertical price linkage in a commodity's value chain, while studies in horizontal price transmission look at the price linkage across marketplaces and different commodities and are also known as market integration studies. The theory of derived demand predicts that in the case of two vertically integrated market levels, a price change that occurs at one stage will create an impact on the price of the other stage for at least one input factor. Horizontal price transmission includes spatial and cross-commodity price transmission. The theoretical foundation of spatial price transmission is the spatial arbitrage and consequence of the Law of One Price (LOP), while the basis for cross-price transmission is the substitutability between and complementary relations among commodities (Singh et al., 2015).

The study of price transmission in a commodity's value chain gives insights about market efficiency, and the size and distribution of producer and consumer welfare (von Cramon-Taubadel & Meyer, 2004). As a result, economists who study market integration and market efficiency investigate the price transmission process. Asymmetric price transmission, which implies that increases and decreases in prices at one level of a value chain of a commodity are transmitted at different rates to other levels, has received considerable attention in agricultural commodity value chain research in recent years (Frey & Manera, 2007; Peltzman, 2000; Simioni et al., 2013; von Cramon-Taubadel & Meyer, 2004).

For a long time, asymmetric price transmission was considered a manifestation of market failure in microeconomic theory. Any exogenous shock to a price system, whether a price shock was negative or positive, should result in symmetric adjustments to the long-run market equilibrium (von Cramon-Taubadel & Meyer, 2004; Frey & Manera, 2007). However, in recent literature, it became clear that asymmetric price transmission can arise in a perfectly competitive market and is therefore incorrect to generalize asymmetric price transmission as a manifestation of market failure. Due to the importance of this phenomenon, researchers have also investigated what causes asymmetric price transmission. In the review papers of von Cramon-Taubadel and Meyer (2004) and Frey and Manera (2007), the documented causes are market power, search costs, adjustment costs of food menus, the nature of the agricultural products, and inventory storage.

Although the literature on asymmetric price transmission on seafood is limited, most of the existing studies confirm asymmetric price transmission (e.g., Ankamah-Yeboah & Bronnmann, 2017; Bittmann et al., 2019; Guillen & Franquesa, 2015; Jaffry, 2004; Simioni et al., 2013). This illustrates the fact that in the study of price transmission across market chains of seafood, price asymmetry is important. Without considering asymmetric price transmission, the estimated results of price transmission might be biased.

The salmon supply chain is more developed compared to any other farmed species (Asche et al., 2018). Some of the reasons for this level of sophistication are the development of diverse salmon product forms, the presence of long-run contracts, and salmon futures markets (Asche et al., 2014; Asche & Smith, 2018). The development of the salmon supply chain has resulted in increased interest in price transmission studies. A few studies have investigated the relationship between different levels in the supply chain. Larsen and Kinnucan (2009) found that price transmission for fresh salmon is complete. Asche et al. (2014) obtained a similar result for fresh salmon but found incomplete price transmission for smoked salmon. Out of 17 retail salmon products examined, Landazuri-Tveteraas et al. (2018) found full-price transmission in only one product value chain. Furthermore, their results showed that price transmission to retail prices decreased, as more processing was involved. As we have discussed above, there are only two studies that investigated price asymmetry along the salmon supply chain (i.e., Ankamah-Yeboah & Bronnmann, 2017; Simioni et al., 2013), but on aggregated product prices. Their conclusion of asymmetric price transmission might not hold when disaggregated data is used.

The European Union (EU) is the world's largest market for farmed salmon, with rapid demand growth (Braekkan et al., 2018). Norway is the primary supplier in the region (Asche et al., 2014; Guillotreau et al., 2005). For instance, Norway exported one million tonnes of salmon in 2017, of which 80% was exported to the EU (EUMOFA, 2017). The largest single markets for Norwegian salmon in 2017 were Poland (18%), France (13%), and Denmark (12%). Poland and Denmark are the hub markets where salmon is reexported to other countries within the EU. For the other European markets, Spain, the UK, the Netherlands, and Italy had market shares of 9%, 8%, 8%, and 7%, respectively.

Theoretical framework of price transmission

Following Asche, Menezes, et al. (2007) and Larsen and Kinnucan (2009), for a specific product in an international marketing channel, the fundamental relationship between retail level and farm level prices and the exchange rate variable can be given as follows:

$$P_R^f = f\left(P_F^f,\ P_C^f\right)\ \text{(International Price Linkage Relation)} \tag{1}$$

$$P_F^f = P_F^d.Z\ \text{(Exchange Rate Identity)} \tag{2}$$

P_R^f denotes the retail level price of a given product in a foreign market measured in the foreign currency, P_F^f is the farm price in the domestic market but measured in the foreign-currency, and P_C^f is the cost necessary to convert the farm product into a retail product (e.g., marketing services, transportation costs, and menu costs) measured in the foreign currency. P_F^d is the farm price in the domestic market measured in the domestic currency, and Z is the bilateral exchange rate expressed as units of foreign currency per unit of domestic currency.

