Salmon Market Volatility Spillovers

Frank Asche [1,2]

Bård Misund [*,3]

Atle Oglend [2]

Working Paper

Abstract

This study investigates the volatility dynamics in input and output markets for the production of fresh-farmed Atlantic salmon. Previous studies suggest that there has been a shift, loosely dated to the beginning of the 2000s, in the relationship between input and output markets for salmon. As the industry has matured, salmon prices have gone from being productivity-driven to being input factor price driven, i.e. salmon prices are increasingly determined by the prices of the agricultural products which are used in the feed. At around the same time, salmon price volatility has more than doubled, possibly linked to an increase in feed prices. In this study, we investigate whether the increased dependence of salmon prices on agricultural feed prices is also evident as volatility spill-overs from agricultural prices to salmon prices, and whether we can find any structural shifts in the volatility spill-over.

1 University of Florida

2 Faculty of natural sciences, Department of Industrial Economics, University of Stavanger

3 University of Stavanger Business School

* Corresponding author. Bård Misund, University of Stavanger Business School, N-4036 Stavanger, Norway. Email: bard.misund@uis.no.

Introduction

The salmon aquaculture industry in has experienced rapid production growth since its early start in the late 1970s. The growth in production has been facilitated by increasing demand as well as a substantial productivity growth (Tveteras and Heshmati, 2002; Asche, 2008; Asche and Roll, 2013; Roll, 2013). Until around 2005, the high productivity growth led to steadily falling costs, closely mirrored by the price as one expects in a competitive industry (Figure 1).

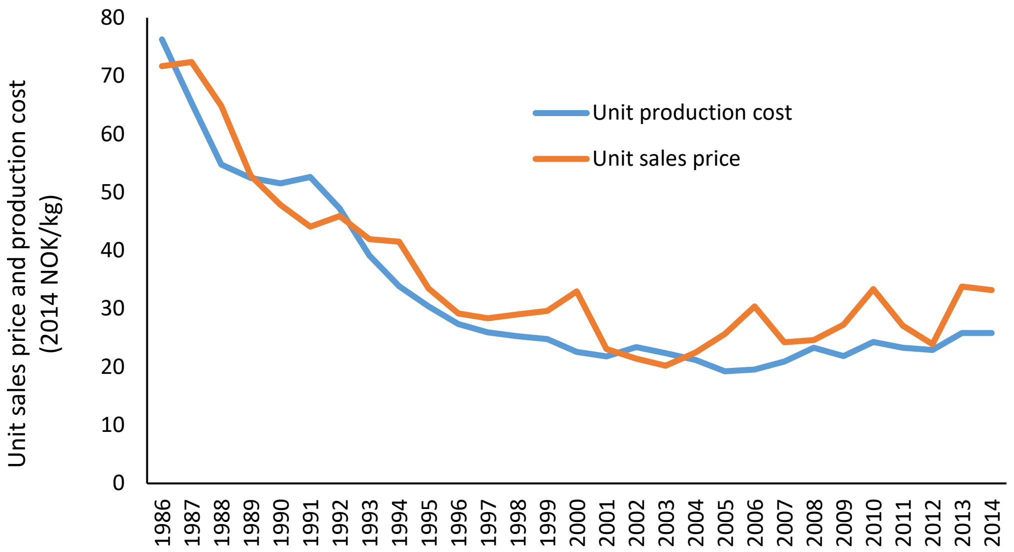


Figure 1. Production, wholesale prices and unit production costs for farmed Norwegian salmon 1985-2015. Source: Norwegian Fisheries Directorate (www.fiskeridir.no).

However, from around 2005 both costs and prices have increased, making 2005 a turning point for the salmon market (Vassdal and Holst, 2011; Asche, Guttormsen and Nielsen. 2013; Asche and Oglend 2016). This turning point represents the transition of this particular commodity market into a more mature phase. In this transition phase, the variations in marginal productivity in an industry falls, and the relative importance of input-factor variations on production costs increases (Asche and Oglend, 2016). The implication is that prices will go from productivity driven to input-factor driven. Empirical results suggest that this is the case in the salmon industry. Asche and Oglend (2016) find that the correlation between salmon price and feed input-factor prices (fishmeal, soybean meal and wheat) has increased in recent years, and Asche, Oglend and Kleppe (2017) show how the salmon price have cycles and spikes as in most commodity markets. Furthermore, Asche and Oglend (2016) also find an emergent cointegration relationship between salmon, fishmeal and soybean prices. There are also indications of a fundamental change in other studies. For instance, Oglend (2013) and Bloznelis (2016) demonstrate that there has been a substantial increase in salmon price volatility in the last 10 years. Oglend (2013) finds that the increase in volatility is associated with an increase in food prices. Bloznelis (2016) dates the shift to 2005-2006.

