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The Spot-Forward Relationship in the Atlantic Salmon Market

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ABSTRACT

This review investigates the market performance of salmon forward contracts. It studies whether the forward price is an unbiased estimator of the spot price and whether the forward market generates price discovery information. The focus is on the Fish Pool market for the period from 2006 to 2017 and relates to forward contracts with maturities up to 60 months. The main finding is that there is strong cointegration up to a period of seven months. After this window, there is marginally significant cointegration up to a period of 12 months and the cointegration relationship disappears for contracts with maturities longer than 12 months, pointing to the inefficiency of these forward markets. The results from error-correction models and Granger causality tests suggest that the salmon forward market does not fulfill the expected price discovery role and that the spot market drives the forward market. These findings suggest the salmon forward market is still immature and cast doubt on the viability of longer-term salmon forward contracts.

KEYWORDS

Cointegration; fish pool; forward markets; risk management; salmon market

1. Introduction

Salmon production has been rapidly growing but has not kept up with demand. With high prices the new normal, stakeholders all along the salmon supply chain are focusing on identifying effective ways of coping with the widening gap between supply and demand (Torrisen et al., 2011). Countries such as the Russian Federation, Canada, Ireland, Iceland, and Australia have invested in developing new aquaculture production sites, and the viability of land-based farming has increased (FAO, 2017). In addition, the industry focuses on developing technologies for efficiency gains in both farming and processing (FAO, 2017). According to the FAO (2017), there is widespread acceptance of the firmness of the new price plateau supported by rapid global demand growth and a number of physical and regulatory constraints on supply growth. These factors have created a strong motivation for stakeholders to explore ways of increasing their share of the revenues generated on relatively little raw material. With increased turnover and price volatility and risk in the salmon market, the salmon forward market might help market participants to manage their price risks. Making or taking delivery on forward sold or bought may eliminate price risk. This manuscript is a study of market structure and performance of salmon forwards and expands the reach of analysis to a five-year window.

The study of food markets from this financial perspective is well-established (see, e.g., Bessler and Covey, 1991; Schroeder and Goodwin, 2006). However, fish markets have not been studied in that much detail. This is mainly because forward markets in these commodities seem to be underdeveloped. This is surprising, given the interest in the fisheries industry (Forster, 2002; Torrisen et al., 2011). This study aims to complement Asche et al. (2016a) and Ankamah-Yeboah et al. (2017). These studies employ cointegration to examine the validity of the unbiasedness and prediction hypotheses in the salmon forward market. Both these studies focus on the short-term horizon and are limited to contract maturities of up to 12-month. The aim is to depart from these two studies and to account for a wider range of forward series. Further, this study investigates a historical period that saw an unprecedented increase of both spot and forward prices in the salmon market. The results partially confirm the results of Asche et al. (2016a) and Ankamah-Yeboah et al. (2017) for short-

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term forward contracts and provide new insights for forwards with longer maturities. In particular, it appears that with the above one-year forward, the market is not informationally efficient.

Futures markets allow market participants to hedge price risk and provide price discovery. As such, it is an important risk management tool for producers and buyers alike; new and young futures markets do not always succeed. Brorsen and Fofana (2001) offer an overview of the drivers of success and failure of agricultural futures contracts in general and Bergfjord (2007) investigates the prospects of the salmon futures market. Bergfjord was not very optimistic, especially because of trade regulations, transportation costs, storage issues, and the very limited interest of financial intermediaries. Nevertheless, the salmon forward introduced by Fish Pool in 2006 was well received and the contracts to be exchanged expanded over the years. This study relies on price data from Fish Pool to analyze the usefulness of the forward market as a price discovery vehicle. It investigates whether the Fish Pool salmon contracts are an unbiased estimator of the salmon spot price. Being an unbiased estimator of the spot price is a crucial feature if the market is to succeed as an instrument to hedge price risks (Ederington, 1979; Giles and Goss, 1981; Slade and Thille, 2006).

This study finds strong cointegration between salmon spot and forward prices up to a period of seven months. After this window, there is only marginally significant cointegration up to a period of 12 months and the cointegration relationship disappears for contracts with maturities longer than 12 months. This suggests that the salmon forward price may not serve as a reliable predictor of the expected future spot price beyond the one-year horizon. The lack of cointegration for longer maturity contracts may result from low trading activity. As such, hedgers would need to look into alternative means to manage medium and long-term salmon price risks. Furthermore, the error-correction models and Granger causality tests provide overwhelming evidence that the salmon forward market does not provide an adequate price discovery function and that the spot drives the forward market. These findings cast doubt on the viability of salmon forwards, particularly on those with longer maturities.