Taking the logarithmic total differential of Equations (1) and (2) yields:

$$d\ lnP_R^f = B_F\ d\ lnP_F^f + B_C\ d\ lnP_C^f \tag{3}$$

$$d\ lnP_F^f = d\ lnP_F^d + d\ lnZ \tag{4}$$

where B_F is the farm-retail international price transmission elasticity, with both prices expressed in the same currency, and B_C is the cost price transmission elasticity when costs are priced in the foreign currency. Substituting Equation (4) into Equation (3), we get the following:

$$d\ lnP_R^f = B_F\ d\ lnP_F^d + B_Z\ d\ lnZ + B_C\ d\ lnP_C^f \tag{5}$$

In Equation (5), if the market is efficient such that changes in domestic exchange rates are perfectly reflected in foreign prices, then $B_F = B_Z$. Assuming a perfect pass-through of the exchange rate in the value chain of salmon in this study, Equation (5) reduces to:

$$d\ lnP_R^f = B_F\ d\ ln\ \tilde{P}_F^d + B_C\ d\ lnP_C^f \tag{6}$$

where $\tilde{P}_F^d$ $(= P_F^d * Z)$ is the farm price in the domestic market measured in the foreign currency. Moreover, in most empirical analyses of a supply chain, P_C^f is assumed to be constant so that it can be included in the constant term.[2] Taking this assumption in our case and appending time subscripts to the variable and incorporating a random error term (μ_t) after simplifying Equation (6), the long-run equilibrium relationship between the upstream and the downstream market stages can be given by:

$$lnP_{R,t}^f = \varphi + B_F \ln P_{F,t}^d + \mu_t \tag{7}$$

where $P_{R,t}^f$ as discussed denotes the retail level price at time t expressed in foreign currency, which is Euro/kg in our study. Different from above, $P_{F,t}^d$

now denotes the farm price at time t expressed in foreign currency units. Estimating Equation (7) creates a simultaneity problem because economic theory does not indicate the direction of the relationships. However, in several studies, the direction of causality is identified based on certain characteristics of the market (Kinnucan & Forker, 1987). It is usually assumed that the price is established at the farm level and it flows forward to the retail level market (Kinnucan & Forker, 1987). A common explanation for the choice has been that supply shock is more common than demand shocks and that retailers follow a fixed markup pricing. Another common approach followed by several other researchers and which is used in this study is to identify the causal market by employing exogeneity tests.

Methodology

Our empirical procedure comprises a series of tests and model estimations. First, we performed a stationarity test using the Augmented Dickey–Fuller (ADF) test (Dickey & Fuller, 1981) on individual price series. Then, we estimated the threshold cointegration models to investigate the presence of possible asymmetric price adjustment between the upstream and downstream prices. For price pairs demonstrating asymmetric adjustment, we estimated the threshold asymmetric error correction model.

Due to the presence of adjustment costs (e.g., menu costs), economic agents often react to a price change only when deviations from the equilibrium exceed a certain critical limit, which is called a threshold value (Blake & Fomby, 1997; Enders & Granger, 1998). The behavior of agents leads to asymmetric price adjustment in a commodity value chain. Therefore, to study price transmission in a commodity value chain, using models that allow asymmetric adjustment is often necessary. In this study, we used the threshold cointegration proposed by Enders and Siklos (2001) because it allowed us to investigate the presence of possible asymmetric price adjustment between the upstream and downstream markets.

The threshold cointegration approach proposed by Enders and Siklos (2001) is an extension of the Engle and Granger (1987) procedure. We start first with a discussion of the Engle-Granger procedure. The procedure relies on the ordinary least squares (OLS) estimate of ρ in the following regression Equation (8):

$$\Delta\mu_t = \rho\mu_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta\mu_{t-i} + \upsilon_t \tag{8}$$

where μ_t is the estimated regression residuals extracted from the price linkage Equation (7), and υ_t is a white-noise disturbance. Equation (8) implies an assumption of symmetric price adjustment since ρ is estimated as an average effect of the lagged error term μ_{t-1} regardless of whether μ_{t-1} is positive or negative. Taking the asymmetry into consideration, Enders and Siklos (2001) extended the Engle-Granger procedure to a Threshold Autoregressive (TAR) model given by Equation (9):

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \sum_{i=1}^{p}\gamma_i\Delta\mu_{t-i} + \upsilon_t \tag{9}$$