In summary, several studies suggest that a structural shift in the salmon markets has occurred as the industry has matured, moving from a period of high productivity growth driving down costs and prices to a more consolidated and mature phase. This provides an opportunity to study price and volatility dynamics as an industry is going through a transitional phase. While previous research suggest that there has been a structural shift in the salmon market, and that feed prices have had in increased impact on salmon prices, no study has yet examined the impact on the relationship between the volatilities in the salmon and input factor markets. In this paper we will test whether the increased importance of input factor prices for formation of salmon spot prices since 2005 has led to an increased volatility spill-over from input prices to salmon prices. The hypothesis is tested by comparing the DY2012 volatility spillover indices before and after 2005.

The input factor prices we consider are the prices for the most important feed components. Feed is the largest cost component in salmon farming, as feed cost account for around 50% of the unit production cost of salmon (Asche and Oglend, 2016). Feed cost has become increasingly important as the labor cost component has decreased and feed price has increased over the last ten years (Oglend and Asche, 2016; Misund, Oglend and Pincinato, 2017). The feed composed of protein, fats, carbohydrates, pigments and various micronutrients. We measure the price of the major raw material components in the feed using fishmeal (protein), wheat (binder), soybean meal (protein), rapeseed oil (fatty acids), and canola (fatty acids) prices. These raw materials provide a connection between the salmon price and major agricultural commodity markets. This forms the basis of our hypothesis of volatility spill-over from input market to salmon prices.

Our study contributes to the literature on risk management in the aquaculture sector. Numerous studies examine price volatility in the salmon industry (Oglend, 2013; Bloznelis, 2016; Asche, Dahl and Steen, 2015; Misund, 2018a; Oglend, Asche and Misund, 2018). These studies document a high and increasing salmon price volatility. High price volatility can adversely affect operational performance and profitability among salmon companies, as well as increase their default probability (Misund, 2017). Knowledge on volatility is also imperative for hedging purposes. Salmon price risk can be managed using futures contracts, and the optimal hedging ratio is affected by volatility. Hence, our study provides insight into how sellers and buyers of salmon can optimize their hedging activities. Several studies have examined the risk transfer and price information properties of salmon futures (Asche, Misund and Oglend, 2016a, Asche, Misund and Oglend, 2016b; Misund and Asche, 2016; Ankamah-Yeboah, Nielsen and Nielsen, 2017, Schütz and Westgaard, 2018). Our study provides additional insight into how volatility in the *input* markets are also relevant for salmon producers.

Investors in salmon farming companies are also exposed to salmon price risk (Misund, 2016; Misund, 2018b; Misund, 2018c). Our findings also highlight that investors also should be aware of the potential impact on the returns on their stock portfolios from sources of commodity price risk other than salmon.

The rest of this paper is structured as follows. First, we present the volatility spillover methodology that is applied, followed by a description of the data. Then the results are presented and discussed. The last section concludes.

Methods

The econometric analysis is conducted using the methodology of Diebold and Yilmaz (2012) (DY2012).[1] The DY2012 method allows us to specifically investigate the direction, magnitude, and net effect of commodity volatility spill-overs between the agricultural input and salmon wholesale markets. The starting point is the generalized vector autoregressive framework of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998). The DY2012 method uses forecast error variance decomposition to calculate the direction of volatility spill-over effects between markets. The benefit of this method is that it allows us to identify a market as a net receiver or a net transmitter of shocks (Diebold and Yilmaz, 2012).

In the following, we rely heavily on the work of Diebold and Yilmaz (2012). The point of departure for the DY2012 method is the following covariance stationary N-variable vector autoregressive process (VAR(p))

$$\boldsymbol{x_t} = \sum_{i=1}^{p} \boldsymbol{\Phi_i x_{t-i}} + \boldsymbol{\varepsilon_t} \tag{1}$$

where $\boldsymbol{x_t} = (\boldsymbol{x_{1t}}, \boldsymbol{x_{2t}}, \dots, \boldsymbol{x_{Nt}})$ and $\boldsymbol{\Phi_i}$ is the associated $N \times N$ autoregressive coefficient matrices, and $\boldsymbol{\varepsilon_t} \sim (\boldsymbol{0}, \boldsymbol{\Sigma})$ denotes a vector of *iid* disturbances. In volatility spillover studies, $\boldsymbol{x_t}$ represents a vector of return volatilities.