The remainder of the paper is organized as follows. First, there is a brief overview of the literature on forward market performance for salmon and other livestock. Then, the methodology used is delineated, followed by an introduction of the Fish Pool data. Next, there is the reporting and discussion of the results from the analysis. The paper ends with a brief conclusion.

2. Literature review

Forward/futures trading or derivative trading at large is a novelty to the seafood industry. Futures trading was introduced to shrimp and salmon. A number of studies have pointed to the deficiency of shrimp futures contracts traded in the Minneapolis Grain Exchange (MGE) as an effective price discovery and hedging tool (Martínez-Garmendia and Anderson, 2001; Maynard et al., 2001). Maynard et al. (2001) evaluate the performance of shrimp futures contracts but can only identify one cointegration relationship between shrimp spot and futures prices from thirteen varieties of shrimp spot prices and two varieties of futures prices during the period from 1994 to 1998. They conclude that shrimp forward prices fail as a price discovery mechanism and attribute this failure to the lack of liquidity in the forward market. Martínez-Garmendia and Anderson (2001) arrive at similar conclusions. These findings seem to cast doubt on the feasibility of seafood for futures trading. On the other hand, forward trading tends to have more success in agricultural and other livestock industries with a tradition of using forward contracts. For example, Yang et al. (2001) study the price discovery performance of futures markets for storable (corn, oats, soybean, wheat, cotton, and pork bellies) and non-storable (hogs, live cattle, feeder cattle) commodities using daily data from 1992 to 1998, and conclude that futures markets can be used as a price discovery tool in all of these markets.

Salmon forward contracts traded in Fish Pool are different from the shrimp futures traded in the MGE as the former is a financial forward contract written on a broad salmon price index with no physical delivery. This setup takes away several market frictions (e.g., cost of carry, deliverable grades) that may hamper the interaction between forward and spot salmon prices. Long-term forward contracts are also available for salmon with maturities up to 60 months. This innovation to seafood futures trading resulted in renewed interest in the examination of futures performance in academic literature. Asche et al. (2016a) study salmon forward with maturities up to six months for the period from 2006 to 2014. They find salmon spot and (lagged) forward prices are cointegrated and that forward prices provide an unbiased estimate of the spot price. They do not find evidence supporting the price discovery function of salmon forwards. Ankamah-Yeboah et al. (2017) extend the data series of Asche et al. (2016b) and rely on a slightly different model specification. They confirm evidence of cointegration between spot prices and up to 6-

month forward contract prices, as well as for 9- and 12-month forwards. For the cases where there is cointegration, this implies there is no significant risk premium and the forward market is efficient. When investigating the price discovery function of forward markets, Ankamah-Yeboah et al. (2017) conclude that the salmon forward market is still maturing, as the unbiasedness hypothesis is not be confirmed for all series.

3. Methodology

The methodology applied in this study is fully in line with the mainstream finance literature, which investigates whether the forward price is an unbiased estimator of the spot price and whether the forward market acts as a price discovery vehicle (Chen and Zheng, 2008; Ederington, 1979; Giles and Goss, 1981). Forward prices relate to spot prices because they are derivatives of spot assets. Commodity forward contracts are specialized cases of forward contracts. They are standardized regarding the specific commodity, delivery date, and delivery location. It is the contract rather than the commodity itself, which is the unit of transaction. The futures market is the organized exchange, which deals in these contracts with respect to delivery or settlement. Asche et al. (2014) provide insightful details about the organization of the salmon market; for a fisheries perspective, see Forster (2002) and Torrisen et al. (2011).

The market efficiency and unbiasedness hypothesis holds that

$$F_{t,T} = E_t(S_T) \tag{1}$$

where $F_{t,T}$ is the forward price quoted at time t with n periods to contract maturity at time T; $E_t(S_T)$ is the market expectation of the future spot price at time T, formed at time t.

Under the condition of rational expectations, this translates to:

$$S_T = E_t(S_T \Omega_t) + u_t \tag{2}$$

where $\Omega_t$is the information set available at time t and u_t is the rational expectation error. Substituting Eq.(2) into Eq.(1), taking the natural logarithm on both sides of the equation and allowing for an intercept, it results:

$$lnS_{t+n} = \alpha_1 + \beta_1 lnF_{t,n} + u_{S,t} \tag{3}$$

Since both lnS_{t+n} and $lnF_{t,n}$ are likely to be integrated of order 1, the above relationship should be tested through cointegration. The unbiasedness hypothesis implies cointegration between lnS_{t+n} and $lnF_{t,n}$. Eq.(3) implies the forward price to be a useful predictor of the subsequent spot price, in other words, the forward price leads the spot price. There also can be situations where the spot market leads the forward market, suggesting a reverse causal relationship:

$$lnF_{t,n} = \alpha_2 + \beta_2 lnS_{t+n} + u_{F,t+n} \tag{4}$$

Though Equation (4) is much less common for an underlying asset with a mature and developed forward market, it may well be true for salmon markets (Asche et al., 2016a; Giles and Goss, 1981; Slade and Thille, 2006).