I_t is an indicator variable defined by Equation (10):

$$I_t = \begin{cases} 1 \ \ if \ \ \mu_{t-1} \geq \tau \\ 0 \ \ if \ \ \mu_{t-1} < \tau \end{cases} \tag{10}$$

where τ is a threshold value and, I_t is equal to 1 when μ_{t-1} is larger than the threshold value, otherwise it is 0. The adjustment is modeled by $\rho_1\mu_{t-1}$, if μ_{t-1} is above the threshold and by the term $\rho_2\mu_{t-1}$, if μ_{t-1} is below the threshold. The model in Equation (9) is known as a Momentum-Threshold Autoregressive (M-TAR) model when I_t in the above Equation (10) is replaced by its differences $\Delta\mu_{t-1}$.

$$I_t = \begin{cases} 1 \ \ if \ \ \Delta\mu_{t-1} \geq \tau \\ 0 \ \ if \ \ \Delta\mu_{t-1} < \tau \end{cases} \tag{11}$$

Furthermore, TAR and M-TAR models are different in that the TAR model can capture a deep cycle process if, for instance, the variation above the threshold level is more prolonged than below the threshold level. Meanwhile, the M-TAR is capable of capturing sharp sequential movement and is especially valuable when the series exhibits more momentum in one direction than the other (Enders & Siklos, 2001).

As indicated by Equations (8) and (9), the Engle-Granger procedure is a special case of Enders and Siklos's test when $\rho_1 = \rho_2$. From Equation (9), cointegration exists if the hypothesis $\rho_1 = \rho_2 = 0$ is rejected. This leads to the test of symmetry $\rho_1 = \rho_2$. If both hypotheses are rejected, the process is called threshold cointegration. According to Enders and Siklos (2001), the cointegration test follows a nonstandard F-test; hence, results are compared to the critical values given in Enders and Siklos (2001). The symmetry test, however, is a standard F-test. Following the procedure proposed by Chan (1993), the best threshold value is used. The estimated residuals (in the case of the TAR model) or the first differences of the estimated residuals (in the case of the M-TAR model) is first sorted in ascending order, then 15% of the largest and smallest values are excluded before the best threshold value that yields the lowest residual sum of squares is selected.

The Granger representation theorem (Engle & Granger, 1987) states that a vector error correction model (VECM) can be estimated when variables are cointegrated. However, a conventional VECM cannot consider the asymmetric transmission issue since the error term has not been decomposed into positive and negative components. In this study, by following Blake and Fomby (1997) and Enders and Granger (1998), we extended the conventional VECM by decomposing the error correction terms into positive and negative components, which allowed us to analyze the asymmetric effects on the dynamic behavior of the prices as presented by Equations (12) and (13).

In Equations (12) and (13), the parameters β_2^+ and δ_2^+ capture the adjustment of the retail and export level prices, respectively, when the equilibrium deviation is above the threshold value. On the other hand, the parameters β_2^- and δ_2^- capture the adjustment of the retail and export prices, respectively, when the equilibrium deviation is below the threshold value. In the empirical results section, we call the estimated model of Equation (12) the retail equation because the dependent variable is the retail level price (i.e., $\Delta lnP_{R,t}^f$), while we call the estimated model of Equation (13) the export equation because the dependent variable is the export level price (i.e., $\Delta lnP_{F,t}^d$).

$$\Delta lnP_{R,t}^f = \beta_1 + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + \sum_{m=1}^{L_1} \delta_m \Delta lnP_{R,t-m}^f + \sum_{n=1}^{L_2} \delta_n \Delta lnP_{F,t-n}^d + \varepsilon_{R,t} \tag{12}$$

$$\Delta lnP_{F,t}^d = \delta_1 + \delta_2^+ ECT_{t-1}^+ + \delta_2^- ECT_{t-1}^- + \sum_{m=1}^{K_1} \alpha_m \Delta lnP_{R,t-m}^f + \sum_{n=1}^{K_2} \alpha_n \Delta lnP_{F,\ t-n}^d + \varepsilon_{F,t} \tag{13}$$

where L_1, L_2, K_1 and K_2 are the lag-lengths to be selected by the Schwarz information criteria (SC). The error correction terms ECT_{t-1}^+ and ECT_{t-1}^+ in Equations (12) and (13) in the case of the M-TAR model can be expressed as:

$$ECT_{t-1}^+ = I_t(\Delta\mu_{t-1} \geq \tau)\left(ln\ P_{R,t-1}^f - \varphi - B_F ln\ P_{F,t-1}^d\right)$$

and

$$ECT_{t-1}^- = I_t(\Delta\mu_{t-1} < \tau)(ln\ P_{R,t-1}^f - \varphi - B_F ln\ P_{F,t-1}^d)$$

Data

Retail prices were used as the prices in downstream markets and export price was used to represent the upstream market (the farm) price since the