[1] See also Diebold and Yilmaz (2009; 2016) for more information on this methodology.

The next step is to generate the variance decompositions. For that, we use the moving average representation of Eq. (1)

$$\boldsymbol{x_t} = \sum_{i=0}^{\infty} \mathbf{A}_i \boldsymbol{\varepsilon}_{t-i} \tag{2}$$

where $A_i = \Phi_i A_{i-1} + \Phi_i A_{i-2} + \cdots + \Phi_P A_{i-P}$. The moving average coefficients, A_i, can used to understand the dynamics of the VAR(p) system, such as impulse-response functions and forecast error variance decompositions (FEVD). In a FEVD, the fitted VAR model is used to calculate *H*-step-ahead forecasts. By exerting exogenous shocks to the variables in the system, we can determine the shares of the *H*-step-ahead forecast error variance for x_i caused by shocks to the other variables, x_j $(\forall j \neq i)$.

Next, we calculate variance shares, both *own variance shares* and *cross variance shares*. Own variance shares represent the proportion of the *H*-step-ahead forecast error variance for x_i from shocks to x_i, and cross variance shares are the proportions of *H*-step-ahead forecast error variance for x_i from shocks to x_j. The H-step-ahead forecast error variance decomposition, $\theta_{ij}^{g}(H)$, can be written as

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_i)} \tag{3}$$

where Σ represents the variance matrix for the error vector $\boldsymbol{\varepsilon}$. The standard deviation of the error term in the *j*th equation is denoted by σ_{jj}. The selection vector, $\boldsymbol{e_i}$, takes a value of 1 as the *i*th element, and a value of 0 otherwise. Since the variance decompositions do not necessarily sum to 1, $\theta_{ij}^{g}(H)$ is normalised (see Diebold and Yilmaz (2012) for details), yielding the measure $\tilde{\theta}_{ij}^{g}(H)$.

Next, we calculate total spillovers, as well as directional spillover effects. The total volatility spillover index can be calculated as the ratio of the sum of contributions across all prices in our study to the total forecast error variance, multiplied by 100.

TOTAL

$$S^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \cdot 100 \tag{4}$$

Directional spillovers are calculated both TO a market (i.e. spillovers received in a particular market from all other markets in the system), and FROM a market (i.e. spillovers transmitted from one particular market to all other markets in the system).

TO

$$S_{i\cdot}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \cdot 100 \tag{5}$$

FROM

$$S_{\cdot i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} \cdot 100 \tag{6}$$

The TO and FROM spillover measures are gross spillovers, while the net direction of spillover from one market to the other markets (NET FROM) can be calculated as the difference between the two gross spillover measures, i.e. FROM less TO. It is also possible to calculate pairwise net directional spillovers for two particular markets by subtracting the spillover FROM market *j* TO market *i* from the spillover FROM market *i* TO *j*

NET

$$S_{ji}^{g}(H) = \left(\frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{i,k=1}^{N} \tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{j,k=1}^{N} \tilde{\theta}_{jk}^{g}(H)} \right) \cdot 100 \tag{7}$$

To investigate the changes in volatility spillover, we divide the sample in two, for the time period 1995-2004 and for 2005-2017.