The intercept α_i in Equations (3) and (4) typically represents convenience yield or risk premium. In the case of salmon forwards, it can be interpreted as a risk premium since the forward contract is a financial one without physical delivery at maturity. To be an efficient and unbiased predictor for one another, it is required that $\alpha = 0$ and $\beta = 1$. $\alpha = 0$ implies zero risk premium under the assumption of risk neutrality, and $\beta = 1$ implies that the two price series share a one-on-one relationship. This constitutes a prerequisite for a perfect hedge.

Conditional on the existence of a cointegration relationship, a vector error correction model (VECM) can be constructed for each price series:

$$\Delta lnS_{t+n} = \mu_1 + \rho_1 u_{S,t-1} + \sum_{i=1}^{k} \Gamma_i^{11} \Delta lnS_{t+n-i} + \sum_{i=1}^{k} \Gamma_i^{12} \Delta lnF_{t-i} + \varepsilon_{1t} \tag{5}$$

$$\Delta lnF_t = \mu_2 + \rho_2 u_{F,t+n-1} + \sum_{i=1}^{k} \Gamma_i^{21} \Delta lnS_{t+n-i} + \sum_{i=1}^{k} \Gamma_i^{22} \Delta lnF_{t-i} + \varepsilon_{2t} \tag{6}$$

Such a VECM allows examining both the long- and short-run dynamics of the causal relationship between spot and forward prices. The main variable of interest in the VECM is the lagged error correction term (ECT), $u_{S,t-1}$ or $u_{F,t+n-1}$, which represents the dynamics of the long-run relation binding the two price series, so that they never drift too far apart. To maintain the long-term relation, the expectation is that at least one out of the two ECTs to be statistically significant (i.e., $\rho \neq 0$) and bear a negative sign so that any deviation from the long-run equilibrium is adjusted in subsequent periods. A statistically insignificant ECT indicates that the dependent variable does not respond to a disequilibrium in the cointegration relationship. The magnitude of the coefficient of the ECT, ρ, measures the speed of adjustment toward equilibrium by the dependent variable in either Equation (5) or (6). In case there is no cointegration relationship for any spot-forward price pair, only the short-run dynamics can be examined by estimating a vector autoregressive model (VAR) with differenced log prices.

The short-run dynamics suggest that the lagged forward prices have significant predictive power for spot prices over finite forecasting horizons and vice versa. This is akin to the Granger-causality concept and can be tested in a VECM/VAR system by:

$$H_0 : \Gamma_1^{12} = \Gamma_2^{12} = \ldots = \Gamma_k^{12} = 0 \quad (7)$$

$$H_0 : \Gamma_1^{21} = \Gamma_2^{21} = \ldots = \Gamma_k^{21} = 0 \quad (8)$$

where Γ_i^{12} is the coefficient for the lagged differenced forward prices in Eq.(5) and Γ_i^{21} is for the lagged differenced spot prices in Eq.(6). Rejecting H_0 in Eq.(7) would imply that the forward prices lead the spot prices. Rejecting H_0 in Eq.(8) would imply the reverse short-run causality between the two price series.

This study also employs the Engle and Granger (1987) single equation residual based cointegration method, next to the Johansen (1988) system based method. The former method is known for its simplicity and suitable in a two-variables setting in which there could be at most one cointegration relationship.

4. Data

Daily data are obtained from Fish Pool Index (FPI) prices (i.e., spot prices) and forward contract prices for the period between 12 June 2006 and 28 April 2017. The forward contracts considered have maturities ranging from one month to 60 months (Contracts with maturities longer than 30 months were introduced after 5 August 2009). Because the interest lies with long-term price co-movements between the two price series, daily prices are converted to monthly prices according to the trading calendar of Fish Pool Exchange. This results in 131 monthly observations (from June 2006 to April 2017). Figure 1 shows the monthly price movement of the spot price and forward prices of the maturities used in the analysis. It shows that in most diagrams there are slightly increasing prices between 2007 and 2011. In 2011, there is a price drop along most maturities. Nevertheless, prices recover soon, and especially pick up in the second half of 2015. Please be aware that forward contracts with maturities longer than 30 months were introduced as per August 2009.

Table 1 provides the descriptive statistics for the spot price and forward prices of selected maturities. It reports the mean, median, standard deviation, and 25th and 75th percentiles for all the maturities used in the analysis. Table 1 shows that there is strong evidence of forward backwardation regarding the means of spot and forward prices as the forward price declines while the maturity increases. The standard deviation and range (i.e., difference between maximum and minimum values) of forward prices also declines with increasing time to maturity, suggesting a falling term structure of volatility. Only for the 12-month and 30-month maturities, there is a hiccup.