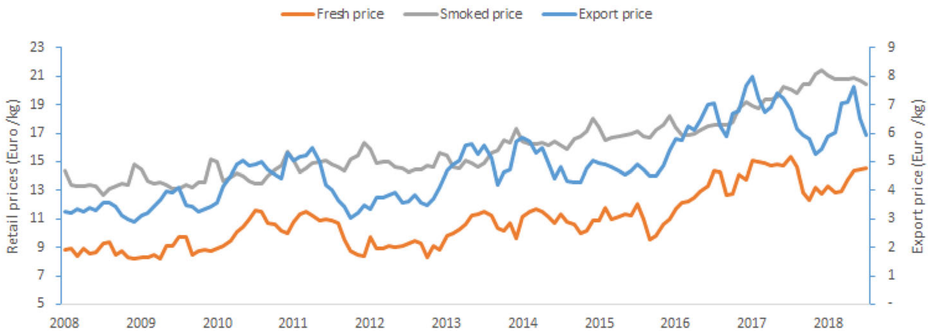

Figure 1. French retail fresh and smoked salmon prices & Norwegian export price. Source: Europanel and Statistics Norway.

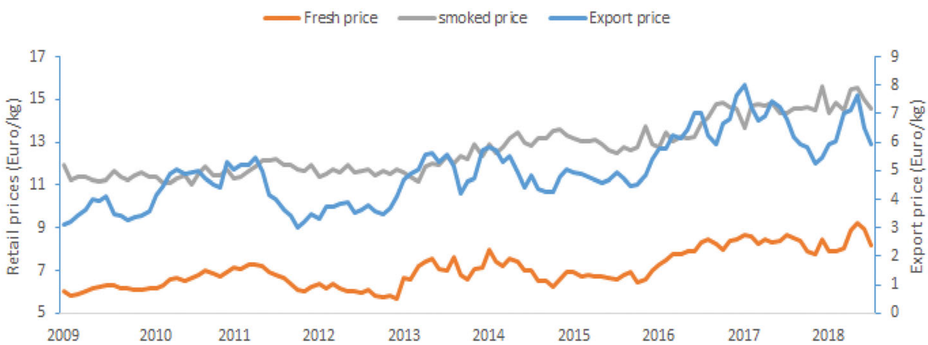

Figure 2. Spanish retail fresh and smoked salmon prices & Norwegian export price. Source: Europanel and Statistics Norway.

export price of the Norwegian whole fresh salmon is quite close to farm gate price with a price transmission elasticity of 1 (Asche et al., 2014). The sample period were January 2008 to December 2018 in the case of the French market, and January 2009 to December 2018 for the Spanish market; periods were selected based on the availability of the data. The retail salmon data was obtained from Europanel (2018) via the Norwegian Seafood Council (NSC) and the export prices were obtained from Statistics Norway (SSB) via NSC. Exchange rates were directly obtained from SSB. Table A1 in the appendix reports the summary of the prices.

Figure 1 illustrates the retail prices for fresh and smoked salmon in the French market together with the Norwegian export price. Figure 2 shows the Spanish market. The figures suggest that for fresh whole salmon, the retail price and export price follow each other closely in both the French and Spanish markets. In contrast, the retail price of smoked salmon and the export price of Norwegian fresh whole salmon behave differently in both markets. As a result, we expect the price transmission along the

Table 1. ADF test.

Prices	France		Spain	
	Constant and trend	First differences	Constant and trend	First differences
Export	−3.35 (1)	−9.286 (0)**	−3.09 (1)	−8.79 (0)**
Fresh salmon	−3.13 (1)	−11.78 (0)**	−2.69 (1)	−10.87 (0)**
Smoked salmon	−2.41 (12)	−1.9 (11)*	−3.28 (1)	−15.82 (0)**

Note. Asterisks ** and * denote significance at 1% and 5%, respectively. Price series are expressed in logarithm. Numbers of lags in ADF tests in parenthesis.

supply chain of fresh salmon and smoked salmon to show different relationships in each market.

Estimated results

The time series properties of the prices were investigated individually using the Augmented Dickey-Fuller (ADF) test, and in line with the general literature all processes were found to be non-stationary in levels but stationary in their first differences. Table 1 reports the results of the unit root tests.

The estimated residuals from Equation (7) in each product chain and market were estimated as a threshold model using both zero threshold ($\tau = 0$) and nonzero threshold ($\tau \neq 0$) values. To save space, we only report the results of the best-selected model based on the value of the Akaike information criterion (AIC). Table 2 reports the results of the selected models.[3]

The estimated statistics for cointegration (i.e., $\rho_1 = \rho_2 = 0$) suggest that the upstream and the downstream prices are cointegrated in the value chain of fresh salmon in both markets, but not cointegrated in the value chain of smoked salmon in either market. For fresh salmon, the estimated F-statistics for the symmetry test ($\rho_1 = \rho_2$) suggest the presence of asymmetric price transmission between the upstream and downstream prices in both markets. This implies that biased results may be obtained by reporting the equilibrium adjustment relationships between the upstream and downstream markets following the results from, for instance, the widely used Johansen cointegration approach in the literature, which assumes symmetric adjustment.