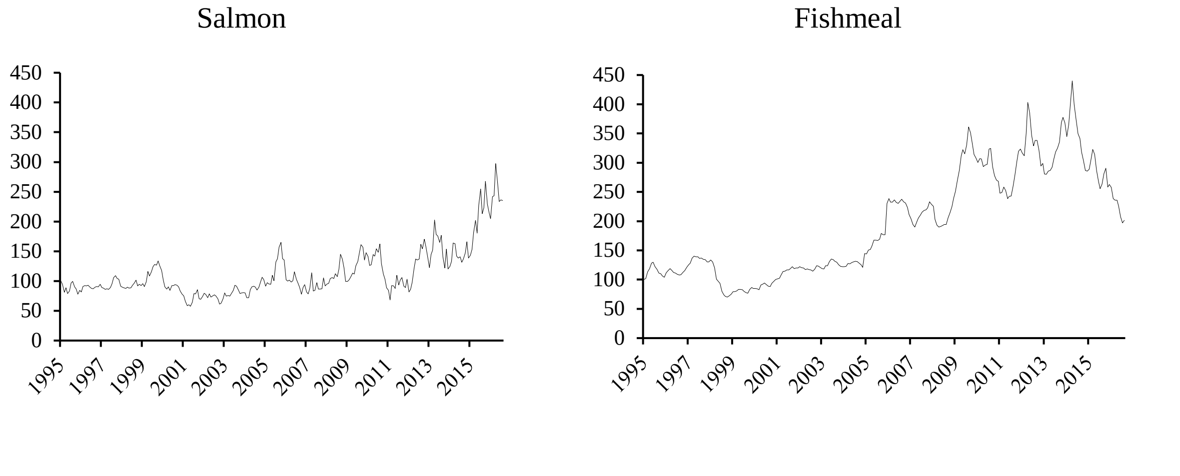
Data

The objective of this study is to examine the volatility spillovers TO and FROM the salmon wholesale market. The input to the VAR system are price volatilities in six input markets related to the salmon farming industry. The primary market is the salmon wholesale market, while the input markets are fishmeal (protein), wheat (binder), soybean meal (protein), rapeseed oil (fatty acids), and canola (fatty acids). Since fishmeal prices are only available on a monthly granularity, all analysis is carried out using monthly volatilities. The input prices represent prices of the main components in salmon feed (Asche and Oglend, 2016). The data is collected from several sources. Weekly spot salmon prices (Nasdaq Salmon Index) are collected from NASDAQ (http://www.nasdaqomx.com/commodities), and monthly prices are obtained by simply taking the last weekly price in the month. The other commodities prices are collected from Quandl (www.quandl.com). The soybean meal price is the Chicago Mercantile Exchange Soybean Meal Front Month Continuous Futures Contract (minimum protein content of 48%). The monthly price is taken as the settlement price observed on the last day in the month. The wheat price from the Kansas City Board of trade No. 1 Hard Red Winter Front Month Futures Contract. We calculate the monthly price as the last price of the month for the continuous futures contract. The rapeseed price is the International Monetary Fund (IMF) Rotterdam Rapeseed Index (monthly). The fishmeal price is the IMF Peruvian Fishmeal index (65% protein) and is reported on a monthly granularity. Monthly Canola prices are taken as the last observed daily settlement Intercontinental Commodities Exchange (ICE) Canola continuous front month futures contract price. We use data from September 1995 to April 2017.

Log-returns are calculated as the log change in monthly prices. Monthly volatilities are generated from monthly log-returns using a ARMA (1,1) – GARCH (1,1) model.

Figure 1 depicts the development in the commodity prices over the length of the dataset, and Figure 2 shows the time series plots of volatilities. Figure 1 shows that the prices in most of the markets were higher in the decade after 2005 than in the preceding decade. In many food markets prices seem to have fallen since 2012.

Figure 1. Time series plots of monthly commodity prices (September 1995 = 100)