5. Results

This section presents the results of the estimations of the models. It first reports the results of the stationarity analysis before the cointegration of the price series is addressed by way of Engle–Granger and Johansen tests. Then, it presents the results of estimating the (vector) error correction model. Lastly, there is a discussion of the results of the Granger causality analysis.

Regarding the application of the cointegration test, it is first considered whether the price series is integrated of the same order of non-stationarity. The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests verify this property. The results for the ADF and PP unit root test are in the Appendix. This yields that, as expected, both ADF and PP tests support the assumption of the existence of a unit root in (log) spot and forward prices and concludes to stationarity in their first differences. Given that all log prices follow unit root processes and are integrated of the first order, the potential for cointegration between spot and forward prices does exist. This suggests the need to test for cointegration. The cointegration test results using the Engle–Granger and the Johansen methods are reported in Table 2.

Based on the results in Table 2, the Engle–Granger cointegration test results based on parametric testing suggest that there is evidence of cointegration between the spot price and the forward price regarding maturities up to 7-month, as the null hypothesis of no cointegration is rejected at the 5% level of significance for these contracts. There is only slight evidence for cointegration regarding salmon forward contracts of 8- and 9-month in case a 10% level of significance is considered. For contracts with maturities beyond 9 months, there is no evidence of cointegration. The test results based on the z-statistic supports cointegration up to 9 months at the 5% level of significance and up to 12 months at the 10% level of significance, respectively.