In general, the estimates of ρ_1 and ρ_2 were significantly different from zero and satisfied the conditions of convergence (i.e., $\rho_1 < 0$, $\rho_2 < 0$, and $(1 + \rho_1)(1 + \rho_2) < 1$). The estimate ρ_1 is the retail price adjustment when the retail price is "too high" with respect to the export price (i.e., when the margin is above its long-run equilibrium value), while the estimate ρ_2 is the adjustment when the retail price is "too low" with respect to the export price (i.e., when the margin is below its long-run equilibrium

Table 2. Consistent threshold cointegration and asymmetry test in France and Spain.

	ρ_1	ρ_2	γ_1	γ_2	τ	AIC	$\rho_1 = \rho_2 = 0$[1].	$\rho_1 = \rho_2$[2]	Model
France									
Fresh	−0.35 (−3.86)	−0.84 (−5.65)	NA	NA	−0.037	−371.92	23.43	8.11 (0.005)	MTAR
Smoked	−0.16 (−2.56)	−0.24 (−3.52)	0.25 (2.81)	−0.16 (1.78)	−0.097	−268.61	5.52	0.948 (0.332)	TAR
Spain									
Fresh	−0.20 (−2.10)	−0.69 (−4.73)	−0.16 (−1.77)	NA	−0.04	−425.09	13.96	8.59 (0.004)	MTAR
Smoked	−0.25 (−2.49)	−0.10 (−1.25)	−0.02 (−0.21)	0.20 (2.14)	−0.07	−423.99	4.21	1.95 (0.165)	TAR

Notes. Numbers in brackets in columns from (1) to (4) are the t-statistics. [1] Entries in this column are the sample values of the M-TAR & TAR-statistics. [2] Entries in this column are the sample *F*-statistics for $\rho_1 = \rho_2$ & significance levels are in parentheses below. Enders and Siklos (2001) critical values for M-TAR for two variables and no lagged are approx. 5.45, 6.51 and 8.78 for 10%, 5% and 1%, respectively. Critical values of M-TAR for two variables and one lagged are approx. 5.47, 6.51 and 8.85 for 10%, 5% and 1%, respectively. Critical values of TAR for two variables and two lagged are approx. 5.80, 6.82, and 9.04 for 10%, 5% and 1%, respectively. τ represents the threshold value, and γ_1 and γ_2 are parameters included in the models to account for autocorrelation.

Table 3. Estimates of asymmetric error correction models in the fresh salmon value chain.

	France		Spain	
Independent variables	$\Delta lnP^f_{R,t}$	$\Delta lnP^d_{F,t}$	$\Delta lnP^f_{R,t}$	$\Delta lnP^d_{F,t}$
ECT^+_{t-1}	−0.43***	−0.13	−0.32***	−0.34
	(−4.91)	(−0.85)	(−3.11)	(−1.45)
ECT^-_{t-1}	−0.77***	0.09	−0.34**	0.71**
	(−6.16)	(0.39)	(−2.52)	(2.28)
$\Delta lnP^f_{R,t-1}$	−0.04	0.06	−0.24**	−0.25
	(−0.59)	(0.47)	(−2.24)	(−0.99)
$\Delta lnP^f_{R,t-2}$	NA	NA	−0.15*	−0.38*
			(−1.75)	(−1.89)
$\Delta lnP^d_{F,t-1}$	0.08	0.12	0.19***	0.16
	(1.15)	(0.95)	(3.52)	(1.24)
$\Delta lnP^d_{F,t-2}$	NA	NA	0.05	0.14
			(0.927)	(1.09)
R^2	0.47	0.04	0.43	0.14
Breusch–Godfrey serial correlation test				
Lag 1	0.016	0.008	0.24	0.002
	(0.898)	(0.928)	(0.622)	(0.967)
Lag 2	0.25	0.149	1.832	1.96
	(0.882)	(0.928)	(0.400)	(0.376)
Lag 3	0.391	1.35	1.99	2.18
	(0.942)	(0.717)	(0.575)	(0.537)
Lag 4	0.673	2.35	2.09	3.16
	(0.955)	(0.672)	(0.719)	(0.532)
Lag 5	5.26	4.18	2.78	3.16
	(0.385)	(0.524)	(0.734)	(0.676)
Lag 10	17.67	13.20	10.49	10.01
	(0.162)	(0.213)	(0.398)	(0.439)
Breusch–Pagan test	3.79	2.88	2.54	3.79
	(0.285)	(0.411)	(0.77)	(0.581)
Jarque–Bera test	5.84	0.11	10.65	0.51
	(0.054)	(0.94)	(0.01)	(0.78)

Notes. Asterisks ***, ** and * denote significance level at 1%, 5%, and 10%, respectively. Numbers in parentheses under coefficients are *t*-values, while significance levels under tests.

value). The result that the estimated magnitudes of ρ_1 were smaller overall than those of ρ_2 suggests that retail prices react more rapidly when the margin is squeezed than when it is stretched.