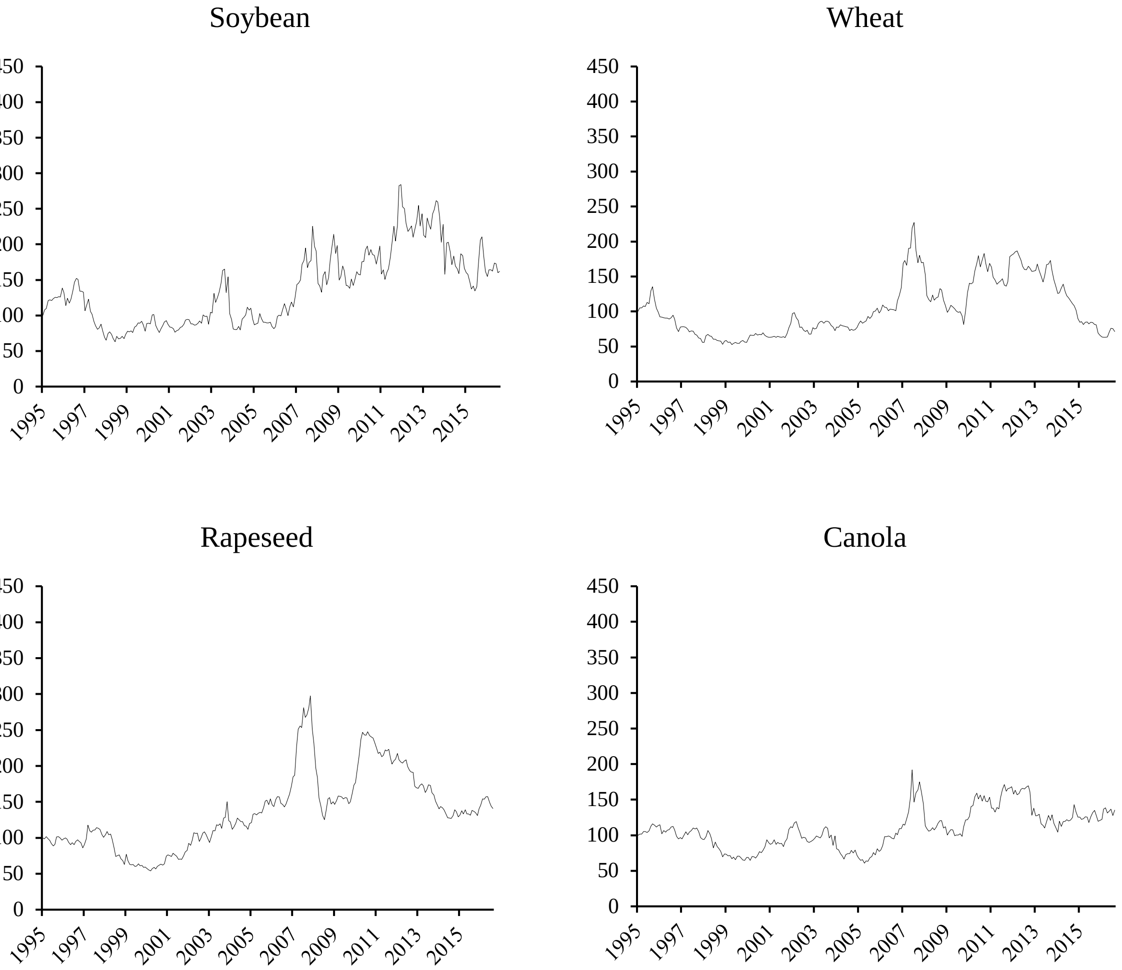

Soybean
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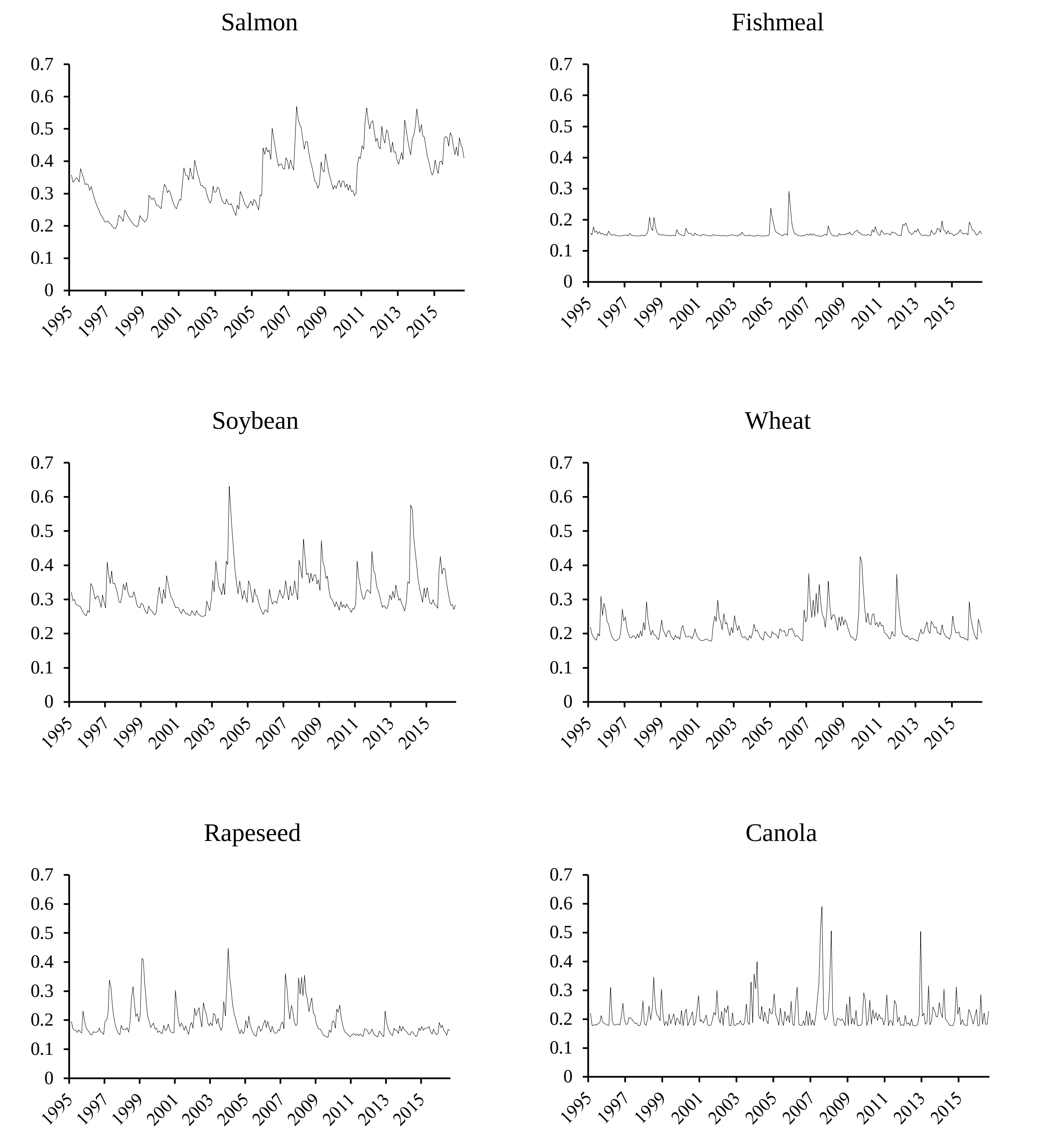
Figure 2. Time series plots of monthly commodity volatilities