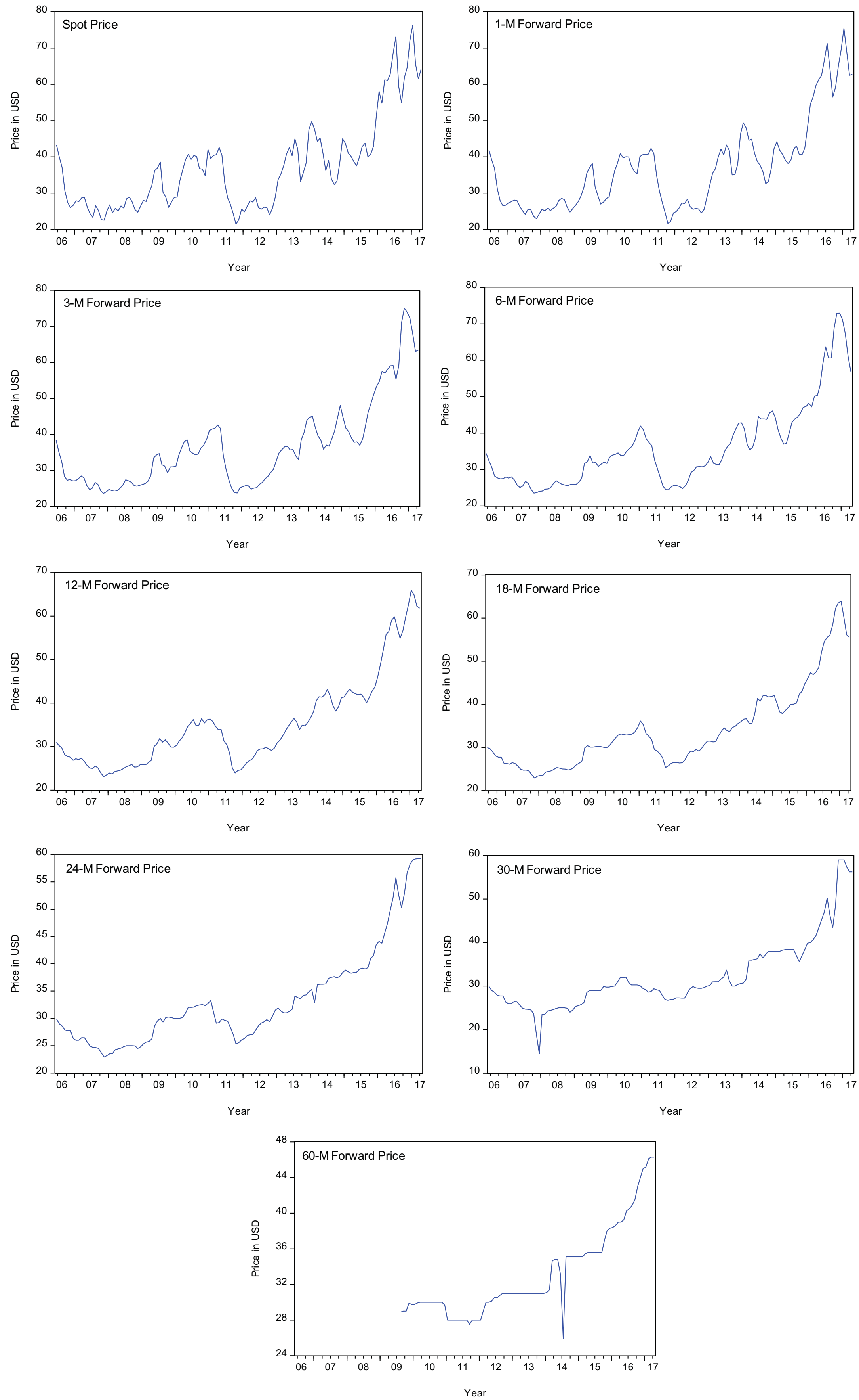

Figure 1. Monthly price movements of spot and forward prices in the salmon market. S notifies the spot market, F*i* is for the forward market with *i* referring to the number of months.

Table 1. Descriptive statistics for spot and forward prices.

Contract length	Mean	Std. Dev.	Min	25%tile	Median	75%tile	Max	Range
Spot	37.09	12.33	21.42	27.14	35.60	41.50	76.30	54.88
1-month	36.98	12.18	21.65	27.04	35.43	41.37	75.44	53.79
2-month	36.79	12.06	22.83	26.83	35.68	40.96	73.52	50.69
3-month	36.53	11.96	23.63	27.05	34.56	41.07	75.12	51.49
4-month	36.39	11.77	23.74	26.95	34.05	41.07	74.08	50.34
5-month	36.19	11.55	23.67	27.07	33.53	41.56	73.75	50.08
6-month	36.04	11.40	23.47	27.06	32.77	41.13	72.92	49.45
7-month	35.82	11.22	23.36	27.10	32.18	40.80	72.15	48.79
8-month	35.59	10.96	23.36	27.21	31.75	40.42	70.99	47.63
9-month	35.45	10.81	23.20	27.03	31.75	40.24	68.79	45.59
10-month	35.32	10.64	23.20	26.92	31.78	40.56	64.64	41.44
11-month	35.18	10.46	23.20	26.85	31.85	40.48	64.54	41.34
12-month	35.04	10.38	23.11	26.93	31.85	40.85	65.93	42.82
18-month	34.01	9.53	22.90	26.47	31.30	38.00	63.89	40.99
24-month	33.22	8.87	22.90	26.66	30.25	37.40	59.25	36.35
30-month	32.21	8.20	14.43	27.13	29.89	36.38	59.00	44.57
60-month	33.16	5.00	25.93	30.00	31.00	35.60	46.30	20.37

These statistics are calculated based on 131 monthly observations from June 2006 to April 2017 except 60-month contract which only has 93 observations as this type of contract was only introduced since August 2009.

The Johansen cointegration test results based on the trace statistic yields similar findings compared to the Engle–Granger *t*-test results in that cointegration with forward contracts with maturities up to 7 months at a 5% level of significance. For maturities beyond 7 months, the Johansen test does not conclude to cointegration. Using the max-Eigen statistic, the evidence for the existence of cointegration is extended to 9-month contracts at the 10% level of significance. These findings partially confirm those of Asche et al. (2016b), who conclude cointegration between spot and forward prices of maturities from 1 to 6 months, as well of those of Ankamah-Yeboah et al. (2017) who conclude the same and also find cointegration for 9- and 12-month forwards.

By considering the full range of contract maturities, it seems that the strength of the cointegration relationship between forward and spot diminishes as contract time to maturity increases. The lack of cointegration for longer maturity contracts points to the inefficiency of salmon forward markets in the sense that they do not incorporate all relevant information and are biased predictors of spot prices, which in turn translates into extra cost and uncertainty for hedgers in the salmon forward markets.

To further test the unbiasedness hypothesis, restrictions have to be imposed on the coefficients of the cointegration relation that are shown to be statistically significant at 10% level by any test statistic in Table 3. The results are in Table 3. Because of these results, the null hypothesis that $\beta = 1$ for any estimated cointegration relation cannot be rejected. This suggests that the futures price is efficient to the extent that there is evidence of cointegration. The joint hypothesis that $\alpha = 0$ *and* $\beta = 1$ is a test for unbiasedness. It is rejected for 9 to 12 months Engle–Granger cointegration relations at the 10%

Table 2. Cointegration test results.