The estimated threshold values were about −0.04 for the fresh salmon value chain and on average −0.084 for the smoked salmon value chain in both markets. The negative threshold value means that a new adjustment takes place after a substantial reduction of the margin (Simioni et al., 2013). The approximately equal threshold values in the two countries might indicate the pricing strategies of retailers in the two countries are similar for the same product form. The fact that the magnitudes of threshold values were greater for smoked salmon than for fresh salmon indicates market response takes a longer time for those products that need further processing before they are sold in the retail market.

Next, we estimated the threshold asymmetric error correction model (ECM) along the fresh salmon value chains in both countries. Estimates of the ECM (Equations [12] and [13]) are reported in Table 3. In the table, consistent with our previous notations, $P^f_{R,t}$ denotes the retail level price while $P^d_{F,t}$ denotes the export level price. The estimated models were checked using various diagnostic tests (such as the Breusch-Godfrey serial Correlation test, Breusch-Pagan test, and Jarque-Bera test) and the results of the tests (reported in the bottom section of Table 3) confirmed the absence of any major misspecification problems except some issues of normality.

In the French market, the estimated parameters of the coefficient ECT^{+}_{t-1} and ECT^{-}_{t-1} were statistically significant for the retail equation but not for the export equation. This shows that the export prices do not adjust to changes in the retail prices, while on the contrary, the retail prices adjust to changes in the export prices following a deviation from the equilibrium. This suggests the leading role of the export price in the value chain of the fresh whole salmon market, and is a common result in the literature (Asche, Jaffry, et al., 2007).

Furthermore, the adjustment of the retail price to changes in the export price is faster when the deviation from the equilibrium is below the threshold. Specifically, the error correction rate of the retail prices in one month period following a shock in the export price is 43% and 77% for above and below the threshold value of −0.037, respectively. That is, the retail prices react more quickly when the margin is squeezed than when it is stretched. More specifically, the results suggest that when the margin is low for retailers; retailers will make a fast adjustment of their price according to the export price, while if the margin is high, the adjustment speed is slower. Retailers usually prefer a relatively stable price in their market to avoid transaction costs and possibly to exploit market power.[4]

In the Spanish market, as in the French market, the adjustment parameters ECT^{+}_{t-1} and ECT^{-}_{t-1} are statistically significant for the retail model. This implies the retail prices adjust to changes in the export prices following a deviation from the equilibrium. However, in contrast to the French market, in the export model of the Spanish market; the adjustment parameter ECT^{-}_{t-1} is statistically significant. This shows that the export prices also adjust to changes in the retail prices following a deviation from the equilibrium. However, the export prices adjust only if the deviation from the equilibrium is below the critical threshold.

Looking at the estimates of the parameters of the short-run coefficients (i.e., $\Delta lnP^{f}_{R,t-m}$ and $\Delta lnP^{d}_{F,t-1}$), in the Spanish market, a significant cross-price effect that goes from the retail price to the export price is observed at two lagged, while a significant cross-price effect that goes from the export to the retail price is detected at one period lagged. This further supports the bi-directional adjustment between the prices in Spain. No short-run cross-price effects were observed in the case of France.

Conclusion and discussion

The nature of price adjustment along the seafood value chain has gained substantial attention in recent years. In this study, threshold cointegration and asymmetric error correction models (ECMs) were estimated. The findings of asymmetric price transmission given by threshold cointegration suggest possible biased results given by the conventional Johansen approach in the previous literature. However, this bias appears to be small as our results where applicable corroborates the results from earlier price transmission studies for salmon.

Our results suggest that price transmission is more complete and quicker in the value chain of products that are less processed than the value chain of more processed products. Specifically, we found price transmission between the marketing chains along the fresh salmon chain in both the French and Spanish markets, but no price transmission was detected in the value chain of smoked salmon in either market.

Further investigation is needed to identify the reasons for the lack of price transmission in the value chain of smoked salmon. There are four main factors that may contribute to this phenomenon. First, if we look at Figures 1 and 2, there is evidence that the retail price of the smoked salmon is just a markup of the raw fish price after including processing costs. Second, there is a substantial time lag between the import of raw fish and retail sales of the final smoked salmon in the markets. For different processing companies, the period of the time lag varies significantly in relation to their production capacities and marketing strategies. Third, given the higher degree of processing for smoked salmon, the cost share of the raw fish is smaller, a feature that generally will tend to make the price transmission weaker. Finally, there appears to be a higher use of contracts where prices are fixed for longer periods for more processed products, making price transmission very slow as prices are infrequently updated. Consequently, compared to the fresh salmon market, it is more difficult to identify the price linkage between imported raw fish and smoked salmon in a retail market.