Note. The volatilities are estimated using ARMA (1,1) – GARCH (1,1) using monthly logreturns.

The volatilities of all markets except salmon seem to fluctuate across a constant volatility level. Salmon volatility shows an increasing trend over the time period in our study. We therefore test the variables for stationarity using an augmented Dickey-Fuller test (ADF). We are unable to reject the null hypothesis of a unit root for all variables. However, including a trend in the ADF test suggests that the variables are trend-stationary, and we therefore include a time trend in the VAR estimation as an exogenous variable.

Results and discussion

In the following section we describe the results from the analysis. The results will be presented mostly in the form of spillover tables. The *ij*th entry (*i* = row, *j* = column) in the spill-over table is contribution of forecast error variance originating in market *j* (FROM) and transmitted to market *i* (TO). The numbers in one particular column are the spillover effects FROM one particular market TO all other markets (including the own market). The column sums are measures of the total spillover FROM one particular market TO all markets. For instance, in our analysis, the first column contain the spillovers FROM salmon wholesale prices TO all markets. We calculate two column sums, the first excludes the own market (denoted 'contribution TO'), while the second includes the own market (denoted 'contribution TO (including own)'). The rows include information on the spillovers TO a particular market origination FROM other markets. Followingly, the row sums are measures of the spillovers FROM other markets, excluding the own market (denoted 'Contribution FROM').

The *gross* spillover effects in the spillover table are easily converted to *net* spillovers by subtracting the TO observation from the FROM observation, both for individual markets and for sums (excluding own spillovers).

Before looking at volatility spillovers, we start off with investigating the connectedness in *log-returns* (Table 1). Return spillovers tell us how changes in price from one month to the next are associated to monthly returns in other markets, in terms of net direction and magnitude.

Table 1. Input factor markets – salmon market connectedness (logreturns)

	From						
To	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Contribution FROM
Salmon	92.23	1.28	0.92	3.02	0.53	2.02	7.77
Fishmeal	1.31	92.00	0.21	0.72	5.13	0.63	8.00
Wheat	0.10	0.42	73.55	10.17	3.11	12.65	26.45
Soybean	0.86	0.62	6.74	68.49	1.07	22.12	31.41
Rapeseed	0.72	4.48	5.79	5.05	70.32	13.64	29.68
Canola	0.06	0.99	4.80	23.73	2.74	67.68	32.32
Contribution TO	3.05	7.79	18.46	42.69	12.58	51.06	135.63
Contribution TO (including own)	95.28	99.79	92.01	111.18	82.9	118.74	Spillover Index = 22.6%

We see that price changes in the salmon and fishmeal markets are mostly determined endogenously (own contribution). The sum (excluding own market) in the first *j*th column, 3.05%, represents the return spillovers from salmon TO all other markets, while the sum in the first *i*th row, 7.77%, is the return spillover TO salmon from all other markets. The net spillover is calculated by taking the difference, 3.05 – 7.77 = -4.72. The interpretation is the net direction of return spillovers are from input markets to the salmon market. The return spillovers are greater between the agriculture markets than between the fish markets (salmon and fishmeal) and between fish and agriculture markets. Soybean and canola markets seem to be the major transmitters of returns to other markets.