	Engle–Granger method		Johansen method	
Contract length	*t*-stat.	*z*-stat.	Trace stat.	Max-Eigen stat.
1-month	−7.3147***	−108.6479***	55.2104***	53.3795***
2-month	−6.8094***	−91.9969***	24.0829**	22.4567***
3-month	−5.5586***	−59.6447***	52.1161***	50.5859***
4-month	−5.0531***	−49.3965***	39.5498***	38.1639***
5-month	−4.6117***	−52.3434***	39.0008***	37.6464***
6-month	−3.8519**	−29.6549***	25.3830***	23.9132***
7-month	−3.6331**	−26.2152**	20.5195**	19.2090**
8-month	−3.2689*	−21.3814**	17.9081	16.5512**
9-month	−3.1405*	−19.7363**	15.7589	14.1406*
10-month	−3.0689	−18.1725*	15.5861	13.7377
11-month	−3.0189	−16.9507*	13.2546	11.2954
12-month	−3.0805	−17.2620*	14.0412	12.5028
18-month	−2.5255	−12.8028	12.0173	9.7098
24-month	−2.3845	−11.7886	7.5237	5.9388
30-month	−2.4939	−12.5470	10.6109	9.3879
60-month	−1.6901	−5.4874	15.7249	13.5241

***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively. The optimal lag length in the VAR under Johansen approach is selected using Schwarz's Bayesian Criterion (BIC) and is found to be two (the cointegration test results appear to be insensitive to lag length selection). Cointegration tests are conducted assuming the presence of an intercept in the cointegrating equation and but not in the VAR. Fourth and fifth columns show the trace and max-eigen value statistics for null hypothesis of no cointegration (i.e., $r = 0$), respectively. Though not tabulated, the alternative hypothesis of one cointegration (i.e., $r = 1$) cannot be rejected for all forward and spot pairs, regardless of the type of test statistic considered.

Table 3. Coefficients for cointegrating relationships.

Contract length	α	*B*	H_0: $\beta = 1$	H_0: $\alpha = 0$ and $\beta = 1$
Engle-Granger method				
1-month	0.0548	0.9852	−0.8279	0.8557
2-month	0.1183	0.9688	−0.8761	1.3044
3-month	0.2378	0.9371	−1.044	1.9242
4-month	0.2819	0.9269	−0.8880	1.9700
5-month	0.2919	0.9268	−0.7147	0.5108
6-month	0.2534	0.9408	−0.5008	2.7095
7-month	0.1920	0.9619	−0.2925	3.6596
8-month	0.1903	0.9649	−0.2492	4.4075
9-month	0.2928	0.9374	−0.4177	5.0960*
10-month	0.3628	0.9193	−0.5003	5.7945*
11-month	0.3939	0.9125	−0.5028	6.4209**
12-month	0.4513	0.8989	−0.5383	7.3413**
Johansen method				
1-month	0.0129	0.9966	−0.6788	0.5085
2-month	0.0716	0.9805	−0.5581	0.3316
3-month	0.0513	0.9883	−0.2636	0.1099
4-month	−0.0060	1.0056	0.0783	0.0006
5-month	0.0236	0.9981	−0.0202	0.0054
6-month	0.1674	0.9585	−0.3014	0.1249
7-month	−0.0281	1.0022	0.0132	0.0023
8-month	−0.1053	1.0435	−0.2784	0.0236
9-month	0.2503	0.9425	0.3253	0.1004

The second and third columns display the coefficient estimates for α and β, respectively; the fourth column presents the *t*-statistic for the null hypothesis that $\beta = 1$; the fifth column presents the chi-square statistic for the joint null hypothesis that $\alpha = 0$ and $\beta = 1$. ***, **, and * indicate statistical significance or rejecting of the null hypothesis at 1%, 5%, and 10%, respectively.

Table 4. Estimation of long- and short-run dynamics.