Asymmetric price transmission in the value chain of fresh salmon was detected, where agents reacted more quickly to shocks when the deviation from equilibrium was below the equilibrium level. Approximately equal threshold values in both the French and Spanish markets indicated that the marketing strategies of retailers in the two markets are somehow similar. The French market results suggest the leading role of the export price in the value chain of the fresh whole salmon market since it was the retail prices that adjusted to changes in the export prices, not vice versa. However, in the Spanish market, bi-directional adjustment was observed.

Noncompetitive behavior and adjustment costs (or transaction methods) are the two most widely cited causes of asymmetry in the price transmission literature (Frey & Manera, 2007; von Cramon-Taubadel & Meyer, 2004). However, since the global salmon market is assumed to be competitive (e.g., Larsen & Kinnucan, 2009), we argue that adjustment costs (transaction methods) are the most likely explanations for the price asymmetries along the salmon value chain.

Notes

1. Futures markets are an alternative mechanism for hedging short-and intermediate-term price risk (Asche et al., 2016; Oglend & Straume, 2020).
2. However, Larsen and Kinnucan (2009) include transportation costs measured in an index of retail auto diesel prices.
3. Results of all estimated models are available upon request from the corresponding author.
4. This is an issue that has received limited attention. However, Sogn-Gruntvåg et al. (2019) show significant differences in product longevity by product form and labelling for whitefish.

Acknowledgments

The authors would like to thank the Norwegian Seafood Council for providing the salmon data. Furthermore, we gratefully acknowledge the constructive and helpful comments received from two anonymous referees and the journal editor on earlier drafts of this paper.

References

Anderson, J. L., Asche, F., & Garlock, T. (2018). Globalization and commoditization: The transformation of the seafood market. *Journal of Commodity Markets*, *12*, 2–8. https://doi.org/10.1016/j.jcomm.2017.12.004

Ankamah-Yeboah, I., & Bronnmann, J. (2017). Asymmetries in import-retail cost pass-through: Analysis of the seafood value chain in Germany. *Aquaculture Economics & Management*, *21*(1), 71–87. https://doi.org/10.1080/13657305.2016.1262478

Asche, F., Cojocaru, A. L., & Roth, B. (2018). The development of large scale aquaculture production: A comparison of the supply chains for chicken and salmon. *Aquaculture*, *493*, 446–455.

Asche, F., Dahl, R. E., Valderrama, D., & Zhang, D. (2014). Price transmission in new supply chains – The case of salmon in France. *Aquaculture Economics & Management*, *18*(2), 205–219. https://doi.org/10.1080/13657305.2014.903309

Asche, F., Jaffry, S., & Hartmann, J. (2007). Price transmission and market integration: Vertical and horizontal price linkages for salmon. *Applied Economics*, *39*(19), 2535–2545. https://doi.org/10.1080/00036840500486524

Asche, F., Menezes, R., & Dias, J. (2007). Price transmission in cross boundary supply chains. *Empirica*, *34*(5), 477–489. https://doi.org/10.1007/s10663-007-9045-0

Asche, F., Misund, B., & Oglend, A. (2016). The spot-forward relationship in the Atlantic salmon market. *Aquaculture Economics & Management*, *20*(2), 222–234.

Asche, F., & Smith, M. D. (2018). Induced innovation in fisheries and aquaculture. *Food Policy*, *76*, 1–7.

Blake, N. S., & Fomby, T. B. (1997). Threshold cointegration. *International Economic Review*, *38*(3), 627–645. https://doi.org/10.2307/2527284

Bergesen, O., & Tveterås, R. (2019). Innovation in seafood value chains: The case of Norway. *Aquaculture Economics & Management*, *23*(3), 292–320. https://doi.org/10.1080/13657305.2019.1632391

Bittmann, T., Bronnmann, J., & Gordon, D. V. (2019). Product differentiation and dynamics of cost pass-through in Germany fish market: An error-correction-distance measure approach. *Journal of Commodity Markets*, 100105. https://doi.org/10.1016/j.jcomm.2019.100105

Braekkan, E. H., Thyholdt, S. B., Asche, F., & Myrland, Ø. (2018). The demands' they are a-changin. *European Review of Agricultural Economics*, *45*(4), 529–531. https://doi.org/10.1093/erae/jby003

Chan, K. S. (1993). Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. *The Annals of Statistics*, *21*(1), 520–533. https://doi.org/10.1214/aos/1176349040

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, *49*(4), 1057–1072.

Enders, W., & Granger, C. W. J. (1998). Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates. *Journal of Business & Economic Statistics*, *16*(3), 304–311.