Next, we turn to volatility spillovers. First, we present the results for the entire sample (Table 2a), then the spillover analysis for the two sub-samples are presented in Table 3a (1995-2004) and Table 4b (2005-2017). In addition, we present the resulting net spillovers in Tables 2b (all sample), 3b (1995-2004) and 4b (2005-2017).

Table 2a. Volatility connectedness (All sample)

	FROM						
TO	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Contribution TO
Salmon	86.83	0.39	0.21	10.86	0.42	1.29	13.17
Fishmeal	0.86	94.56	1.15	0.16	1.89	1.37	5.44
Wheat	2.54	0.88	86.28	2.18	1.28	6.84	13.72
Soybean	1.50	0.98	0.79	85.01	3.11	8.61	14.99
Rapeseed	1.87	0.23	7.41	11.13	66.13	13.22	33.87
Canola	1.42	0.39	0.32	9.14	6.27	82.45	17.55
Contribution FROM	8.19	2.88	9.88	33.47	12.98	31.33	98.73
Contribution FROM (including own)	95.02	97.44	96.16	118.48	79.11	113.79	Spillover Index = 16.5%

The results suggest that the volatility spillovers TO the salmon market from all other markets is 13.17%. The single most important transmitter of volatility to the salmon market is soybean. This is not surprising since the content of soybean meal in salmon feed has increased in the same period. Similar to the analysis for returns, soybean and canola seem to be the largest transmitters of volatility to other markets. The spillover of volatility FROM salmon to other markets is 8.19%, and the net directional effect seem to be a volatility spillover to the salmon market from the other markets.

The overall spillover index is 16.5%, meaning that 16.5% of the volatility forecast error variance in the six markets come from spillovers.

Table 2b. Net connectedness (FROM less TO)

	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Net TO
Salmon	0	-0.47	-2.33	+9.36	-1.45	-0.20	+4.91
Fishmeal	+0.47	0	+0.27	-0.82	+1.66	+1.02	+2.60
Wheat	+2.33	-0.27	0	+1.39	-6.13	+6.40	+3.72

Soybean	-9.36	+0.82	-1.39	0	-8.03	-0.87	-18.82
Rapeseed	+1.45	-1.66	+6.13	+8.03	0	+6.78	+20.72
Canola	+0.20	-1.02	-6.40	+0.87	-6.78	0	-13.12
Net FROM	-4.91	-2.60	-3.72	+18.82	-20.72	+13.12	0

Turning to the two sub-samples, we see that the spillover effect were much larger in the first time period, 1995-2004, (compared to the full sample). The contribution FROM other to the salmon market is 36.41%, while the contribution TO the other markets from salmon was 15.30. The net directional spillover is therefore from other markets to salmon (15.30 – 36.14 = 21.11) during 1995-2004. There also seem to be larger volatility spillovers between the agricultural markets. Soybean, rapeseed and canola have had a volatility spillover of 30-40% to the other markets, which is quite substantial.

Table 3a. Volatility connectedness (1995-2004)

	From						
To	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Contribution FROM
Salmon	63.59	1.55	7.36	11.49	13.18	2.83	36.41
Fishmeal	0.36	84.89	6.65	0.99	4.03	3.08	15.11
Wheat	4.56	7.17	80.73	0.71	1.09	5.74	19.27
Soybean	4.37	1.24	0.16	82.36	5.39	6.48	17.64
Rapeseed	4.77	1.47	4.27	13.30	61.77	14.41	38.23
Canola	1.24	4.09	4.44	13.87	5.67	70.69	29.31
Contribution TO	15.30	15.52	22.87	40.37	29.37	32.53	155.96
Contribution TO (including own)	78.90	100.41	103.60	122.73	91.14	103.22	Spillover Index = 26.0%

Table 3b. Net connectedness (FROM less TO) (1995-2004)

	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Net TO
Salmon	0	+1.19	+2.80	+7.12	+8.41	+1.59	+21.10

Fishmeal	-1.19	0	-0.52	-0.25	+2.56	-1.01	-0.41
Wheat	-2.80	+0.52	0	+0.55	-3.18	+1.30	-3.60
Soybean	-7.12	+0.25	-0.55	0	-7.91	-7.39	-22.73
Rapeseed	-8.41	-2.56	+3.18	+7.91	0	+8.73	+8.86
Canola	-1.59	+1.01	-1.30	+7.39	-8.73	0	-3.22
Net FROM	-21.10	+0.41	+3.60	+22.73	-8.86	+3.22	0

In the second sub-sample, we see that the direction of volatility spillover has changed. The contribution FROM salmon to other markets is larger than the contribution TO salmon from all other markets. The net volatility spillover is +13.73% (22.85%-9.12). Our hypothesis was that the increased integration would lead to increased spillovers. Our results suggest a decreased volatility spillover TO salmon from all other markets (Table 3a:36.41% and Table 4a: 9.12%). However, the volatility spillover from salmon to all other markets has increased (Table 3a:15.30% and Table 4a: 22.85%), so that the net spillover from salmon to other markets has gone from -21.11% to +13.73%. We therefore reject the null hypothesis of increased volatility spillovers TO the salmon market.