Contract length	Dependent variable	ECT	Granger causality	Adj. R^2	Serial correlation
Panel A: Engle–Granger method					
1-month	ΔlnS	−0.0235	0.4483	0.0318	0.6801
	ΔlnF	−0.7111***	888.942***	0.9669	0.7156
2-month	ΔlnS	−0.0091	1.2855	0.0272	0.6928
	ΔlnF	−0.2574***	154.203***	0.7887	1.5116
3-month	ΔlnS	−0.0518	1.4182	0.0314	0.3771
	ΔlnF	−0.2899***	9.7312***	0.5244	5.9157***
4-month	ΔlnS	−0.0544	1.9811	0.0426	0.2542
	ΔlnF	−0.1761***	3.6633**	0.4537	1.3820
5-month	ΔlnS	−0.0590	1.7778	0.0426	0.4330
	ΔlnF	−0.1445***	1.0144	0.3691	0.5751
6-month	ΔlnS	−0.0585	2.3347	0.0535	0.9499
	ΔlnF	−0.1014***	0.4516	0.2873	1.5249
7-month	ΔlnS	−0.0448	1.0538	0.0295	0.9053
	ΔlnF	−0.0807***	0.4718	0.3091	1.6731*
8-month	ΔlnS	−0.0551	1.5016	0.0414	1.0926
	ΔlnF	−0.0722***	2.8250*	0.3204	0.9329
9-month	ΔlnS	−0.0506	1.7126	0.0431	0.9473
	ΔlnF	−0.0504***	0.6265	0.3409	0.8997
10-month	ΔlnS	−0.0368	1.0063	0.0237	1.5741
	ΔlnF	−0.0494***	4.0959**	0.3225	1.7739*
11-month	ΔlnS	−0.0460	1.3515	0.0325	0.7305
	ΔlnF	−0.0400**	5.7007***	0.3472	0.7190
12-month	ΔlnS	−0.0314	1.1182	0.0251	1.1180
	ΔlnF	−0.0407**	0.7666	0.2404	0.6911
18-month	ΔlnS	–	1.3581	0.0318	0.8754
	ΔlnF	–	0.9344	0.1410	1.1034
24-month	ΔlnS	–	2.8743*	0.0687	0.8004
	ΔlnF	–	0.1864	0.0013	0.8269
30-month	ΔlnS	–	0.0965	0.0101	0.5706
	ΔlnF	–	2.3313	0.0635	0.5271
60-month	ΔlnS	–	0.7290	0.1173	2.1368*
	ΔlnF	–	0.7983	0.0527	1.1300
Panel B: Johansen method					
1-month	ΔlnS	0.2926	0.7768	0.0264	3.0460
	ΔlnF	−0.7872***	8.2969**	0.9681	
2-month	ΔlnS	0.0141	2.3155	0.0289	3.7549
	ΔlnF	−0.2693***	93.8194***	0.7933	
3-month	ΔlnS	−0.0384	2.0771	0.0300	3.6782
	ΔlnF	−0.2943***	6.6078**	0.5478	
4-month	ΔlnS	−0.0445	3.0668	0.0405	1.2126
	ΔlnF	−0.1739***	7.0625**	0.4763	
5-month	ΔlnS	−0.0492	2.7680	0.0407	2.7371
	ΔlnF	−0.1403***	13.9942***	0.4047	
6-month	ΔlnS	−0.0487	3.9192	0.0507	3.7987
	ΔlnF	−0.1014***	4.8712*	0.3249	
7-month	ΔlnS	−0.0367	1.4071	0.0285	5.6543
	ΔlnF	−0.0757***	2.6334	0.3334	
8-month	ΔlnS	−0.0471	2.8058	0.0399	3.1138
	ΔlnF	−0.0651***	5.8669*	0.2656	
9-month	ΔlnS	−0.0425	3.1489	0.0410	3.6278
	ΔlnF	−0.0495***	1.4009	0.3094	
10-month	ΔlnS	–	1.6217	0.0245	17.3609***
	ΔlnF	–	8.5441**	0.2913	
11-month	ΔlnS	–	2.4068	0.0298	1.0848
	ΔlnF	–	12.0056***	0.3272	
12-month	ΔlnS	–	1.9479	0.0294	2.1432
	ΔlnF	–	1.7912	0.2173	
18-month	ΔlnS	–	2.3771	0.0303	1.7762
	ΔlnF	–	1.5940	0.1383	
24-month	ΔlnS	–	5.2863*	0.0682	0.7711
	ΔlnF	–	0.4564	0.0034	
30-month	ΔlnS	–	0.1828	0.0140	3.1997
	ΔlnF	–	4.3188	0.0667	
60-month	ΔlnS	–	1.5598	0.0785	1.6628
	ΔlnF	–	1.3522	0.0273	

***, **, and * indicate statistical significance or rejecting of the null hypothesis at 1%, 5%, and 10%, respectively.

level of significance, suggesting that the futures price is a biased estimator of future spot price. The rejection of the joint hypothesis results from the non-zero α. This suggests there is a significant risk premium and risk aversion in the salmon futures market. However, this finding is not observed when the otherwise similar Johansen cointegration relations are considered.

For a futures contract to serve as an effective price risk management tool, the futures price is expected to perform the price discovery function and to lead the spot price (i.e., prediction hypothesis). The lead-lag relationship between salmon forward and spot prices is examined through the error correction model (if applicable) and the Granger causality test. For those spot-forward pairs for which significant cointegration is evident at a 10% level of significance, the estimation of (V)ECM is used, otherwise, a standard VAR is estimated. The estimates of the error correction terms (ECTs) and the Granger causality test results are summarized in Table 4 (with the results for the Engle–Granger method in panel A and those for the Johansen method in panel B).