Enders, W., & Siklos, P. L. (2001). Cointegration and threshold adjustment. *Journal of Business & Economic Statistics*, *19*(02), 166–176.

Engle, R. F., & Granger, C. W. J. (1987). Cointegration and error correction: Representation, estimation, and testing. *Econometrica*, *55*(2), 251–276. https://doi.org/10.2307/1913236

EUMOFA. (2017). The *EU fish market:* 2017 edition. http://www.eumofa.eu/documents/20178/108446/The+EU+fish+market+2017.pdf

Europanel. (2018). *Data file.* http://www.europanel.com/

Fernández-Polanco, J., & Llorente, I. (2019). Price transmission and market integration: Vertical and horizontal price linkages for gilthead seabream (*Sparus aurata*) in the Spanish market. *Aquaculture*, *506*, 470–474.

Frey, G., & Manera, M. (2007). Econometric models of asymmetric price transmission. *Journal of Economic Surveys*, *21*(2), 349–415. https://doi.org/10.1111/j.1467-6419.2007.00507.x

Guillen, J., & Franquesa, R. (2015). Price transmission and volatility along the Spanish fresh fish market chain. *New Medit*, *14*(1), 4–11.

Guillotreau, P., Le Grel, L., & Simioni, M. (2005). Price – Cost margins and structural change: Sub-contracting within the salmon marketing chain. *Review of Development*, *9*(4), 581–597.

Jaffry, S. (2004). Asymmetric price transmission: A case study of the French hake value chain. *Marine Resource Economics*, *19*(4), 511–523. https://doi.org/10.1086/mre.19.4.42629450

Kinnucan, H. W., & Forker, O. D. (1987). Asymmetry in farm-retail price transmission for major dairy products. *American Journal of Agricultural Economics*, *69*(2), 285–292. https://doi.org/10.2307/1242278

Kvaløy, O., & Tveteras, R. (2008). Cost structure and vertical integration between farming and processing. *Journal of Agricultural Economics*, *59*(2), 296–311. https://doi.org/10.1111/j.1477-9552.2007.00149.x

Landazuri-Tveteraas, U., Asche, F., Gordon, D. V., & Tveteraas, S. L. (2018). Farmed fish to supermarket: Testing for price leadership and price transmission in the salmon supply chain. *Aquaculture Economics & Management*, *22*(1), 131–149.

Larsen, T., & Asche, F. (2011). Contracts in the salmon aquaculture industry: An analysis of Norwegian salmon exports. *Marine Resource Economics*, *26*(2), 141–150. https://doi.org/10.5950/0738-1360-26.2.141

Larsen, T. A., & Kinnucan, H. W. (2009). The effect of exchange rates on international marketing margins. *Aquaculture Economics & Management*, *13*(2), 124–137.

Oglend, A., & Straume, H. M. (2020). Futures market hedging efficiency in a new futures exchange: Effects of trade partner diversification. *Journal of Futures Markets*, *40* (4), 617–631. https://doi.org/10.1002/fut.22088

Peltzman, S. (2000). Prices rise faster than they fall. *Journal of Political Economy*, *108*(3), 466–502. https://doi.org/10.1086/262126

Simioni, M., Gonzales, F., Guillotreau, P., & Le Grel, L. (2013). Detecting asymmetric price transmission with consistent threshold along the fish supply chain. *Canadian Journal of Agricultural Economics/Revue Canadienne D'agroeconomie*, *61*(1), 37–60. https://doi.org/10.1111/j.1744-7976.2012.01257.x

Singh, K., Dey, M. M., Laowapong, A., & Bastola, U. (2015). Price transmission in Thai aquaculture product markets: An analysis along value chain and across species. *Aquaculture Economics & Management*, *19*(1), 51–81. https://doi.org/10.1080/13657305.2015.994236

Sogn-Gruntvåg, G., Asche, F., Zhang, D., & Young, J. A. (2019). Eco-labels and product longevity: The case of whitefish in UK grocery retailing. *Food Policy*, *88*, 101750.

von Cramon-Taubadel, S., Meyer, J. (2004). Asymmetric price transmission: A survey. *Journal of Agricultural Economics*, 55(3), 581–611.

APPENDIX

Table A1. Summary statistics of monthly retail prices from France and Spain and farm (or export) price from Norway (price in levels).

	France				Spain			
	Mean	Median	St. Dev.	No. of obs.	Mean	Median	St. Dev	No. of obs.
Export	4.83	4.79	1.24	127	4.99	4.89	1.196	115
Fresh	10.86	10.69	1.93	127	7.06	6.92	0.864	115
Smoked	16.05	15.61	2.28	127	12.67	12.36	1.26	115

Notes. Data for France are from January 2008 to June 2018, while data for Spain are from January 2009 to June 2018.