The increased volatility spillover from salmon TO the agricultural markets is surprising as well as interesting. A possible reason is that production of salmon has increased globally over the sample period. Also, the inclusion of agricultural components in fish feed has increased at the same time (Misund, Oglend and Pincinato, 2017). Our findings suggest that the impact of shocks in salmon prices are mostly transmitted to the input markets since 2005. Furthermore, we find that there has been a shift in the net direction of volatility spillovers between salmon and soymeal since 2005. However, the salmon market is relatively small compared to the global soymeal market. The latter market is around 100 times larger than the quantity of farmed Atlantic salmon. Hence, one should be careful when drawing conclusions. More research is needed in order to investigate if our results hold when other empirical methodology is applied, or when using a longer time series.

Table 4a. Volatility connectedness (2005-2017)

	From						
To	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Contribution TO
Salmon	90.88	1.03	0.09	6.91	0.59	0.52	9.12
Fishmeal	0.95	90.52	3.92	0.44	3.17	1.00	9.48
Wheat	0.94	0.75	79.92	3.75	7.58	7.05	20.08
Soybean meal	12.52	0.82	4.17	74.69	3.05	4.75	25.31
Rapeseed	2.84	1.39	18.75	1.32	68.70	7.01	31.30
Canola	5.60	0.56	0.84	8.61	5.08	79.30	20.70
Contribution FROM	22.85	4.55	27.76	21.02	19.48	20.32	115.99
Contribution including own	113.73	95.07	107.68	95.72	88.18	99.63	Spillover index = 19.3%

Table 5b. Net connectedness (FROM less TO) (2005-2017)

	Salmon	Fishmeal	Wheat	Soybean	Rapeseed	Canola	Net TO
Salmon	0	+0.07	-0.86	-5.61	-2.25	-5.09	-13.73
Fishmeal	-0.07	0	+3.17	-0.39	+1.78	+0.44	+4.93
Wheat	+0.86	-3.17	0	-0.42	-11.16	+6.21	-7.68
Soybean	+5.61	+0.39	+0.42	0	+1.73	-3.86	+4.28
Rapeseed	+2.25	-1.78	+11.16	-1.73	0	+1.93	+11.82
Canola	+5.09	-0.44	-6.21	+3.86	-1.93	0	+0.37
Net FROM	+13.73	-4.93	+7.68	-4.28	-11.82	-0.37	+0.00

Conclusion

This study investigates the volatility dynamics input and output markets for the production of fresh-farmed Atlantic salmon. Previous studies suggest that there has been a shift, loosely dated to the beginning of the 2000s, in the relationship between input and output markets for salmon. Research shows that as the industry has matured, salmon prices have gone from being productivity-driven to being input factor driven, i.e. salmon wholesale prices increasingly being determined by prices of agricultural products which are used in fish feed. At around the same time, salmon price volatility has more than doubled, possibly linked to an increase in food prices. In this study, we investigate whether the increased dependence of salmon wholesale prices on agricultural food prices is also evident as volatility spill-overs from agricultural prices to salmon prices, and whether we can find any structural shifts in the volatility spill-over. The results will be of interest to salmon producers in their hedging decisions for both input factor prices and wholesale salmon prices.

Our results suggest that there has been a shift in the net direction of volatility spillovers since 2005. While the net transmission of volatility went from input markets (agriculture and fishmeal) prior to 2005, our findings suggest that the impact of shocks in salmon prices are mostly transmitted to the input markets since 2005. The increased volatility spillover from salmon TO the agricultural markets is surprising as well as interesting. A possible reason is that production of salmon has increased globally over the sample period. Also, the inclusion of agricultural components in fish feed has increased at the same time (Misund, Oglend and Pincinato, 2017).

However, our results must be interpreted with care. The salmon market is substantially smaller than the input markets. For instance, the soymeal market is about 100 times larger. More research is needed before one can draw any firm conclusions on the spillover dynamics between the salmon markets and the input markets.

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