The long-term dynamics between the forward and spot prices is modeled by the ECTs, as defined in Equation (5), are statistically insignificant for the forward contract maturities examined. This finding is insensitive to the cointegration method employed. This leads to the conclusion that the salmon spot price does not play an active role in restoring the long-run equilibrium relationship with these particular forward series. In contrast, the ECTs for forward returns in Equation (6) all bear negative signs and are statistically significant at a 5% level. This suggests that the forward price adjusts to correct any disparity arising from cointegration relationship, providing strong support for the endogeneity of the forward price. Furthermore, the speed of adjustment, measured by the absolute value of the ECT, shows an inverse relationship with the maturity of the forward contract maturity. This implies that the adjustment speed diminishes as the maturity of the contract increases. This is in line with the lack of cointegration of salmon future forward with longer maturities. From this, the conclusion is that when the self-adjusting mechanism weakens, the cointegrating relationship breaks down as well.

The Granger causality test statistics reported in the fourth column of Table 4 examine the short-run dynamics between forward and spot prices. Please recall that if the null hypothesis is rejected when ΔlnS is the dependent variable, the lagged forward returns Granger cause the spot return. If the null is rejected when ΔlnF is the dependent variable, the lagged spot returns Granger cause the forward return. Table 4 shows that lagged forward returns Granger do not cause the spot return. On the other hand, the channel of Granger causality is very active from spot returns to the forward returns. This especially holds for maturities of 1–5 and 10–11 months. Therefore, the conclusion is that (lagged) spot returns have considerable predictive power regarding the forward returns in the salmon market, whereas the reverse is not true. Finally, the serial correlation test up to 10 lags for the estimated VECM (or VAR) is undertaken. The model is correctly specified if the null hypothesis of no autocorrelation is not rejected. As shown in the last column of Table 4, there are very few cases of rejection, suggesting the results are robust and immune from any bias that might be caused by autocorrelation. The main result from Table 4 is that both long- and short-term causalities are largely unidirectional, running from the spot to the forward market. This finding undermines the usefulness of the salmon futures market as a price discovery tool and raises doubts about its long-term viability.

6. Conclusions

The salmon market is developing rapidly and new technologies are introduced. With recent high prices, stakeholders in the salmon value chain focus on effective ways of coping with the market demand. Risk management becomes increasingly important and can be decisive as to development of markets and market shares. In this respect, salmon forward markets might help manage price risks. So far, most of the literature (Ankamah-Yeboah et al., 2017; Asche et al., 2016a) has concentrated on the short spectrum of the forward markets, i.e., up to a maximum of one year. This study aims to complement this research by investigating longer maturities too, namely up to and including five year forward.

The results of this research suggest that the salmon spot market dominates both the long- and short-run dynamics in relation to the forward market. The forward market is found to be endogenously determined and is not very useful (i.e., informative) as a price discovery vehicle. The existence of a lead-lag relation provides counterevidence of an efficient salmon market, which implies that new information should be impounded simultaneously into spot and forward prices alike. It seems the salmon forward market is sluggish in reflecting new information compared to the spot market. Especially for forward contracts with longer maturities, information efficiency is problematic. This suggests that the salmon forward market is not yet up to the role forward markets perform in other more established agricultural commodity markets (see also Bergfjord, 2007). This may be due to low trading activity observed in the salmon forward market. As a consequence, especially producers and wholesalers require additional, more conventional, instruments (or big pockets) to manage price risk.

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Appendix A Unit Root Test Results.

	Augmented Dickey–Fuller		Phillips–Perron	
Contract length	Log price	Log return	Log price	Log return
Spot	−0.98	−8.97***	−1.47	−8.73***
1-month	−1.32	−7.14***	−1.16	−5.86***
2-month	−1.40	−7.38***	−0.51	−6.93***
3-month	−1.33	−6.57***	−0.77	−6.12***
4-month	−1.27	−6.24***	−0.71	−6.21***
5-month	−1.17	−6.56***	−0.67	−6.51***
6-month	−1.38	−6.36***	−0.71	−6.10***
7-month	−0.69	−6.64***	−0.59	−6.02***
8-month	−0.87	−6.35***	−0.39	−5.89***
9-month	−0.87	−5.92***	−0.06	−5.72***
10-month	−0.28	−6.50***	0.10	−6.50***
11-month	−0.29	−6.28***	0.16	−6.28***
12-month	−0.18	−6.67***	0.23	−6.65***
18-month	−0.11	−6.88***	0.24	−6.78***
24-month	1.87	−8.67***	1.59	−8.61***
30-month	−0.49	−10.08***	0.15	−12.12***
60-month	2.05	−13.08***	0.31	−13.79***

Note: Log prices are tested with intercept; log prices in first difference (i.e., log returns) are tested without intercept and deterministic trend.